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MEDITERRANEAN ACTION PLAN

GEF

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against Pollution

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ASSESSMENT OF TRANSBOUNDARY POLLUTION ISSUES IN THE MEDITERRANEAN SEA

UNEP/MAP
Athens, 2003

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ASSESSMENT OF TRANSBOUNDARY POLLUTION ISSUES IN THE MEDITERRANEAN SEA

UNEP/MAP
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• Introduction

The Mediterranean countries have for long been aware that the degradation of the marine environment is a problem calling for action at the global, regional and national levels. International efforts to protect the Mediterranean Sea resulted in the adoption by the Mediterranean Countries and the EU of the Mediterranean Action Plan (MAP) in 1975 and the adoption of the Barcelona Convention and two related protocols in 1976.

MAP was intended to assist the Mediterranean Governments in improving the quality of the environmental information on which formulation of their national development policies is based and to improve the ability of Governments to better identify options for alternative patterns of development and make better rational choices for allocation of resources.

Since the adoption of MAP, Mediterranean Countries joined their efforts to identify, propose, adopt and implement actions necessary to protect the Mediterranean Sea.

The initial focus of MAP was on marine pollution control, which resulted in the launching of the MEDPOL Programme, the scientific component of MAP. However, experience soon confirmed that poor management and planning of development are at the roots of most environmental problems and that meaningful and lasting environmental protection is inseparably linked with social and economic development. Therefore, focus of the action plan gradually shifted from a sectorial approach of pollution to integrated coastal zone planning and management as the key tool through which solutions are being sought.

Following a gradual shift from pollution assessment to pollution control, a Strategic Action Programme for the Mediterranean Sea (SAP MED), to address pollution from land-based activities, was prepared by MEDPOL and approved in 1997, with the financial support of the Global Environment Facility (GEF) and other donors.

The main objective of this initiative was to prepare a targeted and costed programme to address pollution from land-based activities including the elements for the formulation of national action plans. The SAP is now being implemented in the region and provisions are made to initiate the process of achieving municipal and industrial pollution reductions in all countries.

The present report “Assessment of Transboundary Pollution Issues in the Mediterranean Sea” (ATP MED) aims at identifying the perceived issues and problems affecting the Mediterranean Sea, including those associated with land-based activities which have transboundary concerns, and as such to contribute to the preparation of a policy oriented transboundary diagnostic analysis (TDA) to be considered within the SAP MED. According to the GEF Operational Strategy, the TDA should also be used for other possible projects to be implemented in the future. In other words, the TDA is experienced too offer a platform with data and information on which to base future regional interventions by individual countries and outside donors.

The present report has been prepared on the basis of existing data, particularly those of the “Transboundary Diagnostic Analysis for the Mediterranean Sea” (TDA MED) report prepared in 1997, that were completed and updated through the results of MEDPOL and other MAP programmes and activities.

After a general introduction on the geographical setting, a section on sources of transboundary issues reviews data and information relating to airborne deposition, rivers, agricultural runoff, marine resources, urban centres, industry, ports and maritime transport, and exploitation of the sea bed. The impacts of transboundary elements on living resources, critical habitats, economic activities (land use and tourism) and human health are also assessed as well as the state of management issues. Finally, an overall evaluation of the perceived issues and problems affecting the future perspectives of development in the region are included.

• Executive Summary

The Mediterranean Sea, embracing parts of two continents as diverse as Europe and Africa, is a clear example of a marine region at risk as a result of the activities taking place in its surroundings. Urbanisation and tourism, disposal of industrial and domestic wastes, intensive agriculture and fishing, ports and maritime transport, are only a few of the many factors which are exerting pressure on the Mediterranean environment and may cause a strong impact in the form of coastal and marine degradation and a heightened risk of more serious damage.

Particularly, pollution at the local/national level has been considered a priority issue of concern and several steps towards its abatement and prevention have been taken in the framework of supporting regional agreements and regulatory mechanisms. However, the transboundary components of these environmental issues have not been equally confronted, while its impacts on human activities should be better understood.

In the present report, seven major pollutant sources with a transboundary component have been identified in the Mediterranean from a review of the results of the work done within the Mediterranean Action Plan over the last twenty years, the work of related programmes and the reviews undertaken in the context of the present study. These are shown in Table 1.

Table 2.1 **Major polluted sources**

Pressures to the environment	**Transboundary elements**
Airborne emissions and deposition	• Degradation of the marine environment by airborne deposition of metals, hydrocarbons, etc. • Nutrients enrichment of surface waters
Riverine outflows	• Reduction of water and sediment discharges by damming • Pollution of international waters • Coastal eutrophication
Agriculture runoff	• Eutrophication, algal blooms • Long-range transport of pesticides
Fishery and mariculture activities	• Effects on migratory species by changes in coastal habitats, eutrophication, etc. • Chemotherapeutants residues in fish and effect on non-target species • Modification of gene pool of wild stocks from escaped farm stock
Urban centres and industrial activities	• Urban waters discharged untreated into the sea (dispersion of pathogenic agents, eutrophication,…) • Industrial wastewater discharges • Industrial solid waste disposal
Ports and maritime transport	• Operational and accidental ship generated marine pollution • Pollution from garbage and dredged materials in open waters • Casualties in ports or coastal waters with

Pressures to the environment	Transboundary elements
	foreign flag vessels involved
Exploitation of sea bed and subsoil	• Pollution of international waters

It is apparent that the environmental degradation, particularly of coastal areas, originated by these sources is expected to affect significantly human activities and land uses, mainly by limiting their recreational and residential values as well as impairing the quality and availability of natural resources. Moreover, the detrimental effects may extend towards a reduced geographical area and affect rather distant sites or regions, even belonging to other countries.

As a first attempt at identifying the nature of the transboundary effects of these environmental pressurs, the impacts on the living marine resources and biodiversity, marine ecosystems, land use and tourism and human health have been assessed. The perceived major problems are summarised in Table 2.

Table 2.2 **Perceived major problems**

Major problems	
Degradation of coastal and marine ecosystems	• Damage to transboundary ecosystems, including loss in productivity, biodiversity and stability • Loss of wetlands and seagrass meadows • Decrease of water quality (Degradation due to pollution and eutrophication)
Unsustainable exploitation of marine resources	• Impacts on habitats and biodiversity • Impacts of physical changes in coastal and beach dynamics • Loss of existing and potential income from fishing and tourism
Loss of habitats supporting living resources	• Damage to migratory species and their habitat changing patterns of migration • Endangered biotic resources • Habitat and food web changes
Decline in biodiversity	• Loss of regional values • Damage to endangered and endemic species of regional and global significance • Loss of genetic biodiversity • Introduction of non-indigenous species
Worsened human related conditions	• Human health impacts (bathing waters, seafood consumption, etc.) • Costs of dealing with human migration • Reduced human and institutional capacity • Increased poverty with transboundary

	impacts
Inadequate protection of the coastal zone and marine environment	• Reduction of regional values • Incresing sprawling urbanisation • Tourism development • Decreased quality of life

Five main root causes are identified in Table 3 for the perceived problems. Fortunately, root causes are common to a number of different perceived problems and issues, so addressing a few of them may have positive effects on several problems, although the relative importance of each cause differs in relation to the individual problem.

Table 2.3 **Root causes**

Root causes	
Inadequate legal and institutional framework	• Inadequate cooperation at regional level • Inadequate legislation at national level relevant to regional problems • Inadequate institutional framework and capacity necessary for the implementation of legislation, ICZM and EIA. • Inadequate pollution compliance and trend monitoring • Ineffective coordination between various governmental sectors at local and national levels.
Inadequate planning and management at all levels	• Poorly coordinated intersectorial planning and management. • Lack of integrated CZM plans • Lack of application of ICZM and its tools • Inappropriate harvesting practices in fisheries • Inadequate pollution control strategies with monitoring
Insufficient human and institutional capacity	• Inadequate human and institutional capacity (at local and national levels) for the implementation of the ICZM with its tools • Inadequate human an institutional capacity for compliance and trend monitoring of pollution
Insufficient involvement of stakeholders	• Lack of general environmental awareness • Poor identification of stakeholders • Lack of adequate participation of stakeholders in the planning and management of environmental problems.
Inadequate financial mechanisms and support	• Lack of effective economic instruments • Lack of internationalisation of environmental

	costs • Low value assigned to environment within national economic policies

As a result of this analysis, four major types of action are proposed to address each of the identified problems (Table 4) and again the relative importance of each type of action differs according to the nature of the problem.

Table 2.4 **Proposed actions**

Proposed actions	
Reduction of gaps of knowledge	• Atmospheric emissions and deposition • Urban and riverine discharges of nutrients, metals and organic pollutants • Inventories of coastal habitats • Maritime transport statistics
Reduction of environmental pressures, notably pollution	• Identification and elimination of pollution hot-spots • Adequate compliance and trend monitoring • Improvement of wastewater treatment systems
Resource management	• Full implementation of relevant national and regional legislation • Sustainable management of resources (e.g. fishing) • Protection of biodiversity, endangered species, habitats and sensitive areas • Development of sustainable fisheries, mariculture and tourism
Integrated planning and management	• Improvement of legal and institutional framework at national and regional levels for ICZM • Development of integrated management for river basin/coastal areas and for urban agglomerations • Improved involvement of stakeholders in environmental decision-making

In conclusion, it is worth to point out that for addressing the problems and root causes summarised in Tables 2 and 3 it is necessary to develop and apply a holistic and integrated management and planning approach, as the traditional sectorial coastal zone approach failed to reverse or even slow down negative trends. Integrated Coastal Zone Management (ICZM), a concept developed during the past thirty years, is considered as the major methodological framework for implementing coastal zone specific initiatives and for achieving sustainable development in coastal areas.

Experiences indicate that the wider context of any regional or national coastal zone issue having a transboundary character cannot be addressed outside the ICZM conceptual and methodological framework. Although ICZM provides the basis for successful implementation of transboundary related initiatives in coastal areas, the present level of methodological and practical considerations should be further upgraded and specific approaches and instruments for transboundary related issues tested and adopted.

On the other hand, the measures to achieve cleanup have usually taken the form of uniform abatement targets, that is, a proposal to all concerned parties to undertake the same percentage of abatement within specific timetables and for specific pollutants. However, accruing evidence from international environmental agreements, consistently fosters the idea that uniform rates of abatement are neither a fair, nor an equitable basis for international co-operation and national self-commitments. Documentation of negotiations in environmental agreements abounds with remarks and statements invoking the principles of fairness and equity that should guide the international relations among sovereign states.

Calling upon these principles means supporting a scheme of shared but differentiated responsibility in achieving common abatement targets. An issue that should be explored in the context of future negotiations for land-based pollution reduction within the Barcelona Convention for the Protection of Mediterranean.

• The Mediterranean region

Located at mid-latitudes half way between the subtropical and the temperate zones and surrounded by large continents (Eurasia, Africa), it has climatic and ecological characteristics typical of these latitudes, partly maritime and partly continental. The Mediterranean climate, with mild wet winters and hot dry summers, has been used as a model for many other regions around the world.

Its landscape and monuments continues to be the greatest tourist destination in the entire world. As a consequence, urbanisation has been particularly growing along the coastal strip, to accommodate both permanent and temporal population, with the result of a substantial modification of the coast itself and adverse effects on the quality of the environment.

The highly developed industrial countries in the North and countries on the way to become industrialised stand in stark contrast with the countries in the South. These differences have significant implications when addressing environmental issues, and particularly those related with transboundary pollution.

o ***Environmental characteristics***

▪ *The geographic setting and climate*

The Geology of the Mediterranean region has been described in a MAP Report (UNEP, 1996). There are mountain ranges along the northern part of the sea, namely the Sierra Nevada in Spain, the Pyrenees in Spain/France, the Alps in France, Italy and Slovenia, the Apennine in Italy, the Dinaric Alps in the FormerSerbia and Montenegro, the Pindos ranges in Greece and the Taurus in Turkey. The geographic formations are different along the North African coast, where there is only one big mountainous formation between Tunisia, Algeria and Morocco. The Near East is a mountainless dessert.

The central part of the region is covered by the Mediterranean Sea with an extension of about 2.5 million km^2, and an average water depth of about 1.5 km. The length of the basin along the East-West axis is about 4000 km, whereas the Nord-South width that (from the Gulf of Venice down to Libya) is 800 km. The length of the Mediterranean coastline totals about 46000 km, of which 19000 km represent islands coastlines. It is commonly divided in ten sub-basins, which are shown in Figure 3.1 and listed in Table 3.1. The bordering countries are: Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia,Serbia and Montenegro, Albania, Greece, Turkey, Cyprus, Syria, Lebanon, Palestinian Territories, Israel, Egypt, Libya, Malta, Tunisia, Algeria, and Morocco.

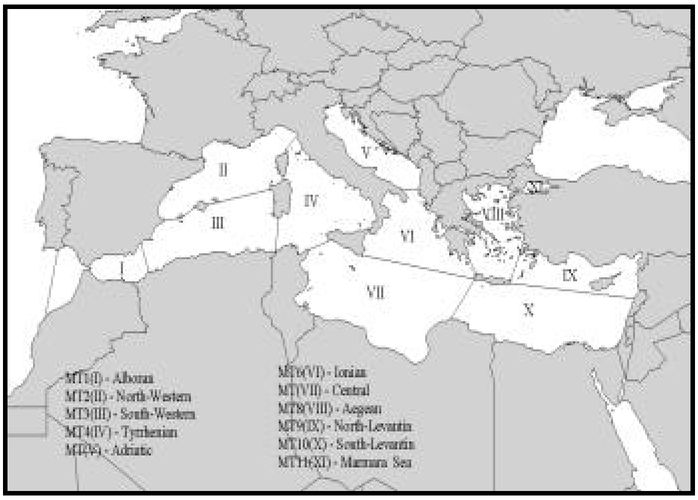

Figure 3.1 - Major sub-basins of the Mediterranean Sea.

Table 3.1**. Major sub-basins of the Mediterranean Sea**

Basin	Code	Bordering countries
1. Alboran	ALB	Spain, Morocco, Algeria
2. North-Western	NWE	Spain, France, Monaco, Italy
3. South-Western	SWE	Spain, Italy, Algeria, Tunisia
4. Tyrrhenian	TYR	Italy, France, Tunisia
5. Adriatic	ADR	Italy, Croatia, Albanian
6. Ionian	ION	Italy, Albanian, Greece
7. Central	CEN	Italy, Tunisia, Libya, Malta
8. Aegean	AEG	Greece, Turkey
9. North-Levantine	NLE	Turkey, Cyprus, Syria, Lebanon
10. South-Levantine	SLE	Lebanon, Israel, Egypt, Libya
11. Marmara Sea	MAS	Turkey

The Western part of the Mediterranean is connected to the Atlantic through the strait of Gibraltar. The width is 12.8 km and the depth only 300m. On the other hand, the north-eastern part of the Mediterranean is connected to the Black Sea through the strait of Dardanelles (depth 97m), the sea of Marmara and the strait of Bosphorus. The south-eastern part is connected with the Red Sea through the Suez Canal.

The climatology of the Mediterranean is characterised by generally warm temperatures, winter-dominated rainfall, dry summers and a profusion of microclimates due to local environmental conditions. Mean annual temperature follows a marked north to south gradient to which local orographic effects are superimposed. Lowest temperatures of <5 °C can be found in the higher parts of the Alps, whereas temperatures of >20 °C are typical for Libya or Egypt. Also mean annual precipitation shows a north to south gradient, with decreasing values towards the south. But orography is naturally the dominant factor here. High precipitation values of 1500-2000 mm and more are found in the Alpine and Pyrenean headwater regions of the Po, the Rhone and the Ebro rivers, and they are very abundant in the Alpine mountain belt bordering the Dalmatian coast, from the Istrian peninsula down to Albania. This makes these countries the most humid countries of the Mediterranean area.

The strong summer-winter rainfall contrast is one of the major characteristics of the Mediterranean climate. This contrast is more and more pronounced when going from the north to the south and from the west to the east. Precipitation mainly falls during winter and autumn whereas summer is very dry. Often, less than 10% of the annual precipitation falls during this period. This contrasts starkly with the continental climate in the drainage basin of the Black Sea, where most of the precipitation occurs during summer. During spring, the rainfall contribution to the mean annual precipitation is quite homogenous in the entire Mediterranean region. High precipitation during autumn is typical for the coasts of Spain, France, Italy, Croatia,Serbia and Montenegro, Albania and Greece. Further east, such as in Turkey and in Lebanon, autumn precipitation is much less important. By far most of the rainfall occurs here in winter.

In certain regions, precipitation especially in autumn can occur in the form of heavy downpours, leading to violent flash-floods in the rivers of these regions. The prevalent zones for flash-floods are the Côte d'Azur, east Pyrenees, Cevennes and Corsica in France, the north-western areas of Italy, and Catalonia and Valencia in Spain.

One result of the seasonal rainfall and high evaporation is that water shortages are endemic. The problem is particularly striking in the southern parts of the Mediterranean in contrast to seasonal shortages in the north (corresponding to the dry months). The dry season in some southern countries exceeds six months, meaning that water shortage is a permanent handicap for sociological and economic development.

- *The hydrodynamic system*

The continental waters are largely influenced by the physiography and climate conditions of the region. The often steep relief in the northern part of the Mediterranean basin is in favour, with few exceptions, of the formation of small coastal rivers with relative short distance between the headwaters and the river mouths. In the south, the hot and dry climate does neither allow the formation of larger river systems.

The hydrological regime of the Mediterranean rivers is quite particular compared to other regions. The differences between low and high water discharge can be extreme. Often, most of the water discharge occurs during short floods. In the large and medium-sized river basins situated in north and central Europe, wide-ranging and continuous precipitation is commonly the main factor in flood generation, often also in association with snow melt. Intense rainfall falling on small catchments is the main cause of floods in the Mediterranean area.

With respect to seasonal variation of the water discharge, one can notice that by far most of the Mediterranean rivers have lowest values during summer (July to September) because of the strongly reduced precipitation and the elevated temperatures during this season. Maximum values are normally observed between February and May. The February maximum is typical for the rivers that are rainfall dominated (such as the Tiber and Arno rivers), since rainfall is strongest in winter. When the headwaters reach up to highly elevated areas, which is often the case, snow melt discharge becomes dominant. This is shifting the maximum discharge to April or May (e.g. the Drini or Ceyhan rivers). Often, both regimes are superimposed. Finally, it may be pointed out that the accentuation of the seasonal contrast towards the south and the east has naturally also a strong impact on the rivers in these areas. Almost all of the discharge occurs during the first half of the year, whereas the second half is very dry (e.g. Moulouya and Ceyhan rivers).

The artificial damming of rivers, mainly executed during the second half of the last century, for the purpose of hydroelectric power generation, irrigation and public water supply, has had a considerable impact on their natural functioning. This impact is highly visible especially in the hot and dry climates of the south, where the reduction of natural water discharge can be dramatic. A well-known case is the Ebro River in Spain. Today, a total of 128 reservoirs exist in the Ebro basin, with a concomitant reduction in water discharge of about 29% (Ibanez et al., 1996). Also the seasonality of the river's hydrography was strongly smoothed. Further south, the examples of water discharge reduction due to damming are even more extreme. Snoussi et al. (2002) estimated that the discharge of the Moulouya River dropped by about 47% after the construction of the Mohamed V dam in Morocco. Zahar and Albergel (1999) reported that the closure of the Sidi Salem Dam in Tunisia led to a reduction of the mean annual discharge of the Medjerdah River by 65% due to diversion for irrigation and evaporative losses. But the most famous example is naturally the Nile River. After the closure of the Aswan Dam in Egypt, probably less than 5% of the 84 km3 of water that enters on average the reservoir ends up in the Mediterranean (Kempe, 1993).

As far as the marine waters is concerned, it is well-known that the Mediterranean has a negative balance with the Atlantic ocean. If the Gibraltar strait was to be closed, the Mediterranean basin would lose 1 m/year. Following a general scheme, Atlantic surface waters come in and the Mediterranean deep waters go out to the Atlantic ocean. In addition to the longitudinal speed, there are important vertical movements which can reach a speed of 15 cm/sec in winter. The general system is such that it seems (still, too few studies have been carried out on this phenomena) the basic mechanism occurs in the Eastern Mediterranean which has very dense waters. Residence time of waters in the Western Mediterranean basin is estimated between 50 and 100 years. If the general circulation is nowadays well known, it is still pretty difficult to predict currents on the coast. This fact raises the problem of connection between general circulation studies and more coastal ones that progress in modelling should gradually solve. Whatever the scale is, the waters (surface or deep) in the Mediterranean are not in a stable state. Moreover, in the last 40 years, there has been a slight but noticeable increase of deep waters temperature and salinity (+0.12°C in temperature; +0.05 % in salinity). It is probably too early to give an explanation but the possibility of a steady increase could be suggested by another observed increase of unusual occurrences in marine life which could be used as indicators of changing Mediterranean Sea conditions.

Finally, as mentioned above, the water inputs to the Mediterranean Sea have decreased dramatically over the last 40 years due to damming and irrigation. The south Levantine, Alboran, south-west Aegean Seas, and the central and northern Levantine basins are probably those most affected by this reduction. Moreover, the impact of dams on sediment loads is drastic: when considering the Nile water discharge reduction and possible reduction for many other rivers, the total sediment load to the Mediterranean Sea may have been reduced by 70%.

The enrichment of waters

Compared to other seas or oceans, primary productivity in the central parts of the eastern and western Mediterranean Sea and in many of the coastal areas away from the influence of major rivers or urban agglomerations is rather low. As a matter of fact, the Mediterranean is considered as a "young" water system compared to oceans because of a much shorter transit period (< 100 years) of deep waters, i.e. the time for surface waters to sink as deep waters and come upwards as, again, surface waters. This system infers lower concentrations of nutrients than in the ocean for the deep waters and higher concentrations (at least for nitrates and silicates) for the shallow waters (the first 300 meters). This last observation is explained by the homogeneity of the water column only affected by the seasonal warming, allowing nutrients to circulate much more easily than in the ocean. Without any doubt, bacteria and macroplancton have a great role in the very fast recycling of organic material. Man-made fertilisation (domestic and industrial wastes discharged through rivers, runoff and the atmosphere) of coastal waters, especially in enclosed bodies of water, is one of the factor triggering eutrophication events affecting marine life in general and benthic ecosystem in particular.

- *The biological diversity*

The full Mediterranean area –covering European, Asiatic and African coasts- is one of the most important centres of species richness in the world. More than 25,000 species, i.e. more than 10% of the world's flowering plants occur in an area amounting to only 1.5% of the earth's surface. About half of the species are endemic to the Mediterranean area.

With regard to marine life, the Mediterranean Sea includes about 7% of the known world marine fauna and 18% of the world marine flora of which 28% are endemic to the Mediterranean Sea. A total of 10,000 to 12,000 marine species have been recorded although new species are regularly discovered and described. The most typical and well-known assemblage of communities is represented by the sea-grass *Posidonia oceanica* ecosystem which develops as extended meadows in the infra-littoral zone (to a depth of 25-40 m) in the whole Mediterranean basin. There are other important coastal ecosystems like the calcareous algal rims formed by *Lithophyllum lichenoides* in the medio-littoral zone, the sea caves which support several rare and endemic species (e.g. sponges and red coral) which are also found in the bathyal zone where the light condition is similar, and the coralligenous communities (circalittoral zone) which constitute the most spectacular underwater scenery in the Mediterranean Sea.

The ichthyological Mediterranean fauna is characterised by a low endemism. The larger part of Mediterranean fish has Atlantic origin and more recently Indo-Pacific origin.

The distribution of species throughout the Mediterranean Sea is not homogeneous: it is greater in the western than in the eastern part. In addition, the distribution of Mediterranean fauna and flora varies with depth as shown in Table 3.2. This diversity is observed also at the community (biocoenosis) level. Compared with the Atlantic, the Mediterranean marine communities are rich in species with smaller individuals having a shorter life cycle. In general terms, the character of the Mediterranean marine life has low biomass and high diversity.

It is well known that the Mediterranean comes second only to tropical sea areas, in terms of biodiversity. Moreover, it is characterised by extensive biodiversity distributed in a lot of different areas throughout the entire basin.

In the following types of ecosystems can be considered:

- the « blue water » ecosystems based on the planktonic communities,
- the benthic ecosystems composed of different benthic communities,
- the sea-grass ecosystem mainly composed of phanerogamic communities,
- and, on land, the lagoon and wetland ecosystems, particularly complex and sustaining a rich biological diversity.

The presence and state of these ecosystems are key in defining sensitive areas all around the Mediterranean basin.

Table 3.2. **Variation of species according to depth zones**
(Fredj et al., 1992)

Zones	Depth (m)	Species (%)
Infralittoral zone	50	63
Circalittoral zone	100	44
Bathyal zone	150	37
Bathyal zone	200	31
Bathyal zone	300	25
Bathyal zone	500	18
Bathyal zone	1000	9
Abyssal zone	2000	3

▪ *Natural resources*

Mediterranean countries mostly lack natural resources. Libya, Algeria and Egypt are considered moderate-sized petroleum producers, Morocco is the world's third-largest producer of phosphates, Albania the third largest producer of chrome, and Spain the second largest producer of mercury. Water resources are relatively plentiful in the North but scarce in the south. Forests have limited economic significance, but are important for the preservation of soil as for recreation and landscape.

Mediterranean agriculture is characterised by multi-faceted crops, particularly olives, citrus fruits, grapes and hard grain; the main livestock is sheep. Increasingly, irrigation is needed in the south to maintain or increase crop production. While coastal regions tend to have little agricultural land, it often is of high quality, particularly around delta areas. However, Mediterranean agriculture is also characterised by long-term misuse and over-exploitation.

In recent years, efficient farming and growing urbanisation in the north has lead to increased abandonment of farmland and rangeland and the corresponding advance of forests. This contrast strongly in the South and east where marginal areas, such as arid steppes and rangelands, are being cleared for grain production; unfortunately, the lack of water resources and especially continually flowing rivers has restricted the use of irrigation. One result has been the increased desertification in North Africa and the Near East. Given the trends of the past 40 years, in the near future virtually all tillable land in the southern and eastern part of the Mediterranean basin will be cultivated for cereal production, even through the risk will be high and the yields low.

Although alluvial and coastal plains are few and not extensive (the Nile Delta being far the largest) most coastal plains have demographic and economic importance ranging from agriculture to industry/ commerce to recreation to historical/archaeological significance. Most areas still contain partly to little-modified natural ecosystems of irreplaceable value. Because of their ecological fragility, related to the land-use transition, and their economic importance, these coastal lowlands are particularly vulnerable to climatic changes that can affect hydrology, sea-level rise and ecosystems. Anthropogenic activities can also affect these areas because of pollution and sediments flows from upstream catchments.

Finally, it should be pointed out that because of both climate and historical/archaeological significance, the Mediterranean continues to be the greatest tourist destination in the entire world. Conversely, tourism is the greatest consumer/user of the Mediterranean coast and the number of tourists continues increasing. Such a growth will mean an increasing demand for coastal space as well as such necessities as electric power and water. Furthermore, the impact on certain habitats (particularly sandy beaches and dunes) will increase.

o ***Socio-economic aspects***

▪ *Demography and human settlements*

In 2000 the countries bordering the Mediterranean Sea had a combined population of about 430 million people (Table 3.3). A considerable part of them live directly in the coastal zone. Especially in the southern countries, population densities are much greater in coastal than in non-coastal areas. Coastal population densities range from more than 1000/km^2 in the Nile Delta to less than 20/km^2 along coastal Libya.

Table 3.3**. Population density and development in the Mediterranean countries**

		POPULATION			DENSITY	
COUNTRY	**AREA**	**2000**	**2025**	**Trend**	**Total**	**Med/Tot ***
	(km^2)	Thousand inhab.		(%)	Inhab./km^2	
SPAIN	504 783	39 815	40 769	+ 2.4	78	2.13

		POPULATION			DENSITY	
COUNTRY	AREA	2000	2025	Trend	Total	Med/Tot *
	(km^2)	Thousand inhab.		(%)	Inhab./km^2	
FRANCE	547 026	59 412	64 177	+ 8.0	103	1.20
ITALY	301 277	57 456	53 925	- 6.1	190	1.04
MALTA	316	389	430	+ 10.5	1145	1.00
MONACO	2	34	41	+ 20.6	15000	1.00
SLOVENIA	20 251	1 965	2 029	+ 3.3	100	0.57
CROATIA	56 538	4 473	4 193	- 6.3	87	0.68
BOSNIA-HERZEGOVINA	51 129	3 972	4 324	+ 8.9	87	0.58
SERBIA-MONTENEGRO	102 000	10 856	12 217	+ 12.5	104	0.55
ALBANIA	28 748	3 114	3 820	+ 22.7	113	1.29
GREECE	131 944	10 558	10 393	- 1.6	78	1.18
TURKEY	779 452	65 627	87 303	+ 33.0	72	1.28
CYPRUS	9 251				54	1.00
SYRIA	185 180	15 936	24 003	+ 50.6	77	4.23
LEBANON	10 230	3 206	4 147	+ 29.4	293	1.88
ISRAEL	20 770	5 851	7 861	+ 34.4	263	2.98
PALESTINE	6 165	3 150	6 072	+ 92.8	365	6.33
EGYPT	997 739	66 007	94 895	+ 43.8	59	3.54
LIBYA	1 759 500	6 038	8 832	+ 46.3	3	8.28
TUNISIA	154 530	9 615	12 892	+ 34.1	57	2.37
ALGERIA	2 381 741	30 332	42 329	+ 39.6	10	22.21
MOROCCO	710 850	28 505	38 174	+ 33.9	37	2.39
TOTAL	8 759 422	426 311	522 826			

* ratio of the population density on the Mediterranean part of the country over that in the entire country.

According to some projections, the population in the Mediterranean is expected to reach about 520 million in 2025 (Attané and Courbage, 2001). Increasingly, the population will urbanise and it is expected that by the year 2025 about 75% of the population will be urban. The economic and environmental burden on cities, therefore, will increase substantially.

Population growth, however, shows major differences between north and south. The European countries have nearly stable population (Table 3.3). In contrast, population growth in southern countries ranges from 2 to 3% per year. As a result the population in the coming years will increase and became younger in the south. With this shift will come increasing problems concerning education and job-creation in southern countries. The wide variation in political and economic systems as well as historic differences have led to great discrepancies in the level of development between Mediterranean countries. The highly developed industrial countries in the north (France, Italy and Spain) and countries on the way to become industrialised (Greece,Serbia and Montenegro and Turkey) stand in stark contrast to the countries in the south.

Human activities pose several threats on the structure and functions of natural ecosystems, on the quality and availability of natural resources (i.e. forests, soil, water) and on the natural and man - made landscape. Particularly, coastal areas are facing significant pressures mainly through the over - concentration of population and economic activities. According to "Blue Plan" scenarios the population residing in riparian states of the Mediterranean Sea will reach 520 – 570 million by the end of 2030 from the current 450 million. The southern rim of the Mediterranean now concentrates more than 50% of the total population while this percentage is expected to grow to 75% by 2025. Urbanisation of the Mediterranean coasts has put great pressures on the labour market, land use and social amenities mainly through infrastructures related to water supply, sanitation and transportation.

- *Industrial activity and tourism*

In the EEA report on the state and pressure of the marine and coastal Mediterranean environment (EEA, 1999), a description of the industrial activities in the Mediterranean region is presented.

The Mediterranean basin has never been a major mining region and thus was not involved in the period of industrial development based on coal and iron. However, its heavy metal cycling has been largely affected by the mercury, copper, zinc and lead deposits present in the Pyrictic streap of the Iberian Peninsula. It is better endowed in oil and natural gas (Algeria, Egypt, Libya, Syria and Italy), leading to the establishment of many refineries all around the Mediterranean basin.

Taking into consideration the world's sixteen most important raw materials, the Mediterranean countries' production (in decreasing order) of mercury, phosphates (Tunisia and Jordan), chromite (Turkey), lead, salt, bauxite (Bosnia, Croatia, France, Greece, Slovenia, Serbia and Montenegro) and zinc (Spain and Morocco) is higher than the world average. Submarine mining in the Mediterranean comprises mainly drilling for oil and gas and dredging of gravel and sand, but this particular type of activity can be considered to be at a relatively early stage of development.

Steel manufacturing, another symbol of industrial development and military power, is concentrated in the north (Italy, France, Spain, Croatia, Turkey and Greece) with a few producers in the south (Egypt, Algeria and Tunisia).

Generally, to date, the gap in industrial development between the northern and south-eastern sides of the basin remains considerable. In terms of added value, within the Mediterranean basin proper, Italy, France, and Spain together are predominant with 87% over the rest of the Mediterranean countries.

Apart from the chemical/petrochemical and metallurgy sectors, the other main industrial sectors include: waste treatment plants, paper, paints, plastics, dyeing and printing, and tanneries.

Distribution of industrial activities

Production activities occurring all over the Mediterranean basin can be differentiated by the different export specialisation for each country. In that respect, we can easily distinguish three groups of countries:

- The first group is highly specialised in some export products, while the rest of commodities are being imported. This is the typical situation for oil producing countries such as Algeria, Syria, Egypt and Libya. The current status does not give any sign of change in the short term for the export trends, in spite of some exceptions like Egypt, which shows a certain diversification with some increase in the production and export of manufactured goods (textiles, shoes, etc.);
- The second group is less specialised in exporting goods even in a situation of comparative disadvantage with other countries. Thus, their exports are more diversified. This is the case for countries like Tunisia, Morocco, Turkey, Serbia and Montenegro, Cyprus and Malta. All these countries export manufactured goods such as clothes,

textiles, and leather, but each one has more specific productions (chemicals, oils and lubricants in Tunisia; chemicals and fertilisers in Morocco; textile fibres, wool, cotton, paper, cement in Turkey and FRSerbia and Montenegro);

- The third group is more diversified and thus much less specialised. It mainly comprises the EU Member States. As mentioned earlier, they account for the largest part of the petrochemical industry in the Mediterranean. Located fully in the Mediterranean basin, Italian industry is certainly the largest, with basic manufactured goods, machines, transport equipments, etc.

In terms of the environmental impacts of industrial activities in the Mediterranean marine environment, industry, besides occupying land area, may also use the territory to dispose of solid wastes, for example in the form of landfill. This is particularly true of mining since it often involves the dumping of mine tailings and ore slurry on land, into rivers or to the sea directly. It may also include the ash from processes such as steel-making.

Tourism

The Mediterranean Basin is considered as the most important tourism destination globally attracting a third of the number of tourists. Domestic tourism has a great significance for the region; of the 450 million visitors, 100 million stay on the Mediterranean coast of their host country, considerably increasing human concentration. This figure is likely to double if not triple by 2025, entailing the risk of over load based depreciation of the tourist capital represented by this activity which is seen as vital to most countries in the region as a source of hard currency and an essential development factor for southern countries.

Tourism growth is not equally distributed even among Mediterranean countries. The significance of tourism development in Mediterranean member states of the EU is higher in comparison to the rest of the Union. France, Spain, Italy and Greece remain by far the main destinations for international tourism. Although 4/5 of international tourism today is monopolised by the traditional countries in the North, a certain degree of dissatisfaction with over – urbanised coasts is likely to benefit the wilder hinterland and the as yet virgin coasts of southern countries. There is no doubt that this could act as a potential balancing factor between the two banks of the Mediterranean.

Tourism is regarded as a prevailing economic sector for the Mediterranean region. More than six million people are employed directly or indirectly in the tourism industry with forecasts showing an increase of two million by 2010. Moreover, efforts have been concentrated in the development of other types of tourism (i.e. health, congress, ecotourism, cultural tourism, etc.), in order to expand its predominant seasonal character. In any case, tourism is currently the first foreign currency source for the Mediterranean countries and its direct and indirect contribution to national GNP can reach 29% (Cyprus) or 35% (Malta). Such a growth will mean an increasing demand for coastal space as well as such commodities as electric power and water. Furthermore, the impact on certain habitats (particularly sandy beaches and dunes) will also increase.

o **_Management and regulatory mechanisms_**

The early recognition for the environmental degradation of the Mediterranean Sea led to the establishment of several institutional arrangements aiming to monitor, assess and improve the state of its marine and coastal environment. The major institutional arrangements, related to coastal zone management in the Mediterranean countries are briefly described below as well as the main issues and problems regarding their operation.

3.3.1 The Barcelona system

Under the United Nations Convention on the Law of the Sea (Montego Bay, 1982; hereinafter UNCLOS) “States have the obligation to protect and preserve the marine environment” (Art. 192) taking measures “necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life" (Art. 194, para. 5).

The Barcelona Convention on the Protection of the Mediterranean Sea against Pollution which entered into force on 12 February 1978, is a notable instance of such cooperation. Concluded under the auspices of UNEP the Convention involved a considerable degree of legal imagination, such as opening up membership to regional groupings sharing the objectives of the Convention albeit not necessarily wholly contained within the Mediterranean basin. In fact, the European Community is a Contracting Party to the Convention and some of its protocols, together with four States which are today members of the Community (France, Greece, Italy and Spain) and provides a significant contribution to the functioning of the Barcelona system.

Since 1994, several components of the Barcelona system underwent important changes. Starting in 1995 an ambitious revision of the Convention began which concluded in 2002. Its objective was to modernise the Convention to bring it into line with the principles of the Rio Declaration, the philosophy of the new Convention on the Law of the Sea and the progress achieved in international environmental law in order to make it an instrument of sustainable development. The revised Convention also aimed to progress from an essentially proclamatory form of law to a much more prescriptive law setting out obligations. The scope of its protocols was extended and new protocols were adopted either to replace the existing ones or to cover new fields of co-operation. In addition, in order to ensure the effectiveness of the new provisions, the need for new capacities as well as public participation and access to information including the adoption of a reporting procedure were part of the revision process.

The structure of the present Barcelona legal system includes the following instruments:

a) the Convention which, as amended in Barcelona on 10 June 1995, changes its name to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, hereinafter "the Convention" (the amendments are not yet in force);

b) the Protocol for the Prevention of the Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft (Barcelona, 16 February 1976; in force since 12 February 1978), which, as amended in Barcelona on 10 June 1995, changes its name to the Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea, hereinafter "the Dumping Protocol" (the amendments are not yet in force);

c) the Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency (Barcelona, 16 February 1976; in force since 12 February 1978), which is intended to be replaced by the Protocol Concerning Co-operation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea, signed in Valletta on 25 January 2002, hereinafter "the Emergency Protocol" (not yet in force);

For the implementation of the LBS Protocol the Strategic Action Programme (SAP) was established. The SAP is an action-oriented MAP/MED POL initiative identifying priority target categories of substances and activities to be eliminated or controlled by the Mediterranean countries. The timetabled schedule for the implementation of specific control measures and interventions extends over 25 years.

The key land based activities addressed in the SAP are linked to the urban environment, (particularly municipal wastewater treatment and disposal, urban solid waste disposal and activities contributing to air pollution from mobile sources) and to industrial activities, targeting those responsible for the release of toxic persistent and bioaccumulative (TPB) substances into the marine environment, giving special attention to persistent organic pollutants (POPs).

Also addressed are the release of harmful concentrations of nutrients into the marine environment, the storage, transportation and disposal of radioactive and hazardous wastes and activities that contribute to the destruction of the coastline and coastal habitats.

d) the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources (Athens, 17 May 1980; in force since 17 June 1983), which, as amended in Syracuse on 7 March 1996, changes its name to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities, hereinafter the LBS Protocol (the amendments are not yet in force);

e) the Protocol concerning Mediterranean Specially Protected Areas (Geneva, 1 April 1982; in force since 23 March 1986), which has been replaced by the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, signed in Barcelona on 10 June 1995, hereinafter “the SPA and Biodiversity Protocol” (in force since 12 December 1999);

f) the Protocol Concerning Pollution Resulting from Exploration and Exploitation of the Continental Shelf, the Seabed and its Subsoil, signed in Madrid on 14 October 1994, hereinafter the Offshore Protocol (not yet in force); and

g) the Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal, signed in Izmir on 1 October 1996, hereinafter “the Hazardous Wastes Protocol” (not yet in force).

The recent updating of the Barcelona legal framework shows that the Parties consider it as a dynamic system capable of being subject to re-examination and improvement, if appropriate.

It may be something of a disappointment to note that the amendments to the Barcelona Convention adopted in 1995 and 1996 and three of its Protocols have not yet entered into force. But this is not necessarily due to a lack of political will by the States which are called upon to become Parties to the updated instruments. In fact it is rather the great number of amendments involving considerable technicality in their final provisions, as well as the high threshold of acceptance necessary for their entry into force that have been a factor of delay. As the present threshold of acceptance of an amendment to the Convention stands at three quarters of the Membership and the number of Parties to the Convention is 21, the required number of acceptances of the amendments should be 16 ($21 \times ¾ = 15.725$). This is a rather high threshold, which explains why the amended Barcelona Protocols are still not in force.

The Mediterranean Commission for Sustainable Development (MCSD), consultative body to the Contracting Parties of the Barcelona Convention established in 1996, was selected to play an assisting role to MAP in the consolidation of strategies for sustainable development in the region. The MCSD has focused, among others, on the sustainable management of coastal zones addressing strategy and political decision making issues. The MCSD has produced recommendations and proposals for action on water demand management, coastal area management, tourism, industry, urban development, free trade and the environment, public participation and awareness raising and sustainable development indicators. Issues now being examined include agriculture and rural development, urban waste management and consumption patterns, local governance and finance and co-operation for sustainable development.

1.1.2 Mediterranean Environmental Technical Assistance Programme

The Mediterranean Environmental Technical Assistance Program (METAP) was launched in 1990 by the World Bank and the European Investment Bank in partnership with the European Union and United Nations Development Program. METAP's mission is to generate funds assisting Mediterranean states to devise policies, programs and investment projects that effectively tackle the obstacles for achieving sustainable development in the region. However, METAP has been ineffective in terms of clarifying investment actions (usually infrastructure driven)

- *European Union Demonstration Program for ICZM*

In 1996, the European Union initiated a demonstration program targeted to identify appropriate remedial measures against the deterioration of European coastal zones. The specific program had the following objectives:

- Provide concrete technical information on the factors and mechanisms which either encourage or discourage sustainable management of coastal zones.
- Stimulate a broad debate and the exchange of information among the various actors involved in the planning, management or use of European coastal zones.
- Test co-operation models and procedures against ICZM requirements.

Thirty-five CZM projects were selected by the Commission for this demonstration program, twelve of which were located in the Mediterranean Sea. Each of these projects has analysed the operation of ICZM co-operation procedures as well as their constraints and efficiency. The main issue regarding the implementation of the specific initiative was the lack of regional level dimension in Integrated Coastal Zone Management.

- *Coastal Zone Management issues*

It is evident that Mediterranean coastal zones face diverse and complex social, economic and environmental problems that demand particular attention and special approach. In this context integrated coastal zone management and planning is seen as the best suited framework accomplished within the agenda of the previously described institutional arrangements. However, certain issues still persist as already described in the UNEP/MAP/PAP: White Paper for Coastal Zone Management in the Mediterranean (2001).

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• The nature and sources of transboundary problems and issues

It is apparent that the environmental degradation in the Mediterranean region, particularly of coastal areas, is expected to affect significantly human activities and land uses, mainly by limiting their recreational and residential value as well as impairing the quality and availability of natural resources. Consequently, pollution at the local/national level has been considered a priority issue of concern and several steps towards its abatement and prevention have been taken in the framework of supporting regional agreements and regulatory mechanisms, as briefly discussed in section 3.3. However, the transboundary components of these environmental issues have not been equally confronted, while its impacts on human activities should be better understood.

The major environmental problems for the Mediterranean Sea have been identified and assessed as a result of the work of the Mediterranean Action Plan over the last twenty years, and mainly originate in the atmospheric pollution and deposition, riverine outflows, agricultural run-off, urban and industrial activities and maritime transport. These pollution sources encompass a series of functional issues which are common to all countries and, therefore, they are the subject of transboundary concern. On the other hand, depending on the source, pollution may extend towards a reduced geographical area and affect sites or regions rather distant or even belonging to other countries and, consequently, become transboundary elements that require attention. In this respect, it has recently been pointed out that the atmospheric and aquatic compartments, both marine and continental, play a major role in the global distribution of land-based pollutant sources in the region (UNEP, 2002). The knowledge of the water circulation in the Mediterranean Sea and of the regional meteorology is well established but only recently a number of studies have intended to document processes that connect the general circulations at the Basin level to regional pollution episodes.

Based on the existing information, the transboundary elements associated to those major environmental problems will be described in the following sections, as well as the assessment of their magnitude and importance.

o *Airborne deposition*

The main causes of transboundary air pollution are emissions from transport and energy usage in the form of sulphur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O_3) as well as volatile organic compounds (VOCs), heavy metals and persistent organic pollutants (POPs). These pollutants can remain in the atmosphere so long as to be transported thousands of kilometres far from the original sources. The main effects of transboundary air pollution are acidification of water and soil, summer smog by tropospheric ozone, eutrophication of soil and waters and dispersion of hazardous substances.

▪ *Nutrients deposition in the Mediterranean region*

Nutrients deposition to the Mediterranean Sea includes deposition of nitrogen and phosphorus. Although data on N deposition to Mediterranean is more abundant than data on P deposition, estimation of true N deposition using experimental measurements is difficult due to the presence of various forms of nitrogen compounds in the atmosphere. Phosphorus, on the other hand, occurs only as particulate phosphate, for which some data are available in the Mediterranean atmosphere.

4.1.1.1 Nutrient concentrations in the Mediterranean atmosphere

Concentrations of NO_3^- and NH_4^+ measured at different locations of the Mediterranean basin range between 1.3 - 1.6 µg/m^3 and 0.9 – 1.2 µg/m^3, respectively. Average concentrations of NO_3^- and NH_4^+ in the Mediterranean rain water are 36± 20 and 30± 11 µeq/L, respectively.

Nitrate and NH_4^+ concentrations in both aerosols and rain water are distributed fairly uniformly throughout the basin. For example, the median rain water NO_3^- concentrations in the Western and Eastern Mediterranean are 28 and 33 µeq/L, respectively. However, concentrations of NH_4^+ and NO_3^- in rain water and aerosol at the south coast of the Mediterranean Sea are apparently slightly lower than those measured at the north.

Measurements performed at the EMEP stations that are located on the Mediterranean coast have shown that the NO_3^- and NH_4^+ concentrations at the basin have not changed significantly over the last 20 years.

Information on concentrations of gaseous nitrogen species, namely NO_2, NH_3 and HNO_3, is scarce in the Mediterranean region. Among these species, NO_2 is measured in 8 EMEP sites, but HNO_3 and HNO_3 are measured in only two of the stations. Average concentrations of NO_2 for the year 1999 vary between 2.7 µg/m^3 measured at the Anatolia and 13 µg/m^3 measured on the Spanish Mediterranean coast. The average value is 10 ± 5 µg/m^3. For NH_3 and HNO_3 data are too few to assess the levels of these N-species in the Mediterranean.

As in the case of NO_3^- and NH_4^+, concentrations of NO_2, NH_3 and HNO_3 also do not show a dramatic change between 1987 and 1999.

Comparing the concentrations of these nitrogen species measured at EMEP stations located on the Mediterranean coast with those measured in other parts of Europe it can be inferred that mean aerosol NO_3^- concentrations in Mediterranean and non-Mediterranean EMEP stations are 1.4 and 1.7 µg/m^3, respectively. The average rain water NO_3^- concentrations is 41 ± 26 µeq/L (median 30 µeq/L) in Mediterranean EMEP stations and 27 ± 29 µeq/L (median 27 µeq/L) in non-Mediterranean EMEP stations. Statistical analysis of both data sets indicated that they were not significantly different.

A similar comparison was also performed for NH_4^+ concentrations. The average aerosol NH_4^+ concentrations in the Mediterranean and other parts of Europe are 1.1 ± 0.6 and 0.9 ± 0.7 µg/m^3, respectively. Similarly, rain water NH_4^+ concentrations are 30 ± 12 µeq/L in the Mediterranean region and 29 ± 18 µeq/L in other parts of the Europe.

Finally, the gaseous NO_2 concentration measured in the Mediterranean region is 9.9 ± 3.7 µg/m^3 (median 10 µg/m^3), whereas in non Mediterranean EMEP stations is 3.3 ± 5.3 µg/m^3 (median is 5.9 µg/m^3). The statistical evaluation of these data indicated that NO_2 concentrations measured in the Mediterranean EMEP stations are higher than those measured in other parts of Europe.

4.1.1.2 Emissions of N species in the Mediterranean region

Country based emissions of NO_x, NH_3 and total nitrogen are given in Table 4.1. Emission data was obtained from UNEC/EMEP data base (Webdab) (Vestreng and Klein, 2002). The data base contained emission information officially reported by each country, as well as “expert estimates” made to fill the gaps. As this data base do not include emissions from countries on the southern and eastern coast, emission data for these countries was obtained from Bashkin et al. (1997).

Total NO_x, NH_3 and total N emission in the Mediterranean region are 1800, 2300 and 4200 kt N in 1999, so that NH_3 and NO_x accounted for 57% and 43% of total N emissions in the Mediterranean region. These emissions account for 14%, 36% and 24% of respective emissions in whole Europe indicating that the Mediterranean region is a significant contributor to the total European emissions, particularly for NH_3.

These emissions did not change significantly between 1980 and 1999 but the relative contribution of the Mediterranean region to total European emissions have increased in the last 20 years, particularly for NH_3 (27% in 1980 to 36% in 1999). The increase in the share of Mediterranean region in the emissions of both nitrogen species are due to decrease in these emission in Europe. Based on EMEP projections NO_2 and ammonia emissions in the

Mediterranean region are expected to account for 17% and 34% of European emissions, respectively, in the year 2010.

The share of Mediterranean region NH_3 emissions should be considered as the lower limit, because data do not include emissions from Turkey and Serbia and Montenegro which are expected to be significant emission areas [estimated emission for Turkey andSerbia and Montenegro in 1992 is 395 and 174 Kt N, respectively (Bashkin et al., 1997)].

Table 4.1 **Country based emissions of NO_x and NH_3 in the Mediterranean region**

	NOx (kt N/yr)	**NH_3** (Kt N/yr)	**Total N** (Kt N/yr)
Albania	9.1	30	39
Bosnia H.	16	36	52
Croatia	22	20	42
Cyprus	7	2	8
France	466	663	1129
Greece	116	62	178
Italy	452	369	821
Monaco	0.17		0.17
Slovenia	18	16	34
Spain	363	385	748
Turkey	277	395	672
Serbia and Montenegro	20	174	194
Algeria	4	82	86
Egypt	15	33	48
Israel	24	16	40
Libya	5	34	39
Morocco	0.39	3.0	3.4
Tunisia	1.1	38	39
Lebanon	3.0	9.0	12
Malta	1.0	1.0	2.0
Syria	9.0	58	67
Jordan	1.5	1.0	2.5

Although there is no change in NH_3 emissions in any of the Mediterranean countries between 1980 and 1999, NO_x emissions in Italy and France decreased and that in Spain leveled off after 1992. The NO_x emissions in countries located at the central and eastern part of the Mediterranean continuously increased in the same time period.

France, Italy and Spain emit most of the NO_x in the Mediterranean region. These three countries which are located on the western part of the basin totally accounts for 78% of NOx emissions in the basin in 1999. The rest of the emissions is accounted for by the remaining 6 countries located on the central and eastern Mediterranean. Data reveals that the relative contribution of these countries have increased by approximately 10% in the last 20 years, basically due to doubling of NO_x emissions (from 6,800 in 1980 to 12,900 tonnes NO_x in 1995) in Turkey.

Breakdown of NO_x emissions into sectors in the Mediterranean region is given in Table 4.2. Mobile sources are by far the most important source of NO_x emissions. They account for 63% of NO_x emissions in the basin. Approximately 73% of mobile source emissions are from road transport, and the remaining 27% is from other heavy machinery. Combustion processes accounts for 35% of NO_x emissions in the basin. Approximately 40% of NO_x emission from combustion process is from combustion to produce energy, 34% is from combustion in the manufacturing sector and 27% is from non-industrial combustion, such as space heating.

The table does not include most of the countries on the south and east of the basin, but as discussed previously, emissions from these countries are not large enough to change the conclusions.

Data on NH_3 emissions is too fragmentary to make a general assessment, but existing data (Tarrason et al., 2000) indicates that agriculture is the main source of NH_3 emissions which is followed by waste treatment, road transport and production processes.

Table 4.2 **Sector based NO_x emissions in the Mediterranean region (Ktonnes N/year)**[a]

	Energy production	**Non-industrial combustion**	**Combustion in manufacturing**	**Production process**	**Road transport**	**Other mobile sources**	**Waste treatment**	**Agricult.**	**Other**
France	134	103	135	16	728	397	16		3,8
Croatia	14	3,8	8,6	1,6	29	15	0,04		
Italy	186	79	156	11	748	286	18	1	1
Slovenia	15	3,1	3,1		36	0,5			
Turkey	173	192	173	11	361				
Cyprus	6,2	1,2	2		11			0,9	
Serbia and Montenegro	40	1,6	4,4						
TOTAL	569	384	482	40	1912	698	34	1,9	4,8

[a]data from Tarrason et al. (2000)

4.1.1.3 Deposition of N species to the Mediterranean Sea

Deposition of NO_3^- and NH_4^+

Considering the simplicity of collection and analysis of NO_3^- and NH_4^+ wet-only samples, wet deposition fluxes are expected to be reliable. The uncertainties are higher in dry deposition measurements. However, uncertainties in dry deposition fluxes do not increase the uncertainties in total nitrogen deposition fluxes because dry deposition accounts for a significantly smaller fraction of total nitrogen deposition.

The total deposition fluxes are summarised in Table 4.3 and are either derived from analysis of bulk deposition samples or by analysis of wet and dry deposition samples separately.

Table 4.3 **Summary of nitrogen deposition fluxes in the Mediterranean basin (mg N/m^2/y).**

	East Med.	**West Med.**	**All Med.**
		NO_3^-	
Wet	210 ± 100	410 ± 310	310 ± 260
Dry	94 ± 33	110 ± 55	110 ± 50
Total	350 ± 130	460 ± 320	420 ± 270
%wet	60 ± 14	76 ± 4	68 ± 13

		NH_4^+	
Wet	220 ± 120	280 ± 240	250 ± 190
Dry	76 ± 62	25 ± 12	45 ± 47
total	310 ± 130	320 ± 200	320 ± 180
%wet	67 ± 23	91 ± 4	81 ± 20
		Total (NO_3-N + NH_4-N)	
Wet	360 ± 180	630 ± 520	500 ± 410
Dry	170 ± 92	140 ± 65	150 ± 80
Total	590 ± 270	760 ± 470	680 ± 400

The average value for the total wet inorganic N deposition (NO_3^--N + NH_4^+-N) to the whole Mediterranean basin is 500 mg N/m^2/y. Wet inorganic N deposition in the Eastern than to the Western Mediterranean (360 and 630 mg N/m^2/y, respectively). These values are similar to those reported by Guerzoni et al. (1999), after reviewing existing data.

Wet deposition flux of NO_3^- is higher in the Western Mediterranean (410 mg N/m^2/y) compared to the Eastern part of the basin (210 mg N/m^2/y). Ammonium wet deposition, on the other hand, is approximately the same in both basins (220 mg N/m^2/y in the Eastern Med and 280 mg N/m^2/y in the Western Med). Total wet NH_4^+ deposition flux to the whole basin is 250 mg N/m^2/y. These deposition flux values suggest that NH_4^+ and NO_3^- contribute approximately equally to total inorganic nitrogen wet deposition in the Mediterranean basin. This last statement also agrees with the conclusion reached by Guerzoni et al. (1999) on the relative contribution of NO_3^- and NO_3^- to total wet N deposition in the Mediterranean.

Average dry deposition flux of inorganic N to the Mediterranean basin (NO_3^- + NH_4^+) is 150 mg N/m^2/y . Corresponding values for the Eastern and Western basins are not significantly different (170 mg N/m^2/y in the Eastern Med and 140 mg N/m^2/y in the Western Med). Total inorganic nitrogen dry deposition flux estimated in this study agrees well with the dry deposition flux assessed by Guerzoni et al. (1999) for the whole basin (127 mg N/m^2/y).

The contribution of nitrate to dry deposition flux (110 mg N/m^2/y) is more than twice that of NH_4^+ (45 mg N/m^2/y). This is not totally unexpected, because NO_3^- is known to be associated with large sea salt and crustal particles which can dry deposit faster compared to sub-micron particles with which NH_4^+, is associated. On the other hand, the NO_3^- dry deposition fluxes are similar in both basins (94 mg N/m^2/y in the Eastern Med and 110 mg N/m^2/y in the western Med). However, dry deposition flux for NH_4^+ is higher in the Eastern than in the Western Mediterranean (76 and 25 mg N/m^2/y, respectively).

Inorganic nitrogen deposition in the Mediterranean region occurs mostly as wet deposition. Approximately, 70% of nitrate deposition and 80% of NH_4^+ deposition occurs in the wet mode. Relative contribution of wet mode to total nitrogen deposition is higher in the Western Mediterranean, probably owing to higher annual rainfall in this basin.

Using emission data for the year 1999, Tarrason et al. (2000) have calculated deposition fluxes of oxidised and reduced forms of nitrogen to Mediterranean sub-regions as summarised in Table 4.4. Results suggest that total N deposition flux is significantly high in the Eastern (1132 mg N/m^2/y) compared to the Western Mediterranean (448 mg N/m^2/y), although a previous study (Erdman et al., 1994) showed that fluxes in the Eastern and Western basins are not very different.

Table 4.4 **Average deposition fluxes of nitrogen species to Mediterranean sub-regions calculated by modelling (mg N/m^2/y)**

	Oxidised	Reduced	Total N
1. Alboran	40	1	41
2. Northwest	128	21	149
3. Southwest	148	27	175
4. Tyrrhenian	355	278	633
5. Adriatic	372	871	1243
	Oxidised	**Reduced**	**Total N**
6. Ionian	535	707	1242
7. Central	377	333	710
8. Aegean	814	990	1804
9. Northeast	577	561	1138
10. Southeast	462	305	767
West Med	208	239	448
East Med	553	579	1132
All Med	380	409	790

Nitrogen deposition loads to Eastern, Western and whole Mediterranean are given in Table 4.5 using the deposition fluxes indicated in Table 4.3 and the corresponding surface area of the Eastern, Western and whole Mediterranean (2,512,000 km^2 or whole Mediterranean and 1,256,000 km^2 for the Eastern and Western parts).

Table 4.5 **Nitrogen deposition load to Mediterranean (ktonnes/year)**

	NO_3^-			NH_4^+			TOTAL -N		
	Wet	**Dry**	**Total**	**wet**	**dry**	**total**	**wet**	**dry**	**total**
East Med	261	118	322	281	81	395	456	201	737
West Med	519	152	427	330	30	370	792	180	532
All Med	780	267	778	611	114	754	1248	386	1247

Total inorganic nitrogen deposited to the whole basin is 1250 ktonnes/y. Approximately 750 ktonnes/y, from this total, are deposited to Eastern and 530 ktonnes/y to the Western basins. 1250 ktonnes/y are deposited as wet deposition whereas 390 ktonnes/y are in the dry mode. As pointed before, NO_3^- and NH_4^+ contribute equally to total deposition.

On the other hand, the calculated total inorganic nitrogen deposition load to the Mediterranean sub-regions is given in Table 4.6 (Tarrason et al., 2000). Apparently, the total inorganic N deposition is much hochger in the Eastern basin.

Table 4.6 **Deposition of N species to Med sub-regions calculated by modelling (ktonnes/year)**

	Oxidised	Reduced	Total N
1. Alboran	5	0,1	5
2. Northwest	41	7	48
3. Southwest	57	11	68
4. Tyrrhenian	127	99	226
5. Adriatic	59	137	196
6. Ionian	164	217	381

7. Central	294	260	554
8. Aegean	208	252	460
9. Northeast	136	132	268
10. Southeast	291	192	483
Total			
West Med	289	254	543
East Med	1093	1053	2146
All Med	1382	1307	2689

Deposition of other forms of N

The data presented in the previous section includes measurements of NO_3^- and NH_4^+ in dry deposition, wet deposition, bulk deposition and aerosols. Therefore, other species like NO_2, NH_3 and HNO_3 have not been considered. When these species dissolve in cloud droplets or raindrops, they readily convert to NO_3^- or NH_4^+. Hence, deposition of these gases is accounted for in wet deposition measurements. The fraction that is not accounted for is their dry deposition. However, it is not possible to make an assessment on dry deposition of gaseous N species in the Mediterranean region owing to scarcity of data. Among these gases, dry deposition of NO_2 and NH_3 is expected to be too small to make a significant contribution to total inorganic N deposition, but not HNO_3. Guerzoni et al. (1999) suggested that HNO_3 dry deposition flux is expected to be comparable to NO_3^- dry deposition flux. If that is the case, it would increase the total N flux by 10 – 20%.

Another nitrogen species that is not included in this section is the organic bound nitrogen. Recently it had been suggested that input of organic bound N can be as large as 50% of input of inorganic nitrogen (Cornell et al., 1995; Duce, 1997). However, Guerzoni et al. (1999) reviewing few existing data in the Mediterranean region concluded that contribution of deposition of organic bound N to total N deposition is not significant (<5%).

Deposition of phosphorus to the Mediterranean Sea

There are few measurements of atmospheric P in the Western (Bergametti et al., 1992; Migon et al., 2001) and Eastern (Herut and Krom, 1996; Herut, 2001) Mediterranean. Guerzoni et al. (1999) reviewing these concluded that the atmospheric input of inorganic P is 40 mg P/m^2/y in the Western Mediterranean and 20 mg P/m^2/y in the Eastern basin. Although these fluxes are small compared to deposition fluxes of various forms of N, actual P fluxes that act as nutrient in the Mediterranean are even smaller, because large fraction of this total P input originates from crustal material transported from North Africa and is insoluble (Migon et al., 2001). Bergametti et al. (1992) estimated soluble input as 30% of total inorganic P input to the Western Mediterranean Sea.

Source regions and vectors affecting N deposition to the Mediterranean Sea

The source regions responsible for the observed inorganic N deposition in the Mediterranean region is obtained from EMEP modelling studies (Tarrason et al., 2000). Italy is by far the most important contributor to inorganic nitrogen deposition in the Mediterranean region, accounting for approximately 40% of total, oxidised and reduced N deposition to the basin. Italy is followed by Spain, France, Greece and Turkey. These four countries are responsible for approximately 85% of all forms of inorganic N deposition in the Mediterranean region. Oxidised, reduced and total N deposited to the Mediterranean basin largely originates from countries bordering the basin. Mediterranean countries account for 85% of nitrogen deposition to the Mediterranean Sea. Other countries in Europe (Bulgaria, Romania, Austria, Portugal and Switzerland) account for the remaining 15% of nitrogen deposition.

It should be noted that, countries contributing to N deposition in the Eastern and Western parts of the Mediterranean basin can be significantly different. Unfortunately, there is no data for separate assessment of source regions affecting different parts of the basin.

Modelling studies have demonstrated that atmospheric input of N is equal in magnitude to riverine input (Bashkin et al., 1997). Comparison of riverine and atmospheric inputs of nitrogen to the Mediterranean sub-regions are presented in Table 4.7. The atmospheric deposition for the south and south-eastern sub-basins (4, 6, 7 and 10) which represent about one third of the total surface is 87% of the total nitrogen input.

Table 4.7 **Comparison of inputs of nitrogen to the Mediterranean Sea sub-basins through riverine contributions and by atmospheric deposition (Erdman et al., 1994)**

Mediterranean Sea subbasins	Input through rivers (kt N / year)	Atmospheric input (kt N / year)	% of Atmospheric deposition
1. Alboran	121.7	16.0	11.6
2. Northwest	297.6	174.8	37.0
3. Southwest	99.3	112.8	53.2
4. Tyrrhenian	58.6	155.2	72.6
5. Adriatic	182.2	122.4	40.2
6. Ionian	29.5	103.5	77.8
7. Central	0	120.1	100
8. Aegean	169.5	122.2	41.9
9. Northeast	51.7	44.5	46.3
10. Southeast	1.5	95.8	98.5
Total Mediterranean	1011.5	1067.3	51.3

1.1.2 Deposition of heavy metals in the Mediterranean region

For very long time riverine inputs were believed to be the only pathway with which heavy metals are transported to the marine environment. However, evidence accumulated in the last 15 years, have clearly demonstrated that deposition from atmosphere is also an important pathway with which metals enter to regional seas (Milliman and Martin, 1997).

Monitoring of metals in the Mediterranean Sea has been carried out since early 70's through the MED-POL program. Unfortunately, implementation of the atmospheric monitoring program was not very successful and the number of reporting atmospheric monitoring sites was too scarce to assess the levels of metals throughout the whole basin.

- *Concentrations of heavy metals in the Mediterranean atmosphere*

Fair amount of data on atmospheric concentrations of metals exist for both the Western (Dulac et al., 1987; Guerzoni et al., 1999; Bergametti et al., 1989a; 1989b; Chester et al., 1990; 1993; 1997; Migon et al., 1993; 1997; Migon and Caccia, 1990; Sandroni and Migon, 1997; Mateu et al., 1993; 1999; Sandroni and Migon, 2002; Medinets, 1996) and Eastern Mediterranean basins (Cornille et al., 1990; Medinets, 1996; Herut et al., 2001; Ezat 2000; Chabas and Lefèvre, 2000; Ganor et al., 1998; Kubilay et al., 1995; Al Momani et al., 1998; Gullu et al., 1998; Foner and Ganor, 1992). Zinc, Cd, Cu and Pb are the selected elements for discussion, as they have been the most generally measured.

The Zn values reported for the Mediterranean region varies between 12 and 136 ng/m^3 with a median value of 24 ng/m^3. Values in the Eastern Mediterranean varies between 19 ng/m^3 measured at Erdemli and 136 ng/m^3 measured at the Mediterranean sub-region VIII during shipboard sampling with a median value of 23 ng/m^3. The values on the Western basin vary between 12 – 47 ng/m^3 with a median value of 25 ng/m^3. Consequently, there is not a statistically significant difference between the Zn concentrations measured in the Eastern and Western Mediterranean.

Zinc concentrations reported for the Western Mediterranean are more homogeneous than those reported for the Eastern Mediterranean, with decreasing gradients offshore and between the French coast and the island sites, such as Sardinia, Corsica and Majorca.

Concentrations of Cu in the Mediterranean regions vary between 1.9 ng/m^3 and 28 ng/m^3, with a median value of 7.5 ng/m^3. The values in the Eastern Mediterranean varies between 3.8 and 8.9 ng/m^3 with a median value of 7.2 ng/m^3, whereas values in the Western Mediterranean varies between 1.9 and 28 ng/m^3 with a median value of 7.6 ng/m^3. Concentrations of Cu are not significantly different in different parts of the basin.

Copper concentration is more uniformly distributed throughout the Mediterranean basin compared to Zn. Concentrations reported are fairly similar to each other throughout the basin, except for Sub-region II (NW Mediterranean), probably due to the proximity of emission sources in Europe.

Cadmium concentrations in the Mediterranean region varies between 0.04 ng/m^3 measured in sub-region II during ship borne sampling and 0.6 ng/m^3 measured at coastal sites located again in sub-region II. The median value for the Cd concentrations reported in the Western Mediterranean is 0.36 ng/m^3 and that for the eastern Mediterranean is 0.29 ng/m^3. These figures indicate that there is not a significant difference between the concentrations reported for the Eastern and Western parts of the Mediterranean basin.

Cadmium concentrations are fairly uniformly distributed throughout the Mediterranean basin. Although some higher Cd concentration values are reported in the NW Mediterranean, the data are too variable to generalise these high concentrations for the whole Sub-region II

Lead concentrations in the Mediterranean region vary between 2.5 and 68 ng/m^3 with a median value of 14 ng/m^3. In the Eastern Mediterranean values vary between 7.9 and 68 ng/m^3 with a median value of 25.5 ng/m^3. In the Western Mediterranean measured Pb concentrations cover a range between 2.5 and 58 ng/m^3 with a median of 12 ng/m^3. Among Zn, Cu, Pb and Cd, Pb is the only element which has a statistically significant difference between the Eastern and Western parts of the basin. Observed lower Pb concentrations in the Western Mediterranean is probably due to earlier phasing out of leaded gasoline in Europe (Ryaboshapko et al., 2001).

Unlike the other three elements, Pb concentrations show a clear difference between stations located on the coast and stations located far in the sea (stations located on islands or shipboard samples). The median Pb concentrations in coastal and open-sea locations are 48 ng/m^3 and 10 ng/m^3, respectively. Roads are very close to the coast in the Mediterranean region and none of these coastal sites are free from the influence of local Pb emissions from traffic.

There are some indications of temporal decreasing trends for Pb and Cd in the region. However, accurate data correlation analysis demonstrate that none of the observed variations are statistically significant, indicating that other factors, such as different locations, different sampling and analytical methods are more important on observed variability of reported average concentrations than the time of sampling.

Comparison of heavy metal concentrations measured in the Mediterranean region with those measured in different parts of Europe can be useful to understand the degree of pollution in the Mediterranean atmosphere. The results are shown in Table 4.8.

Table 4.8 **Median values of metal concentrations measured in the Mediterranean region and Europe (ng/m^3)**

			Eastern	Western
	Europe	**Mediterranean**	**Mediterranean**	**Mediterranean**
Zn	17,6	23,5	23,5	25,3
Cu	1,31	7,50	7,15	7,65
Pb	7,50	14.0	25,5	12,2
Cd	0,20	0,32	0,30	0,36

The median Zn levels in the Mediterranean region are approximately 25% higher than in European atmosphere. However, Zn concentrations reported both in Europe and Mediterranean are highly scattered and not statistically different. Comparison of Cd concentrations in Europe and Mediterranean revealed a similar conclusion. Conversely, Pb levels in the Eastern Mediterranean are significantly higher than those of the Western basin, and all of them also higher than the median Pb concentration in Europe. A similar conclusion can also be reached for Cu. Copper concentrations in Eastern and Western Mediterranean are not significantly different but they are six times higher than those measured in Europe.

The discussion presented above included average concentrations of metals reported for various locations in the Mediterranean basin to obtain a general idea about the levels and distributions of these elements. However, more detailed information on the characteristics of aerosol population at each site is given in each of the references listed previously. In this respect, the contributions from different components (e.g. crustal material, anthropogenic particles, sea salt and biogenic particles) have been widely discussed in the literature (eg. Chester et al., 1993; Guerzoni et al., 1999; Amouroux and Donard, 1996).

Concentrations of metals show short (episodic) and mid-term (seasonal) variations both in the Western and Eastern parts of the Mediterranean Sea. Such changes in concentrations of metals are attributed to air mass trajectories for that particular day(s) (Remoudaki et al., 1991; Gullu et al., 1998). Consequently, flow patterns, namely the frequency of upper atmospheric air mass movements from each wind sector, to Eastern and Western Mediterranean have a profound effect on the amount of pollution derived material transported to these regions and subsequently deposited there.

The general feature of the flow climatology that is observed in all studies is the higher contribution of N and W sectors and small contribution of E and S sectors to annual air mass movement to the region. Higher frequency of northerly and westerly air mass transport has important implications in terms of pollutant transport to the region. Since most of the high emission areas are located to the north of the Mediterranean Sea, frequent transport from north and west sectors implies that the Mediterranean basin is under the influence of emissions from these wind sectors.

In addition to short term variations, concentrations of metals also show seasonal variations with higher concentrations during summer season. This trend is consistently observed in both western (Nicolas et al., 1995; Buart–Menard, 1993; Guerzoni et al., 1999) and eastern (Gullu et al., 1998; Kubilay and Saydam, 1995) parts of the basin. The reason for the observed seasonality in the concentrations of heavy metals is the more extensive scavenging of particles from atmosphere, either during transport or at the site, in winter period (Bergametti et al., 1989; Remoudaki et al., 1991; Gullu et al., 1998; Kubilay and Saydam, 1995)

Mercury is a special element. Data on Hg concentrations in the Mediterranean atmosphere is scarce. Recently, concentrations of various forms of Hg were measured with fairly good spatial distribution through the MAMCS study. Elemental gaseous Hg (Hg^0) concentrations vary between 0.48 and 4.1 ng/m^3. Although there is no significant difference between the values reported in Eastern Mediterranean and central parts of the basin (two station in Italy), consistently high concentrations are reported at the only Western Mediterranean station (Mallorca, Spain).

Particulate Hg accounts for approximately 0.3 – 12% of total Hg. Concentrations of Hg^o in the Mediterranean region vary between 0.006 and 0.115 ng/m^3 without showing a consistent difference between the stations.

Reactive gaseous Hg (RGM) also accounts for a small fraction of total Hg (0.3% - 16%) in the atmosphere. Its concentration in the Mediterranean region varies between 0.01 and 0.1

ng/m^3. As in the case of Hg^0, higher concentrations of RGM are consistently reported in the Mallorca station.

4.1.2.1 Heavy metals emissions in the Mediterranean region

The emissions of metals from Mediterranean countries are given in Table 4.9. The quality of emission data is not the same for all countries listed in the table. Fairly reliable emission estimates, based on values reported from individual countries, are available in Europe through EMEP (Ilyin et al., 2002). The emission data for North African countries was obtained from an EMEP modelling study for heavy metals in the Mediterranean region, back in 1994 (Erdman et al., 1994). However, high uncertainty in emissions from North Africa does not affect conclusions reached in this study, because they makes up only a small fraction of total emissions in the region (approximately 18% of Pb, 16% of Cd, 22% of Cu and 10% of Zn total emissions by the Mediterranean countries are from North Africa).

Countries located in the western Mediterranean region account for approximately 55% of the Pb, Cd, Zn and 48% of Cu emissions. Central and Eastern Mediterranean, which includes countries east of Italy, including Syria and Israel, account for 28% of Pb and Cd, 32% of Cu and 35% of Zn emissions in the region. Countries located at the south of the basin account for approximately 15% of Pb and Cd emissions, 20% of Cu emissions and 9% of Zn emissions in the Mediterranean basin.

A pronounced decrease of emissions of Pb by the Mediterranean countries has been observed between 1990 and 1999. Emissions have decreased from 14300 tonnes in 1990 to 5900 tonnes in 1999. Mercury and Cd emissions also decreased in the same time period, but not as much as Pb. Mercury emissions decreased from 102 tonnes/y to 70 tonnes/y in 1999 (31%) and Cd emissions decreased from 114 t/y in 1990 to 82 tonne/y in 1999 (27%). The decrease observed in these three metals can also be seen in other anthropogenic elements like Ni, As etc. However, emission data for the other elements are too fragmentary to derive certain percentages.

Metal emissions have decreased not only in the Mediterranean region but also in most parts of Europe since the 80's. As a result, for all three elements the share of Mediterranean emissions in total emission in Europe is gradually increasing because the decrease in the region is not as fast as in other parts of Europe. Even in the Mediterranean region the decrease in emissions is not uniform. The decrease in reported emission values in Western Mediterranean countries (Spain, France and Italy) is more pronounced compared to countries located in the Central Mediterranean. Unfortunately, such long term emission data is not available for the Eastern Mediterranean basin.

Table 4.9 **1999 Emissions of Pb, Hg, Cd, Cu and Zn in the Mediterranean countries (tonnes/year)**

Country	Pb	Cd	Hg	Cu	Zn
Spain[a]	944	14	18	118	1164
France[a]	868	12	17	88	1310
Italy[a]	2174	30	13	8576	1949
Slovenia[a]	50,2	1,62	0,6		
Croatia[a]	178	1,05	0,31	11	68,4
Bosna Herzogovina[a]	5	0,28	0,21		
Serbia Montenegro[a]	358	6,32	3,36	1950	1804
Albania[a]	24	0,6	0,46	170	37
Greece[a]	470	3	13	1104	175
Turkey[a]	744	14	4,3	2220	611
Syria[b]	565	2,7		565	136

Lebanon[b]	35	0,7		325	35
Israel[b]	62	1		440	62
Egypt[b]	145	4,37		832	145
Libya[b]	47	0,79		399	47
Tunisia[b]	91	1,8		338	91
Algeria[b]	204	3,95		1149	204
Morocco[b]	27	0,5		80	27
Cyprus[b]	75	0,2	0,3	26	9

[a] Emission data for these countries are from Ilyin et al., 2002
[b] Emission data for countries in North Africa and Middle East are from Erdman et al., 1994

The relative contribution of each Mediterranean country to total Pb, Cd, Cu and Zn emissions in the Mediterranean basin is as follows. The main Pb emitter in the region is Italy (30% of total emissions), which is followed by Spain (13%), France (12%), Turkey (10%), Syria (8%), Greece (7%) and Serbia and Montenegro (5%). These seven countries (out of 19) accounts for approximately 85% of lead emissions in the Mediterranean basin.

Italy is the highest emitter for Cd, Cu and Zn as well. It accounts for 30% of Cd emissions. The countries that also contribute to Cd emissions are Spain (14%), Turkey (14%), France (12%), and Serbia and Montenegro (6%). These five countries emit approximately 75% of Cd in the region.

The highest Cu emitters in the region are Italy (47%), Turkey (12%), Algeria (6%), Serbia and Montenegro (10%) and Greece (6%). They together accounts for approximately 80% of Cu emissions in the Mediterranean region.

The highest Zn emitting countries in the region are the same with the countries that that are high emitters of other metals, namely Italy (25%), Serbia and Montenegro (22%), France (17%), Spain (15%) and Turkey (8%). The only exception to the general trend is the very high Cu emissions in Serbia and Montenegro. In other metals that were discussed previously, Serbia and Montenegro is the fifth and sixth larger emitter in the Mediterranean basin, but it is the second largest Zn emitter after Italy.

4.1.2.2 Deposition fluxes of metals to the Mediterranean Sea

Estimation of wet deposition is relatively easy if there are data on chemical composition of rainwater. It should be noted that for metals, rainwater data is very scarce probably because of the difficulties involved in the analysis of the extremely low levels. The existing data on metal composition of rain water and wet deposition fluxes of metals are confined to Northwestern Mediterranean. Unfortunately, very few data on the metal concentrations in rainwater exists for the rest of the Mediterranean Sea. This is a serious drawback for a basin-wide assessment of wet deposition fluxes of metals.

Estimation of dry deposition fluxes is even more difficult because it requires accurate information on size distributions of elements, which is lacking throughout the basin.

Three different information sources can be used to assess the input of metals to the Mediterranean Sea, namely deposition fluxes reported in the literature (largely confined to the NW Mediterranean, Sub-region II), EMEP modelling results (Ryaboshapko et al., 2001), and wet and dry deposition fluxes calculated from aerosol data, using the “scavenging ratio” concept:

$$(SR_x) = [(C_x)_{rain\ water} / (C_x)_{aerosol}]\ \sigma_{air}$$

where, (SR_x) is the scavenging ratio for test element x, $(C_x)_{rain\ water}$ is the concentration of test element in rainwater, $(C_x)_{aerosol}$ is the concentration of the same test element in atmospheric particles and σ_{air} is the density of air, which is used to make the SR dimensionless.

Fluxes and deposition

A median dry, wet and total Cd, Pb, Cu and Zn deposition fluxes were calculated for the Mediterranean using all measured wet, dry and total deposition fluxes in the basin. This experimental median flux values were then compared with the corresponding median dry, wet and total deposition fluxes obtained only using calculated values. The results are given in Table 4.10. For all the elements the difference between the observed and calculated fluxes is within a factor of 2.5, which is the level of uncertainty in calculations of deposition fluxes of elements.

Table 4.10 **Measured and calculated median total, wet and dry deposition fluxes in the Mediterranean region (µg/m²/d)**

	Cd			**Cu**			**Pb**			**Zn**		
	Total	**Wet**	**Dry**	**Total**	**Wet**	**Dry**	**Total**	**Wet**	**Dry**	**Total**	**Wet**	**Dry**
Measured	0.25	0.12	0.04	2.6	1.6	1.0	3.9	2.1	3.5	92	66	34
Calculated	0.19	0.12	0.05	5.1	3.9	1.3	7.9	6.0	1.9	43	24	22
Obs/calc Ratio	**1.4**	**1.0**	**0.9**	**0.5**	**0.4**	**0.8**	**0.5**	**0.4**	**1.8**	**2.1**	**2.8**	**1.5**

Estimated deposition fluxes of Cd, Pb and Zn to each sub-region is also shown in Table 4.11. Deposition fluxes found by Erdman et al. (1994) are approximately a factor of 2 – 3 higher than those found by (Ryaboshapko et al., 2001). The difference is even larger for Pb (by factors of 4 to 6).

The median deposition fluxes of Cd in the Eastern and Western basins do not show a significant difference, although large deposition fluxes are generally measured and/or calculated in the North-western basin (sub-region II). However, the flux values measured or calculated even only in sub-region II are so variable that it is not possible to reach a definite conclusion on the similarities or differences of the Cd deposition fluxes in both basins.

The values calculated and measured in the Western Mediterranean for Cu appear higher than those calculated fluxes in the Eastern part of the basin. Owing to the small number of data and high variability, particularly in the western basin, the difference is not statistically significant, as pointed out earlier.

Table 4.11 **Deposition fluxes of Cd, Pb and Zn to Mediterranean sub-regions calculated by modelling (µg/m²/d)**					
Sub-region	**Cd** 1999[a]	**Cd** 1991[b]	**Pb** 1999[a]	**Pb** 1991[b]	**Zn** 1991[b]
1. Alboran	0,028	0,08	1,091	6,60	2,19
2. Northwest	0,045	0,11	2,065	9,78	3,29
3. Southwest	0,047	0,11	1,625	9,78	9,78
4. Tyrrhenian	0,049	0,08	2,225	10,19	3,26
5. Adriatic	0,068	0,14	3,886	17,95	4,52
6. Ionian	0,063	0,08	2,483	11,53	3,26
7. Central	0,032	0,05	1,186	5,21	1,67
8. Aegean	0,050	0,16	2,261	9,78	4,41
9. Northeast	0,043	0,05	1,986	4,88	1,56
10. Southeast	0,025	0,05	0,891	0,41	1,32
11. Marmara	0,110		3,951		
[a]From Royabashapko et al., (2001) [b]From Erdman et al. (1994)					

The distribution of Pb deposition fluxes in the Mediterranean basin do not show significant differences between the Eastern and Western basins. As discussed in the distribution of Pb concentrations in the previous section, deposition fluxes are higher at coastal stations.

As in the case of other metals the deposition flux data for Zn also show a significant spatial variability, which makes the assessment difficult. Higher flux values are reported in the Northwestern part of the Mediterranean Sea, particularly on the French coast.

Experimental data for Hg deposition fluxes are not available for the time being. However, there are two modelling studies where Hg deposition to Mediterranean Sea is calculated. One was performed within the MAMCS project and the other by EMEP (Erdman et al., 1998). Although the MAMCS study was performed with fairly recent emission data (1995), results presented in the report are not in the form that can be readily adopted for this study. The total Hg deposition fluxes obtained by EMEP (Erdman et al., 1998), where 1990 emission data were used, varies between 0.001 µg/m^2/day in sub-region VII and 0.019 in sub-region I, with a mean value of 0.008 µg/m^2/day. There is no significant difference between deposition flux values calculated for the Eastern and Western Mediterranean. Deposition fluxes for particulate Hg vary between 0,001 and 0,005 µg/m^2/day with a mean value of 0,002 µg/m^2/day. As in total Hg fluxes, there is not a significant difference between particulate Hg fluxes in the Eastern and Western basins.

Measured, calculated and modelled total Cd, Cu, Pb, Zn and Hg deposition load to the Eastern and Western Mediterranean are given in Table 4.12. There are very few experimental deposition data available in the Eastern Mediterranean, as pointed earlier, consequently, data for this area is largely based on calculated values.

Solubility of deposited metals

The significance of atmospheric deposition on marine pollution is well documented, but a point that is not generally addressed is the availability of deposited metals to the ecosystem. All metals deposited from atmosphere to sea surface are not readily available to organisms in the sea. If the deposited metal is in dissolved form, or if it readily dissolves in sea water after deposition, it can be easily picked up by the organisms. On the other hand, if the metal does not dissolve from particles in rain or sea water, then it sinks to the sediments without being absorbed by the marine organisms. Consequently, the fraction of the deposited metal that is soluble is an important factor affecting its bioavailability.

Solubility behaviour of metals in the Mediterranean region has been extensively studied (Chester et al., 1993a,b; 1997; 1999; 2000; Nimmo and Chester, 1993; Nimmo et al., 1998; Lim et al., 1994) and recently reviewed by Guerzoni et al. (1999). Detailed discussion of the fate of metals in the marine environment is beyond the scope of this study. However, some data on solubility of metals must be presented in order to give, at least an impression on how much of the deposited Cd, Cu, Pb and Zn, given in the previous section are readily available for marine organisms and how much of the deposition is likely to end up in the sediments without affecting ecosystem. According to Guerzoni et al. (1999), approximately 49 – 82% of Cu, 68 – 76% of Zn, 21 – 65% of Pb and 75 – 92% of Cd deposited to the Mediterranean Sea are in soluble form and can be readily utilised by organisms.

Table 4.12 **Total deposition load of metals to the Mediterranean Sea (tonnes/year)**

	Cd	Cu	Pb	Zn	Hg
Eastern Med Calculated	86	1,715	3,400	28,420	
Eastern Med Measured			4,400		
Eastern Med Model 99	24		1,000		2.69
Eastern Med Model 91	47		3,700	1279	
Western Med Calculated	45	2,832	3,700	19,437	
Western Med Measured	83	1,192	1,100	44,010	
Western Med Model 99	14		580		3.06
Western Med Model 91	24		3,700	2,100	
Total Deposition	71 - 169	2,900 – 4,500	4,500 – 7,400	48,000 – 72,000	5.75

Atmospheric deposition vs. riverine input

The relative importance of atmospheric and riverine inputs of metals and litophilic elements in the Mediterranean Sea has been assessed in different studies (Martin et al., 1989; Guieu et al., 1993; Hydes et al., 1988; Morley et al., 1997; Davies and Buart-Menard, 1990) and the topic has recently been reviewed by Guerzoni et al. (1999). Most of these studies clearly demonstrated the significance of atmospheric deposition on metal chemistry in the sea. However, quantitative information on relative importance of atmospheric inputs is not known.

Table 4.13, which is taken from Guerzoni et al. (1999) shows total and soluble Cd, Cu, Pb and Zn inputs to Northwestern Mediterranean Sea from atmosphere and by rivers. Data in the table show that 91% of total Cd input, 49% of Cu input, 65% of Pb input and 89% of Zn input to the Northwestern Mediterranean are from atmosphere. If only the inputs of metals in soluble form are considered, the role of atmospheric deposition becomes more pronounced (ranging between 52% and 98%).

Table 4.13 -**Atmospheric and riverine inputs of Cd, Cu, Pb and Zn to North-western Mediterranean Sea (tonnes/year)**

	Cd		Cu		Pb		Zn	
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble
Atmosphere	126	16	486	189	579	252	12,600	6813
Rivers	13	1	505	175	318	8	1,545	105
[a]Data from Guerzoni et al. (1999)								

4.1.2.3 Source-receptor relationship

The identification of the regions which are the sources of metals found in the Mediterranean basin is as important as understanding metal inputs to the basin, because without knowing the source-receptor relation, nothing can be done to minimise metal inputs to the Mediterranean Sea through atmosphere. The only information on quantitative source-receptor relationship comes from EMEP modelling exercises.

Based on the modelling results, the main contributors to Pb deposition in the Mediterranean Sea are Spain, France, Italy and Greece. These four countries accounts for approximately 70% of Pb deposited in the whole basin. Both European countries and countries located around the Mediterranean Sea contribute to the observed deposition levels. Approximately 65% of Pb deposited to the basin can be accounted for by the emissions in the Mediterranean countries and the remaining 35% is from emissions in non-Mediterranean countries in Europe. Among these countries Bulgaria, which contributes 5% to total atmospheric Pb input to Mediterranean, Romania, which accounts for 3% of total Pb deposition and Ukraine, which accounts for 5%, are the most important ones. It should be noted that contribution of these countries to Pb input to Mediterranean are higher than contributions of many Mediterranean countries.

Spain, Italy and France totally accounts for 63% of total Cd deposition to the Mediterranean. Most of the Cd deposited to the Mediterranean is emitted in the Mediterranean region. Non-Mediterranean countries in Europe accounts only for approximately 10% of Cd deposition in the entire basin.

The contribution of countries outside the Mediterranean basin to Hg deposition in the Mediterranean Sea is significant. These countries account for approximately 40% of Hg deposited to Mediterranean Sea. Remaining 60% of deposited Hg is emitted from Mediterranean countries. Spain, Italy and France accounts for 56% of Hg deposition, remaining 44% of annual Hg deposition is contributed by other 16 countries.

This discussion shows that more than half of the annual metal deposition in the Mediterranean region is due to emissions from Mediterranean countries. Among Mediterranean countries, France, Spain, Italy are the highest contributors. Greece, Turkey and Serbia and Montenegro makes up the second group. Remaining Mediterranean countries do not contribute to metal deposition significantly. However, it should be noted that, the model study from which the data is obtained do not provide information on different regions in the Mediterranean basin. This grouping of countries may change in different sub-regions depending on the proximity of that particular area to emissions.

Countries outside the Mediterranean region also contribute to metal deposition to the Mediterranean Sea. Among these Bulgaria, Romania and Ukraine appears as the most important.

- *Current state of the POPs in the Mediterranean region*

Persistent organic pollutants (POPs) are organic chemicals that are semivolatile, resistant to degradation and, therefore, amenable to transport over long distances, thus constituting a transboundary issue. Unlike nutrients and heavy metals discussed in previous sections all POPs are synthetically produced.

Information on levels, fate and effects of POPs in the Mediterranean region has recently been published (UNEP, 2002). However, data on the atmospheric compartment is very limited. Consequently, most of the discussion in this part of the report will be based on the modelling studies carried out by EMEP-E (Erdman et al., 1999).

- *Concentrations of POPs in the Mediterranean atmosphere*

The atmospheric compartment is one of the less studied in the region, probably due to the methodological difficulties. Data are basically restricted to HCB, HCHs and PCBs and PAHs, and, except for PAHs, which have been determined in a large number of countries, mostly in urban areas, the other measurements are not really representative for a global assessment. Only in France a systematic determination of pesticides has been carried out in a few urban and rural areas since the end of the 80's.

In this respect, HCB concentrations ranged from 9-2400 pg/m^3, with mean levels in continental air of 300 pg/m^3 (Chevreuil et al., 1996; Sanusi et al., 2000). Based on modelling calculations, the Meteorological Synthesising Centre-East (MSC-E) has estimated mean concentrations in natural media of all northern countries of the Mediterranean region, for 1998 (Dutchak et al., 2002). Air concentrations ranged from 39 to 66 pg/m^3, with a slight decreasing West-East trend and the lower values for Malta and Cyprus.

PCBs were measured in the Mediterranean atmosphere by Iwata et al. (1993) (Σ PCB av. 0.49 ng/m^3). More recently lower values were found in Crete (15.7 and 1.2 pg/m^3, gaseous and particulate, respectively), which may constitute the background value for the region.

The mean annual PCB concentration in air reaches its maximum in the centre of Europe (0.8 ng/m^3) and decreases to averages of 0.34 and 0.16 ng/m^3 in coastal and open sea air, respectively (UNEP/MAP/WMO, 2001).

Atmospheric lindane concentrations varied from 0.75-1.5 ng/m^3 with no significant differences between urban and rural sites, in France (Sanusi et al., 2000; Chevreuil et al., 1996). Mean annual concentrations over the Mediterranean were estimated to be around 0.5 ng/m^3 (UNEP/MAP/WMO, 2001).

PAH concentrations have been reported in dry deposition in a number of urban areas as well as in remote places, including the open Mediterranean Sea. Concentrations of total PAHs vary between 0.07 and 4.5 ng/m^3 in the NW Mediterranean. Lipiatou et al. (1997) indicated that concentrations measured in the coastal stations are significantly higher than those measured on islands and attributed this to the closer proximity of PAH sources.

There is a PAH data set generated in the Crete Island in the Eastern Mediterranean (Gogou et al., 1998). The PAH concentrations, measured in 1993 and 1994, are in line with the data generated in the Western Mediterranean, which could indicate that concentrations in the Eastern Mediterranean are not significantly different from concentrations measured in coastal stations in the NW basin.

- *POPs emissions in the Mediterranean region*

Emission data for POPs in the Mediterranean region is fragmentary. Some of the data do exist in EMEP emission data base, but even that data is far from complete. Various estimates of emission data for lindane, HCB, PCB, total PAHs and B(a)P are given in Table 4.14. The data consists of three compilations for the year 1990 and one compilation for the year 1982. Unlike emission data for nutrients and heavy metals, very few data in the table are official values reported by countries; most of the data are so called "expert estimates".

Table 4.14 **Different estimates of POP emissions in the Mediterranean region**

	Lindane (t/y)	**HCB** (t/y)	**PCB** (t/y)	**PAH** (t/y)	**B(a)P** (t/y)
France	281[a], 56[b], 211[a], 13[c,e]	4[c,e], 0.011[d]	20[a], 20[d]	1230[a], 3480[d]	108[a]
Greece	26[a], 5.2[b], 4.9[c,e], 19[d]	0,54[c,e]	0,36[a], 025[d]	146[a], 153[d]	10[a]
Italy	60[a], 12[b], 13[c,e], 45[d]	3,5[c,e], 0.4[d]	6,4[a], 5.8[d]	688[a], 694[d]	47[a]
Spain	132[a], 23[b], 24[c,e]	3,2[a], 1.2[d]	9,2[a], 8.5[d]	449[a], 521[d]	28[a]
Serbia and Montenegro	50[a], 10[b], 10[c,e], 19[d]	1,1[c,e], 0.05[d]	1,1[a], 0.4[d]	346[a], 172[d]	27[a]
Bosnia	6,23[d]	0,02[d]	0,128[d]	47,8[d]	

Croatia	11[d]	0,03[d]	0.13[d]	54[d]	
	Lindane	**HCB**	**PCB**	**PAH**	**B(a)P**
	(t/y)	(t/y)	(t/y)	(t/y)	(t/y)
Cyprus			0,04[d]	0.18[d]	
Slovenia	1.2[d]		0.07[d]	50[d]	
European Total	1930[a], 387[b], 416[c,e], 1310[d]	51[c,e], 8[d]	143[a], 119[d]	13510[a], 15800[d]	1140
[a]Baart et al. (1995), [b]Hout et al. (1994), [c]Axenfeld et al. (1991), [d]Berdowski et al. (1997) [All cited in Erdman et al., 1999]					

Although emissions estimates by Baart et al. (1995), Hout et al. (1994) and Berdowski et al. (1997) for the year 1990 agrees fairly well, emission estimates by Axenfeld et al. (1991) for the year 1982 are generally lower than emissions estimated for 1990 by other authors. This may indicate that significant reductions in POP emissions have occurred between 1982 and 1990 in the Mediterranean region. It should be noted, however, that the total emissions values given in the table are lower limits for the Mediterranean region, because there is no emission data for several countries on the east and south of the Mediterranean basin.

For all the organic compounds mentioned in the Table and for both 1982 and 1990, emissions in the Mediterranean region accounts for 25 – 30% of total emissions in Europe. The contribution of Mediterranean emissions can increase (but not much) when emissions from countries on the south and east of the basin become available and included in estimations.

For all of the selected POPs, except for HCB, France is the dominant contributor to total emissions in the Mediterranean region. It accounts for 50 – 70% of lindane, PCB, PAH and B(a)P emissions in the region. Spain and Italy are also important POP emitters in the region. They together account for 39% of lindane emissions, 41% of PCB emissions, 24% of PAH emissions and 34% of B(a)P emissions in the basin.

HCB emissions do not follow the same trend. Spain accounts for 70% and Italy accounts for 24% of HCB emissions. Unlike other POPs, the contribution of France is less than 1%.

- *Deposition of POPs to the Mediterranean Sea.*

Atmospheric deposition estimates of POPs in the Mediterranean Sea are scarce. First calculations were reported by GESAMP (1989), based on very few data, but concluding that 80-95% of total inputs of POPs (e.g. HCB, HCHs, DDT, chlordane and PCBs) were atmospheric. More recently, calculations have been performed for certain compounds by the EMEP/MSC-E (Erdman et al., 1999). The results are shown below.

Deposition fluxes of POPs to Mediterranean and its sub-regions are given in Table 4.15. For lindane the largest fluxes occur in sub-regions 5, 11 and 2 (total lindane deposition fluxes in these sub-regions are 39, 33 and 29 g/km^2/y, respectively). It should also be noted that lindane fluxes in the sub-regions at the south of basin, such as sub-regions 3, 7 and 10 are smaller than fluxes calculated for the sub-regions at the north of the basin. Erdman et al. (1999) attributed this to the proximity of sub-regions at the north to lindane emission sources in Europe and surrounding areas. Average total (wet+dry) deposition flux of lindane in the Mediterranean basin is 16 g/km/y. Approximately 12 g/km^2/y of this amount is accounted for by dry and 3.6 g/km^2/y is due to wet deposition, indicating that dry deposition flux of lindane is approximately a factor three higher than its wet deposition flux.

Table 4.15 **Deposition fluxes of selected POPs in the Mediterranean region (g/km²/y)[a]**

	Lindane			PCB			B(a)P[b]
Sub-basins	Dry	Wet	Total	Dry	Wet	Total	Total
1. Alboran	3.1	0.8	3.8	0.05	0.07	0.12	0.50
2. Northwest	20	8.5	29	0.21	0.47	0.69	2.9
3. Southwest	9.0	2.8	12	0.11	0.20	0.31	1.3
4. Tyrrhenian	17	5.7	22	0.15	0.37	0.52	1.8
5. Adriatic	25	14	39	0.23	0.69	0.92	3.6
6. Ionian	16	5.2	21	0.11	0.29	0.41	1.4
7. Central	8.8	1.5	10	0.07	0.11	0.18	1.0
8. Aegean	18	5.4	24	0.09	0.23	0.32	1.1
9. Northeast	12	2.9	15	0.07	0.18	0.24	0.48
10. Southeast	8.8	1.2	10	0.05	0.08	0.13	0.41
11. Marmara	23	9.9	33	0.12	0.35	0.46	2.4
Basin average	12	3.6	16	0.10	0.21	0.32	1.5

[a]Data from Erdman et al. (1999), [b]Data from Shalatov et al. (2002)

PCB deposition fluxes show a similar trend with those of lindane. Highest flux values were calculated for sub-regions 5, 11 and 2 and deposition fluxes in sub-regions 3, 7 and 10, which are at the south of the basin are generally lower than fluxes in sub-regions at the north of the basin. Basin-wide average deposition flux for PCB is 0.32 g/km²/y of which 0.10 g/km²/y is due to dry deposition and 0.21 g/km²/y is due to wet deposition. Unlike in lindane wet deposition flux of PCB is higher than its dry deposition flux, which is due to differences in physicochemical properties of the two POPs.

Total deposition fluxes of B(a)P, which were obtained from Shatalov et al. (2002), also show the same spatial variation with lindane and PCB, with higher flux values in sub-regions 5, 11 and 2. Average deposition flux for this POP in the whole Mediterranean is 1.5 g/km²/y.

Deposition loads of lindane, PCB and B(a)P are given in Table 4.16. For all three POPs the sub-regions with largest deposition values do not necessarily correspond to sub-regions with the largest flux values because the surface areas of the sub-regions are different.

Each year approximately 55 tonnes of lindane deposits to the Mediterranean, of which 42 tonnes enter the sea through dry deposition and remaining 12 tonnes by wet deposition. The 55 tonnes deposited to the Mediterranean corresponds to approximately 4% of total lindane emissions in Europe (Erdman et al., 1999). The annual PCB deposition to whole basin is 1.1 tonnes. Thirty-two percent of this total deposition is in the form of wet and 68% is in the form of dry deposition. Erdman et al. (1999) pointed out that approximately 30% of PCB deposited to the Mediterranean Sea is degraded and 70% remains in the sea water even after 10 years (some of it re-emitted back to atmosphere).

Table 4.16 **Deposition loads of selected POPs in to the Mediterranean Sea (kg/year)[a]**

	Lindane			PCB			B(a)P[b]
	Dry	Wet	Total	Dry	Wet	Total	Total
1. Alboran	260	69	330	5	6	10	42
2. Northwest	5000	2100	7100	53	120	170	670

3. Southwest	3400	1000	4400	41	74	120	360
4. Tyrrhenian	5900	2000	8000	56	130	190	450
5. Adriatic	3400	1900	5300	31	96	130	410
6. Ionian	3600	1200	4800	26	68	94	300
7. Central	7500	1300	8800	62	95	160	570
8. Aegean	3900	1100	5000	19	48	67	200
9. Northeast	2200	510	2700	12	31	43	80
10. Southeast	6500	860	7400	39	59	99	180
11. Marmara	630	270	900	3	10	13	26
Total	42400	12400	54800	350	740	1100	3300
[a]Data from Erdman et al. (1999), [b]Data from Shalatov et al. (2002)							

The highest B(a)P deposition occurs in sub-region 2 (670 kg/y), which is followed by sub-region 7 (570 kg/y). Approximately 3.3 tonnes of B(a)P deposits to the Mediterranean Sea annually, mostly contributed by Italy (1499 kg, 24%), France (885 kg, 14%) and Spain (523 kg, 8%) as shown in Figure 4.1.

Measured deposition of total and individual PAHs to northwestern Mediterranean is reported by Lipiatou et al. (1997). Total deposition of total PAH to the western Mediterranean, reported by the authors is 30 – 70 tonnes/y (the B[a]P deposition to the Western Mediterranean is between 1.9 and 5.6 tonnes/y).

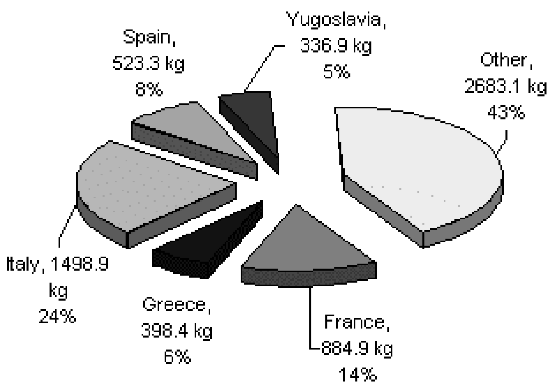


***Figure 4.1** - Deposition of B[a]P to the Mediterranean*

Lipiatou et al. (1997) also pointed that atmospheric deposition (mainly wet deposition) is the most important source of PAH input to the western Mediterranean. Calculations based on the mean values reported for atmospheric deposition and river inputs, show that atmospheric deposition accounts for approximately 87% of inputs, whereas river discharges accounts for the remaining 13%. However, authors also pointed out that a significant input of PAH also occurs by water exchange through the Gibraltar and Sicily.

Despite the uncertainties of these calculations it appears that POP sources located in the countries of the region contribute significantly to the atmospheric deposition in the Mediterranean Sea, and that the maximum deposition densities correspond to the North-Western basin, the Adriatic and the Marmara Sea, although the total amount in the latter is small due to the reduced dimensions.

o *Rivers*

▪ *Water discharge trends in Mediterranean rivers*

River water discharges are the most important factor controlling the matter transfer from land to the sea. Even if the average concentrations of different pollutants can be determined with reasonably good precision, flux estimates can only be as good as the estimates for the corresponding water discharge. Moreover, for many dissolved and particulate species in rivers, concentrations are not independent from runoff, and an evaluation of possible trends has to take into account the hydrological conditions during which the observations have been made.

The hydrological and climatic conditions that regulate these discharges have already been summarised in section 3.2.

Discharge records of about 30 rivers over time are available in the Mediterranean region. (Medhycos, 2001; Vörösmarty et al., 1998). The spatial distribution of the rivers covers most of the Mediterranean drainage basin, although certain regions are not well represented. In general, data coverage of the north-European rivers is good, whereas data on south-Mediterranean rivers are less abundant. Especially Turkish rivers are underrepresented.

- *Temporal trends*

Long-term trends can be established for a number of rivers for which records of more than 70 years are available. This concerns mainly the north-western European rivers such as the Rhone River, and Italian rivers, the country for which the data coverage is the best. In most of the cases, clear negative trends are prominent (e.g. Ebro, -47%; Adige, -36%; Tiber, -40% and Nile, -40%, over the last 80 years). The Po and the Rhone rivers do not depict any long-term trend and the records are in good agreement with the evolution of rainfall. Also the discharge of the Danube River does not show any trend (although the Danube does not discharge into the Mediterranean Sea, we included it here for comparison), indicating that this may be a general feature for the rivers taking their headwaters in the Alps.

Data coverage since 1960 is shown in Table 4.17. Because of the shorter time span considered, it is possible that general trends may be overwhelmed by the general cyclicity of dry and wet periods, which seem to occur, at least in the northern part of the Mediterranean region, in time intervals of about 20-25 years. Probably also as a consequence of this, only for about half of the rivers, significant trends were found. But in all cases, these trends are negative.

The strongest reduction is found for rivers that were affected both by the construction of dams and by precipitation decrease, such as the Ebro River in Spain, the Moulouya River in Morocco and the Cetina River in Croatia. In general, discharge reduction is frequent in the rivers of the Eastern Mediterranean, mainly when the records extend to the recent years and do not stop in the 80’s. It seems also that the reduction becomes more important from the north to the south.

Finally, it is worth being mentioned that also for the evolution since 1960, the Po and the Rhone rivers do not follow the general trend of a reduction in water discharge. This is important because also in these basins, impoundments and dams are frequent. In the Rhone, for example, a considerable part of the tributary discharge from the Durance River has been deviated to the Berre Lagoon (near Marseille) during the sixties, leading to an overall reduction of the Rhone discharge of about 100 m^3/s on average (Vivian, 1989). In the discharge record of the Rhone this is not visible. Apparently, human activities have less impact on the amount of annual water flow out of these basins, or this impact is compensated by more humid conditions.

Table 4.17 **Discharge trends since 1960 in some Mediterranean rivers**

Code basin[(1)]	River	Country	Station	Area (km^2)	Record period		Average Q		Q change
					start	end	(m^3/s)	Ref.	(%)
Black Sea	Danube	Rumania	Tulcea Ceatal Izmail	807000	1960	2000	6574	(3)	--(2)
NWE	Rhône	France	Beaucaire	95590	1960	1999	1721	(3)	--
NWE	Aude	France	Carcassonne	1730	1969	1999	21	(3)	--
NWE	Têt	France	Vinça	930	1960	2000	12	(4)	--
NWE	Ebro	Spain	Tortosa	84230	1960	1999	416	(3)	-53.8
ALB	Moulouya	Morocco	Dar el Caid	24422	1960	1988	21	(5)	-76.1
ADR	Adige	Italy	Boara Pisani	11954	1960	1980	200	(3)	--
ADR	Po	Italy	Pontelagoscuro	70091	1960	1996	1569	(3)	--
NWE	Arno	Italy	San Giovanni	8190	1960	1995	84	(3)	--
ADR	Pescara	Italy	Santa Theresa	3130	1960	1999	46	(3)	-20.0
TYR	Tiber	Italy	Ripetta	16500	1960	1997	217	(3)	-31.2
ADR	Ofanto	Italy	S.Samuele	2720	1960	1999	12	(3)	-42.8
ADR	Zmanja	Croatia	Jancovica buk	907	1961	1990	38	(3)	--
ADR	Krka	Croatia	Skradinski buk gornji	2285	1960	1998	53	(3)	-35.1
ADR	Cetina	Croatia	Tisne stine	1460	1960	1998	32	(3)	-88.5
ADR	Mati	Albania	Shoshaj	646	1960	1988	25	(3)	--
ADR	Erzeni	Albania	Ndroq	663	1960	1992	13	(3)	-44.1
ADR	Shkumbini	Albania	Paper	1960	1960	1990	35	(3)	-33.6
ADR	Semani	Albania	Ura Vajgurore	2070	1960	1989	33	(3)	-29.4
ADR	Vijose	Albania	Dorze	5420	1965	1984	145	(5)	--
AEG	Axios	Greece	Konitsa	24700	1964	1986	24	(3)	--
ION	Acheloos	Greece	Avleko	5540	1965	1995	51	(3)	-30.2
AEG	Aliakmon	Greece	Il Arion	9500	1963	1987	50	(3)	--
AEG	Vadar	Greece	Skopje	4650	1961	1998	58	(3)	-47.1
AEG	Nestos	Greece	Temenos	5740	1966	1995	40	(3)	-54.8
NLE	Ceyhan	Turkey	Misis	20466	1971	1983	222	(5)	--

(1) see Table 3.1 (chapter 3)
(2) no value means that trends were not significant at $P \leq 0.05$
(3) Medhycos (2001)
(4) Stucky (2001)
(5) Vörösmarty et al. (1998)

- *Regional water budgets*

The above-presented trends allow evidencing the relative changes of river inputs to the Mediterranean over time. But the data are not sufficient to establish regional water budgets. In order to translate these data into absolute values, a reliable estimate for the overall amount of freshwater inputs at a given time is needed. We retained for this purpose the water budget of Collectif (1978) that has been established in the framework of the UNEP MEDPOL X programme. It distinguishes the water input into the Mediterranean with respect to its ten sub-basins and results in an overall water input of about 440 km^3/yr. This value is close to other estimates found in the literature, such as those of Tixeront (1970) or of Margat (1992).

As shown in Figure 4.2, the Adriatic Sea is the sub-basin that receives the greatest amount of terrestrial runoff: more than one third of the overall freshwater input enters the Mediterranean Sea in this sub-basin. By far most of the water comes from Italy, the country with the highest contribution. The groundwater discharge to the Mediterranean may represent an additional freshwater contribution of about 10% of the river discharge. The water loss due to direct evaporation of the water bodies has also been estimated in the range of 10% of the river discharge, with about one third related to the evaporation from water dams (mainly the Aswan dam in Egypt). Almost one fifth of the water resources (90 km^3/yr) are affected by anthropogenic water consumption.

The most striking feature is naturally the reduction of the inputs to the South-Levantine Sea due to the damming of the Nile. The actual value is only about 5-10% of the original one at the beginning of the last century. Otherwise it is remarkable that the Q-20 to Q-70 evolution is rather uniform in the different sub-basins. The reduction towards the seventies is almost everywhere in the range of 20-30%. More severe reductions such as in the Ebro and/or Arno rivers are compensated by the more or less constant discharge of the Rhone or the Po rivers. The Q-70 to Q-95 evolution, however, is more variable, and the general trend of a decrease of the freshwater inputs is accelerated. The overall reduction is in the range of 110 km^3/yr, compared to about 170 km^3/yr for the Q-20 to Q-70 time span, although the latter period is about twice as long and strongly impacted by the closure of the Aswan dam. During the more recent years, the North-Levantine, the North-Western and the Adriatic basins are the less affected by the reduction (about 10 to 20%), whereas the drop is more pronounced in the Thyrrhenian, Ionian and Aegean basins (about 25 to 50%). With an estimated reduction of about 75%, the Alboran Sea encounters the strongest reduction.

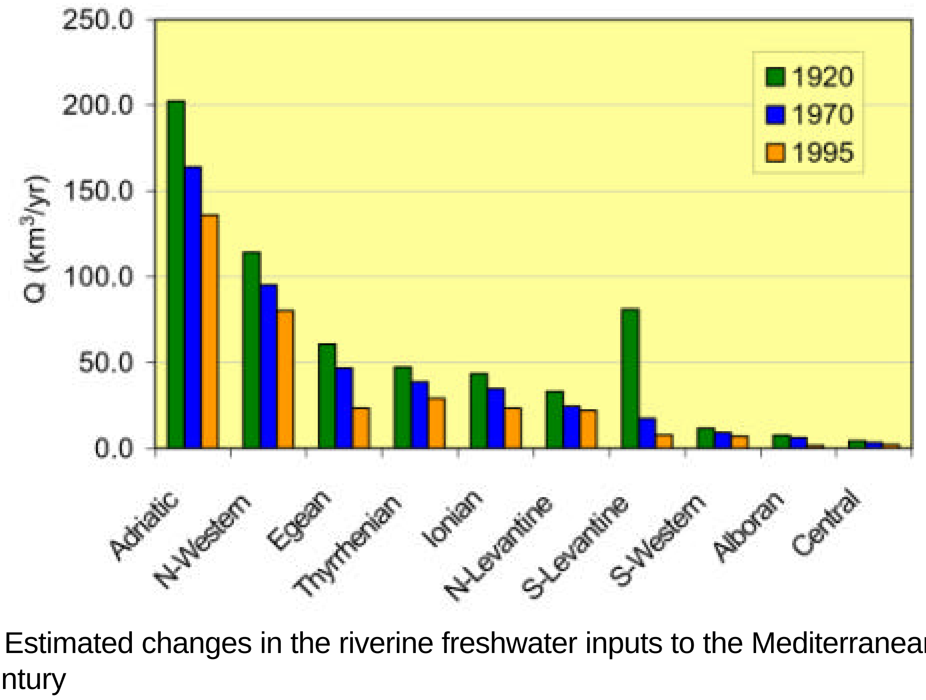


Figure 4.2 Estimated changes in the riverine freshwater inputs to the Mediterranean during the 20th century

In summary, the freshwater discharge to the Mediterranean by rivers is actually only about 330 km^3/yr compared to about 600 km^3/yr at the beginning of the last century. Boukthir and

Barnier (2000) also established a riverine freshwater budget for the entire Mediterranean for the period of 1974-1994 of about 350 km^3/yr.

Finally, it is also worth being pointed out that the average discharge of the two largest northern rivers, the Rhone and Po, has remained more or less constant. This means that their relative importance in the overall supply of terrestrial matter to the sea increased. Both rivers together account actually for about 31% of the total water discharge to the Mediterranean, whereas this was only about 17% at the beginning of the last century.

- *Sediment Fluxes*

River sediment fluxes to the sea play an important role in various natural geochemical cycles such as the global carbon cycle. Also the transport and cycling of human released pollutants is often strongly coupled to the transport of sediments in rivers, since many contaminants are strongly associated with the particulate phase in water. Modern changes in drainage basin characteristics, such as river damming, extensive agriculture and/ or the broad construction of buildings and roads can highly alter natural erosion rates and river sediment transport. Such perturbations may have severe consequences for the land use, through the loss of fertile soils, or for the geomorphologic evolution of the riverbeds. But also in the estuaries and coastal zones, where sediments end up, an alteration of the natural river sediment supply can provoke considerable changes of the coastal metabolism, the biogeochemical cycling, or the coastline morphology.

Because of the strong seasonality of climate, the presence of elevated mountain ranges, the wide dominance of younger, softer rocks, and a long history of human activity, Mediterranean rivers tend to have high values of natural sediment fluxes (Milliman, 2001). At the same time, the warm and dry climate makes that anthropogenic pressure on the water resources is great, and human perturbations may have had more severe consequences on the natural fluxes than in other regions of the world. An assessment of the evolution of the river sediment delivery over time is therefore one of the crucial tasks in order to evaluate the impact of rivers on the biogeochemical and hydrosedimentological functioning of the Mediterranean Sea.

Most of the sediment discharge occurs during floods, which are brief and violent in the Mediterranean area, and which are difficult to be monitored. Moreover, the occurrence of strong floods is very irregular over time, which implies that the inter-annual variability of river sediment fluxes can be very important, too. Monitoring a particular river during a few years is not necessarily representative for the long-term average sediment transport in this river, even if the monitoring has been carried out under optimal conditions.

- *Variability of natural sediment fluxes*

The estimates of river sediment yields for various Mediterranean rivers indicate that they are generally characterised by very high sediment yields and inter-annual variability. In the case of the Rhone River, the annual fluxes from 1980 to 1999 vary within one order of magnitude (from about 2.4 to 25 Mt/y), with an average long-term mean of 8.5 Mt/y. The corresponding water discharge varies only by a factor of two, from about 34 to 68 km^3/y (average: 55 km^3/y). However, it would be misleading to take this variability as representative for other rivers of the Mediterranean area. Almost all rivers have values that are clearly above 150 – 200 t/km^2/y, which is the world average for the ice-free and exorheic parts of the continents (Milliman and Meade, 1983; Milliman and Syvitski, 1992). For some rivers, sediment yields of several thousands of tonnes/km^2/y are reported, which are among the greatest values that are known for world rivers. Note that the Yellow River in China (or Huanghe River), which owns his name to his very high sediment load that provokes the characteristic yellow colour of the water, has an average sediment yield of about 1400 tonnes/km^2/y (Milliman and Syvitski, 1992).

By far the greatest sediment yields are found for the rivers of Albania. It is here were the environmental conditions that are leading to high soil erosion rates and river sediment fluxes are unified: very high drainage intensities, steep slopes, strong seasonality of climate and the abundance of soft lithologies. For the same reasons, also in the Greek and Italian rivers that are discharging to the Ionian Sea, the values are very high. Further west, in the Western Mediterranean basin, sediment yields are generally lower. Drainage intensities and relief become less important, and older and harder rocks such as the Pyrenees may be dominant.

Although the scatter between rivers of the same region can be great, a tentative budget for the natural sediment delivery to the Mediterranean Sea gives an overall sediment flux of 730 million tonnes per year (Table 4.18). About 75% of the sediments enter the Mediterranean in its eastern basin, and 25% in the western basin. The sediment yield for the entire drainage basin, including the Nile, is about 175 $t/km^2/y$, close to the global average. Excluding the Nile from the calculation increases the value to an average of about 580 $t/km^2/y$, which is very high compared to other regions of the world (Ludwig and Probst, 1998).

A general problem in extrapolating sediment yields for individual rivers to larger scales is that it is normally not known were the gauging stations were situated to which the measurements correspond. In the headwater regions of river basins, sediment yields are normally much greater than further downstream (Milliman and Syvitski, 1992; Ludwig and Probst, 1998), and extrapolating these values the entire drainage basin often leads to an overestimation of the total sediment discharge for a given river.

Table 4.18 -**Tentative budgets for the natural sediment delivery to the Mediterranean Sea**

Basin *	**Country**	**Area 10^3 km^2**	**F_{TSS} 10^6 t/yr**	**Basin**	**Country**	**Area 10^3 km^2**	**F_{TSS} 10^6 t/yr**
ADR	Albania	30	46	ADR	Albania	231	122
ION	Albania			ADR	Italy		
ALB	Algeria	100	33	ADR	Serbia&Montenegro		
SWE	Algeria			AEG	Greece	215	151
NLE	Cyprus	9	2	AEG	Turkey		
SLE	Egypt	2920	146	ALB	Algeria	102	25
NWE	France	131	47	ALB	Morocco		
TYR	France			ALB	Spain		
ION	Greece	171	124	CEN	Italy	46	25
AEG	Greece			CEN	Tunisia		
SLE	Greece			ION	Albania	52	65
SLE	Israel	10	2	ION	Greece		
NWE	Italy	301	143	ION	Italy		
SWE	Italy						
TYR	Italy			NLE	Cyprus	108	27
ADR	Italy			NLE	Syria		
ION	Italy			NLE	Turkey		
CEN	Italy			NWE	France	277	75
SLE	Lybia	7	1	NWE	Italy		
ALB	Morocco	63	16	NWE	Spain		
ALB	Spain	182	38	SLE	Egypt		

NWE	Spain			SLE	Greece	2941	150
SWE	Spain			SLE	Israel		
NLE	Syria	6	1	SLE	Lybia		
SWE	Tunisia	34	20	SWE	Algeria	115	41
CEN	Tunisia			SWE	Italy		
AEG	Turkey	154	66	SWE	Spain		
NLE	Turkey			SWE	Tunisia		
ADR	Serbia&Montenegro	55	44	TYR TYR	France Italy	87	48
				Total		**4174**	**729**

*) see Table 3.1 (chapter 3)

- *Sediment retention in reservoirs*

For many Mediterranean rivers, the building of dams in their respective drainage basins originated a severe reduction in their sediment delivery to the sea (Table 4.19). Before the closure of the Aswan High Dam, the Nile River alone carried on average about 120 Mt of sediments per year to the Mediterranean Sea (Kempe, 1993), representing thus more than 15% of the above-calculated budget for the entire Mediterranean basin. Today, the Nile's sediment transport seems to be less than 0.3 Mt/yr (Abdel-Moati, 1999). Another striking example is the Ebro River, where the sediment discharge decreased continuously during the last century in parallel with the increasing number of dam constructions in its drainage basin. Its actual sediment is probably less than 1% of its original value (Guillén and Palanques, 1992).

Table 4.19 **The impact of reservoir construction on the sediment fluxes in some Mediterranean rivers**

River	**Pre-damming sediment flux** (Mt/yr)	**Actual sediment flux** (Mt/yr)
Nile	120	0.24
Rhone	30	6-10
Ebro	17-25	0.12-0.15
Moulouya	12	0.84
Tiber	7.5	0.33

Unfortunately, direct measurements of the fluxes before and after the reservoir construction are rare, and most of the studies that attempted an evaluation the sediment trapping behind dams are based on indirect methods.

Taking into account the almost complete stop of the sediment discharge of certain rivers such as the Nile and Ebro rivers, and generalising the above mentioned trapping efficiencies, we finally may conclude that the overall reduction of the riverine sediment discharge to the Mediterranean Sea may be in the range of 75%. This means that probably only less than 200 Mt of sediments enter actually the marine realm every year. Much uncertainty is accompanied with this value, but the scarcity of data on this topic does not allow establishing more detailed estimates.

- *<u>Organic pollution</u>*

Organic pollution in rivers results from inputs of organic matter from various sources, such as household wastewater, industries (e.g. the paper industry or food processing industry), or silage effluent and slurry from agriculture. Severe organic pollution may therefore lead to rapid deoxygenation of river water, decreasing the oxygen concentrations down to levels that are harmful for of fish and aquatic invertebrates. Moreover, when the oxygen levels are low, ammonium often becomes the dominant inorganic nitrogen species, which can lead to high levels of un-ionised ammonia when the water temperature and pH values increase.

The amount of organic pollution in freshwater systems can be gauged by measuring the biological oxygen demand (BOD). Alternatively, the chemical oxygen demand (COD) can be used to quantify organic pollution.

Spatial variability of BOD levels

The BOD concentration of clean freshwater is normally around 2 mg/L, which is about the median value in world rivers. Values exceeding 5 mg/L indicate heavy pollution (Kristensen and Hansen, 1994).

A compilation of average BOD and COD values in different Mediterranean rivers is presented in Table 4.20. In general, the values correspond to the most downstream stations of the drainage basins, close to the river mouths. For comparison, average values for the carbon content in these rivers obtained by direct measurements of the dissolved organic carbon (DOC) and particulate organic carbon (POC) contents were added whenever this information was available. In some cases, only total organic carbon (TOC) has been measured.

Table 4.20 **Average BOD, COD, DOC, POC and TOC values in some Mediterranean rivers**

Rivers	BOD_5	COD	Period	DOC	POC	Period	TOC	Period
	mg/L	mg/L		mg/L	mg/L		mg/L	
Adige	5.7	11.4	89-92				2.7	
Akheloos				1.1	0.3	83-84		
Aliakmon				1.2	0.7	83-84		
Argens	3.5	10.0	85-96	2.4				
Arno		32.3	89-92				6.1	
Aude	3.1	15.0	85-96	3.3				
Axios				1.4	0.4	83-84		
Besos	19.2	38.0	90-92					
Buyuk Menderes		3.1						
Ceyhan	4.6	24.4						
Ebro	4.0	3.8	86-92	4.8	1.4	86-87		
Evros				3.0	1.8	83-84		
Fluvia	1.2	3.7	90-20					
Goksu	1.5	22.2						
Herault	2.5		85-96	2.5		85-96		
Kishon	275	1700						
Krka	2.5	9.7	90					
Llobregat	5.3	15.3						
Manavgat	1.3	9.2						
Martil *	9.0		84-90					
Metauro		2.8	84-92					

Rivers	BOD_5	COD	Period	DOC	POC	Period	TOC	Period
	mg/L	mg/L		mg/L	mg/L		mg/L	
Moulouya *	2.6		84-90					
Neretva	2.0	9.8	78-90					
Nestos	3.6	8.0	92-94	1.7	0.7	83-84	2.4	
Nile				3.5	4.4			
Orb	3.1		85-96	2.7		85-96		
Pinios	4.0	3.8	92-94					
Po	7.0	18.1	82-92	2.6		88-90	4.7	
Rhone	1.5	5.0	85-96	2.6	5.2	94-95		
Semani	3.4	3.3	90					
Seyhan	6.9	48.0						
Shkumbini	5.2	3.7	90					
Strymon				2.1		83-84		
Tavignano	1.0		85-96	2.3		85-96		
Ter	2.6	7.9	90-92					
Tet	5.6		85-96	3.5		85-96		
Tiber	4.5	5.8	83-91				5.4	79-83
Var	2.5	8.0	85-96	1.6		85-96		

Since the values are not necessarily based upon the same number of measurements, and do not exactly refer to the same reference period, such a compilation has naturally to be considered with caution. There is also no single standardised system of water monitoring and assessment for surface waters in the different countries. In some cases, COD values are even lower that BOD values, which may be related to these difficulties. Nevertheless, most of the BOD and COD values correspond to about the same period (e.g., 1985-1990), and we may assume that they still allow a general overview of the degree of organic pollution in the Mediterranean rivers. By far the strongest pollution is found in the Kishon River of Israel, which receives the wastewaters of Haifa and which is regarded to be the most polluted river in Israel (Herut and Kress, 1997). Also the Besos, Martil (a small coastal river in Morocco), Po, Seyhan, Adige, Arno, Tet Llobregat and Shkumbini rivers have to be considered as heavily polluted rivers, which is generally also related to the effluents of large urban agglomerations (such as for the Besos River, who receives the wastewaters of Barcelona in Spain). On the other hand, rivers with almost no or only weak pollutions are the Tavignano, Fluvia, Manavgat, Goksu, Rhone, Neretva, Krka, Herault and Var rivers.

The median BOD value of all rivers in Table 4.20 is 3.5 mg/L. This is greater than the median value for European rivers (EEA, 1999). On the other hand, the median DOC concentration is 2.5 mg/L, whereas the average for world rivers is around 4-5 mg/L (Meybeck, 1982; Ludwig et al., 1996). DOC might largely reflect the organic compounds originating from the leaching of soil organic matter which are chemically rather inert and which are not necessarily available for rapid biological decomposition in the river waters. Because of the steep morphologies, the often low drainage intensities and the carbon poor soils in the Mediterranean area, it is therefore not surprising that DOC concentrations are generally low in these rivers.

Temporal variability of BOD levels

Average values for BOD or COD alone may not be satisfactory for an evaluation of the risk of environmental damage related to organic pollution. It is also the variability of the values that has to be considered in this context. Even if the averages were moderate, it is possible that maximum values can be high enough to induce irreversible damage in the fluvial ecosystems. The Mediterranean rivers are more vulnerable in this respect than the rivers of other regions because of the strong hydrological contrast between the dry and the wet seasons. Especially the small rivers draining the coastal regions are very dry in summer, and even relatively small amounts of urban and/ or agricultural wastewaters may be sufficient to cause environmental problems. Moreover, intense tourism in summer is often responsible for peak discharges of wastewaters in these regions, accentuating the seasonality of organic pollution.

In France, many of the coastal rivers can therefore be temporarily affected by pollution although the BOD averages are not always very elevated. Going further to the south, the situation can be more extreme. The Martil River in Morocco, a typical “oueds” (a coastal river that is dry during certain periods of the year), has a median BOD value of about 9 mg/L, which is among the highest values of the rivers in Table 4.20. But the variability of the values is even more striking: about one quarter of the values are greater than 28 mg/L. In the Moulouya River, which is a relatively large Moroccan river that flows permanently, BOD values are much lower. Specific wastewater inputs to this river may be less important, but part of the better water quality is certainly also related to the fact that the auto-purification capacity of this river is greater. However, even if the median value of the Moulouya River is comparable to most of the coastal rivers in France, the variability of the values is still somewhat greater than for the French rivers.

BOD Trends

The above-described data mainly reflect the organic pollution in the Mediterranean rivers about 10-15 years ago. In the meantime, the situation has improved for many of them. It is mainly from the 40’s onwards that increased industrial and agricultural production coupled with more of the population being connected to sewerage meant that the discharge of organic waste into surface water increased in most European countries (EEA, 1999). Over the past 15-30 years, biological treatment of wastewater has increased and the organic loading has consequently decreased in many parts of Europe. However, in southern Europe, where many of the Mediterranean rivers are situated, the decrease only started in the 80’s and is much less significant. No information was available about the north African rivers that are discharging to the Mediterranean Sea, but it can be expected that, if there was any improvement, it was not as important as in the western European rivers.

The evolution of the BOD concentrations and loads in the Rhone, Po and Ebro rivers are good examples to illustrate the general trend during the last 20 years (Figure 4.3). At the beginning of the 80’s, the Po was heavily polluted, with average BOD concentrations far above 10 mg/L. Since then, the values decreased starkly, and they are nowadays below the 5 mg/L limit (Figure 4.3A). Also in the Rhone River, BOD concentrations decreased considerably during the same period, but the values were already much lower at the beginning of the 80’s compared to the Po River. Nowadays, the Rhone seems to be free of organic pollution. The evolution in the Ebro River, however, is opposite to these trends. In this river, the BOD levels rather increased during the last decades. Apparently, wastewater treatment was not improved in this basin, or any improvement was compensated by a greater number of pollution sources.

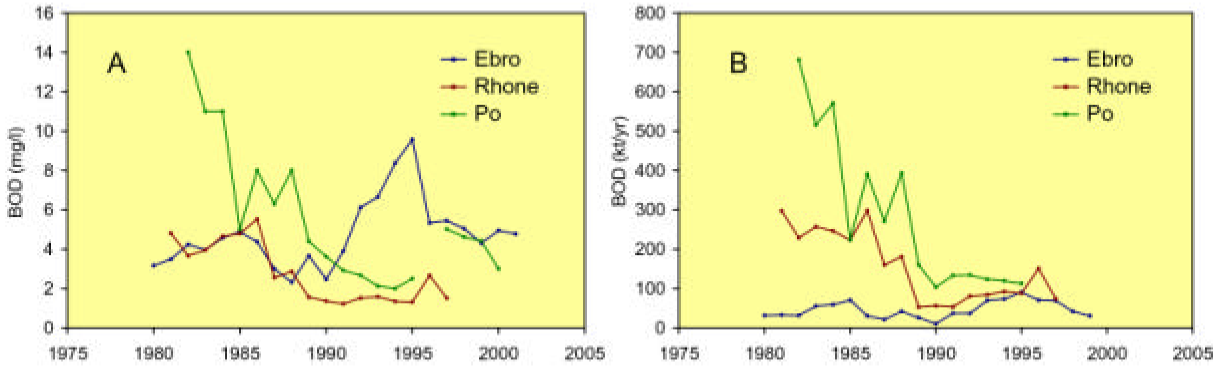


Figure 4.3 -Evolution of BOD concentrations (A) and loads (B) in the Ebro (at Tortosa), Po (at Pontelagoscuro) and Rhone (at Arles) rivers
Data sources: Kristensen, 1997 for the Po River (except for the 1997 to 2001 data which have been supplied by the Po River Authority); "Confederación Hidrográfica del Ebro" (http://www.oph.chebro.es/#) for the Ebro, River and the French monitoring Agency "Agence de l'Eau Rhône - Méditerranée - Corse (http://www.rdbrmc.com/) for the Rhone River.

Comparing average concentrations alone does not allow estimating the exact changes of the wastewater inputs because of the variations in water discharge in these rivers (see section 4.2.1). When looking at the BOD loads (Figure 4.3), one can notice that from the beginning of the 80's to the beginning of the 90's, the BOD loads depict a three- to fivefold reduction in the BOD inputs in the Rhone and Po rivers respectively. In the Ebro, the loads are less variable but rather tend to increase towards recent years. It has to be noted that around 1995, the BOD load in the Ebro was about the same as in the Rhone, although the water discharge of the Rhone is on average 5-6 times greater than the water discharge of the Ebro.

- *Bacteriological pollution*

In many cases, organic pollution in rivers is also accompanied by bacteriological pollution, since wastewater inputs from households and agriculture (especially with animal farming) often contain great numbers of bacteria and viruses that are pathogenic for humans. Also the organisms living in the aquatic ecosystems may suffer from these pathogens. Harmful pathogens, however, are generally difficult to detect and to monitor directly in freshwaters. Therefore, counts of indicator bacteria are normally used to assess microbiological water quality. These bacteria are harmless themselves, but their presence in high numbers indicates that the water may be contaminated. The most widely used indicator bacteria are of the total coliform, faecal coliform, enterococci and faecal streptococci groups, and *Escherichia coli*.

Bacterial counts are available for a limited number of Mediterranean rivers, and the observation period mainly corresponds to the second half of the 80's (Table 4.21). According to these data, the most polluted rivers are the Po, Tiber and Ebro rivers, which is principally in agreement with the BOD and COD data in Table 4.20. Lowest bacteria counts were found in the Rhone and Akheloos rivers. Ranking of the rivers naturally depends to some extent on the choice of the bacterial indicator. One may also mention here that a precise evaluation of the averages bacteria numbers may be more difficult than for other constituents in river water because of the great variability of the values. Nevertheless, the data are interesting because they are somewhat complementary to the data in Table 4.20. Especially for certain Greek rivers, bacterial counts are available, whereas BOD and COD values are missing (such as the Akheloos, Aliakmon, Axios and Strymon rivers). Except for the Strymon River, which has a rather high degree of pollution, this is indicating that the pollution level of the other rivers is rather moderate.

Table 4.21 **Bacteriological water quality in some Mediterranean rivers** *(all data from Kristensen (1997), except for the Rhone River where the data are from the "Agence de l'Eau Rhône - Méditerranée - Corse (http://www.rdbrmc.com/).*

Rivers	Country	Coli-faecal (n/100mL)			Coli-total (n/100mL)			Strepto-faecal (n/100mL)			Period	Sample No.
		mean	min	max	mean	min	max	mean	min	max		
Rhone	Fr				2100	30	11700	515	1	6000	88-92	52
Akheloos	Gr	133	0	4600	301	0	4600	32	0	266	84-92	71
Aliakmon	Gr	3520	0	240000	12423	6	1000000	765	0	24500	82-92	103-104
Axios	Gr	5320	240	46000	10740	450	46000	1892	0	11000	83-89	51
Nestos	Gr	1696	0	11000	3106	23	24000	905	0	8000	82-92	55
Pinios	Gr	1159	0	11000	2677	0	37000	78	0	700	82-91	72-91
Strymon	Gr	14830	43	1000000	20395	110	1000000	2883	0	30000	82-92	116-117
Adige	It	2335	0	36300	14007	200	90200	409	0	4200	87-92	74
Arno	It	2752	50	9180	7355	200	24000	393	20	2300	88-92	42
Metauro	It	5549	10	36000	6146	30	100000	783	0	9180	84-92	55-58
Po	It	26636	1000	330000	57203	1000	1000000	10133	700	302000	82-92	113
Tevere	It	188454	4300	2000000	284024	7500	4000000				89-91	17-18
Ebro	Sp	11790	7	456000	106756	38	810000	138	0	2500	87-92	69-75

For the three larger river basins of the Rhone, Po and Ebro rivers more recent data shows a positive evolution of the bacteriological water quality. For the Po River, there is an ongoing improvement of the water quality from the beginning of the 80's, whereas the water quality of the Ebro River remains bad (although a slight improvement may be visible). The best water quality is found in the Rhone River.

- *Nutrients*

This chapter deals with only those nutrients that are important in terms of their nutritive value for plants and nuisance level. They are in practice phosphorus and nitrogen compounds (also called 'macro-nutrients'). Dissolved silica is another element that is commonly included in the group of macro-nutrients. However, the data available for Mediterranean rivers is too scarce and will not be considered.

- *Monitoring of N and P species*

When looking at the proportions of specific forms of nutrients in individual rivers, the dissolved forms are often more important as it might be expected from the global budgets. In the case of nitrogen, nitrate is normally the dominant form (Table 4.22). The other DIN species (NO_2^- and NH_4^+) are only abundant when the rivers suffer from organic pollution, reducing the oxygen levels and allowing hence the reduced forms to be stable. This makes that the monitoring of nitrate is normally sufficient to evaluate the eutrophication potential in rivers related to nitrogen enrichment.

Table 4.22 **Relative importance of the different nitrogen and phosphorus species in the Po, Rhone and Ebro rivers**

River	Nitrogen						Phosphorus				Source
	TN	N-NO_3	N-NO_2	N-NH_4	DON	PN	TP	P-PO_4	DOP	PP	
	mg/L	%	%	%	%	%	mg/L	%	%	%	
Po	3.1	<--	71.0	--->	17.0	12.0	0.17	49.0	6.0	45.0	(1)
Rhone	1.7	78.2	1.2	5.4	8.4	6.9	0.12	36.0	18.5	45.5	(2)
Ebro	2.6	75.5	1.1	4.2	11.5	7.7	0.20	58.0		42.0	(3)

Sources: (1) Tartari et al., 1991; (2) Pont, 1996; (3) Munoz and Prat, 1989.

In the case of phosphorus, however, the particulate forms cannot be neglected (Table 4.22) compared to the dissolved forms (mainly phosphate). National monitoring agencies also determine the total phosphorus (TP = sum of all dissolved and particulate P species) content in rivers, although it is not known whether this phosphorus is really biologically available or not. Another problem is that TP concentrations can be strongly coupled to the concentrations of total suspended solids, making it difficult to monitor this parameter accurately. As mentioned previously, the sampling frequency of most monitoring programs is normally too scarce to determine reliable average sediment concentrations, which also affects the concentrations of TP. This has to be kept in mind when considering the temporal and spatial variability of average TP levels in rivers. Phosphate levels are less variable and, even if phosphate is not necessarily the dominant P form, average values might sometimes be more suitable for trends analyses in order to assess the evolution of nutrient pollution in rivers.

N and P levels in Mediterranean rivers

The available data on the average nutrient concentrations in the Mediterranean rivers are presented in Table 4.23. More than 30 rivers are documented for nitrate with average values. The median nitrate concentration is about 1.24 mg N/L, with a rather low variability of the values. This is indicating that most of the Mediterranean rivers are affected by nitrate pollution. The pollution levels, however, are low compared to other European rivers.

Elevated concentrations among the listed rivers in Table 4.23 are found in the intensely cultivated river basins of Italy, Spain, and/or Greece, such as the Arno, Po, Ebro and/ or Pinios rivers. Also the Nile River has one of the highest average nitrate concentrations, although this value has been derived from only a few published values and it is not clear whether this value really is representative for this river. If the organic pollution level is too elevated, however, the bulk of the inorganic nitrogen is transported in the reduced form (NO_2^- and NH_4^+), which is hence not necessarily leading to elevated nitrate concentrations. This is the case, for example, for the Besos River, which receives the waste waters of Barcelona in Spain. The lowest nitrate concentrations of clearly less than 1 mg N/L are typical for rivers where agriculture may be less intense in the catchments, and/ or accompanied by crops that do not require much fertiliser (such as the Var, Tavignano and Herault rivers in France). Also the rivers of Croatia seem to have rather low nitrate values (e.g. the Krka and Neretva rivers), but in these cases this may at least partly also be a dilution effect. Nitrogen inputs may be more diluted due to the often-high drainage intensities in these rivers.

The average phosphorus levels in the Mediterranean rivers are generally in agreement with the nitrate levels, even if the data coverage is less important. The median phosphate and total phosphorus concentrations of all rivers are 0.10 and 0.24 mg P/L, respectively. Also here, the values indicate a rather moderate pollution level compared to the rivers in the northern part of western Europe. In the case of phosphorus, the spatial variability of the values can be greater than in the case of nitrogen, because of the stronger dependence of phosphorus loads to point source pollution.

Table 4.23 **Documented rivers for dissolved nutrients**

Rivers	Qact Km3/yr	N - NO_3^- mg/L	N - NO_2^- mg/L	N - NH_4^+ mg/L	N k mg/L	P - PO_4^{-3}	Tot P mg/L
Adige	7.29	1.25		0.111		0.03	0.1126
Akheloos	5.67	0.60		0.035		0.02	0.0151
Aliakmon	1.168	0.395		0.05		0.10	0.0168
Argens	0.38	0.74	0.02	0.09	0.5	0.11	0.22
Arno	2.10	0.912		0.042		0.500	0.01
Aude	1.31	1.42	0.03	0.09	1.2	0.09	0.49
Axios	4.90	1.584		0.0658		0.48	0.48
Besos	0.130	1.9	0.3	31			12.7
Buyuk Menderes	4.70	1.44				0.55	
Ceyhan	7.10						8.68
Ebro	9.24	2.3		0.1672		0.029	0.243
Evros	6.80	1.9		0.05		0.36	
Fluvia	0.36			0.054			0.35
Gediz	1.87	1.65		0.05		0.19	
Goksu	2.50						8.87
Herault	0.92	0.61	0.012	0.06		0.045	0.22
Kishon	0.063						20
Krka	1.61	0.45	0.001	0.031		0.029	
Llobregat	0.466	1.9	0.5	3.2		1.2	1.53
Metauro	0.43	1.366		0.0		0.005	0.119
Neretva	11.01	0.269		0.029			0.050
Nestos	1.03	1.24		0.071			0.127
Orb	0.86	0.67	0.045	0.44	0.9	0.14	0.45
Pinios	0.672	2.323		0.167			0.2431

Rivers	Qact Km3/yr	N - NO_3^- mg/L	N - NO_2^- mg/L	N - NH_4^+ mg/L	N k mg/L	P - PO_4^{-3}	Tot P mg/L
Po	48.90	2.03		0.21		0.084	0.2393
Rhone	48.07	1.48	0.033	0.124	0.80	0.101	0.14
Semani	3.02	0.24					0.002
Seyhan	7.20	0.59		0.31	0.27	0.01	
Shkumbini	1.94	0.73					0.01
Strymon	2.59	1.236		0.053		0.11	0.125
Tavignano	0.06	0.34	0.045	[0.003]		[0.005]	
Ter	0.84			1.2			2.15
Tet	0.40	1.8	0.18	1.5	2.7	0.47	0.8
Tevere	7.38	1.37		1.04		0.26	0.355
Var	1.57	0.18	0.003	0.031	1.5	0.006	0.13

Ranking the Mediterranean rivers in Table 4.23 according to their average phosphorus concentrations does therefore not exactly follow the ranking of nitrate pollution. Highest P values are typical for the rivers suffering from organic pollution due to urban waste water inputs, such as the Besos and Llobregat in Spain, the Axios in Greece, the Tet in France and/ or the Arno in Italy. Lowest phosphorus concentrations are also found in the rivers with low nitrate concentrations (e.g. the Var or the Neretva rivers), indicating that these rivers are probably the closest to a pristine state.

Trends

The average values in Table 4.23 stretch over the period of about the last 30 years, with most of the values representing the 80's and the beginning of the 90's. It can be expected that the nutrient levels did not remain stable over these periods, as it is indicated by the variability of the values when different estimates were available for individual rivers. However, since the values often refer to different time slices, and may have been determined by different methods, they cannot directly be used for the evaluation of trends. Knowing these trends is nevertheless crucial for an evaluation of the impact of riverine nutrient levels on the Mediterranean ecosystems. Primary and secondary producers in the oligotrophic waters of the Mediterranean Sea adapted to low nutrient levels, and abrupt changes in the riverine nutrient loads may considerably affect the biological systems, even if the average concentrations are rather moderate compared to other densely populated regions of the world.

Large river basins

Monitoring programs for large river systems are generally better developed than for small rivers, and water quality data are more easily accessible. Another advantage is that large river basins integrate the variety of human activities at regional scales, making them more representative than smaller basins. Data on annual nutrient concentrations in the Rhone, Po and Ebro rivers for about the last 30 years, allow the establishment of a detailed picture of the evolution during this time (Figures 4.4A and 4.5A). Moreover, together with the discharge data for these rivers (see section 4.2.1), also the evolution of the annual nutrient loads can be examined (Figures 4.4B and 4.5B).

For nitrate, it can be noted that the concentrations increased steadily from the beginning of the 70's in all three rivers. Only since the beginning of the 90's, the values seem to remain at more or les constant levels. The increase was more important in the Ebro and Po rivers than in the Rhone River. Also the annual nitrate loads increased on average in all three rivers. On the basis on linear correlation of the loads and time, it can be estimated that for the 1970 to 1995 period, the nitrate loads increased on average by about 10% per year in the Ebro River. In the Rhone and Po rivers, this increase was about 4% and 5% per year, respectively.

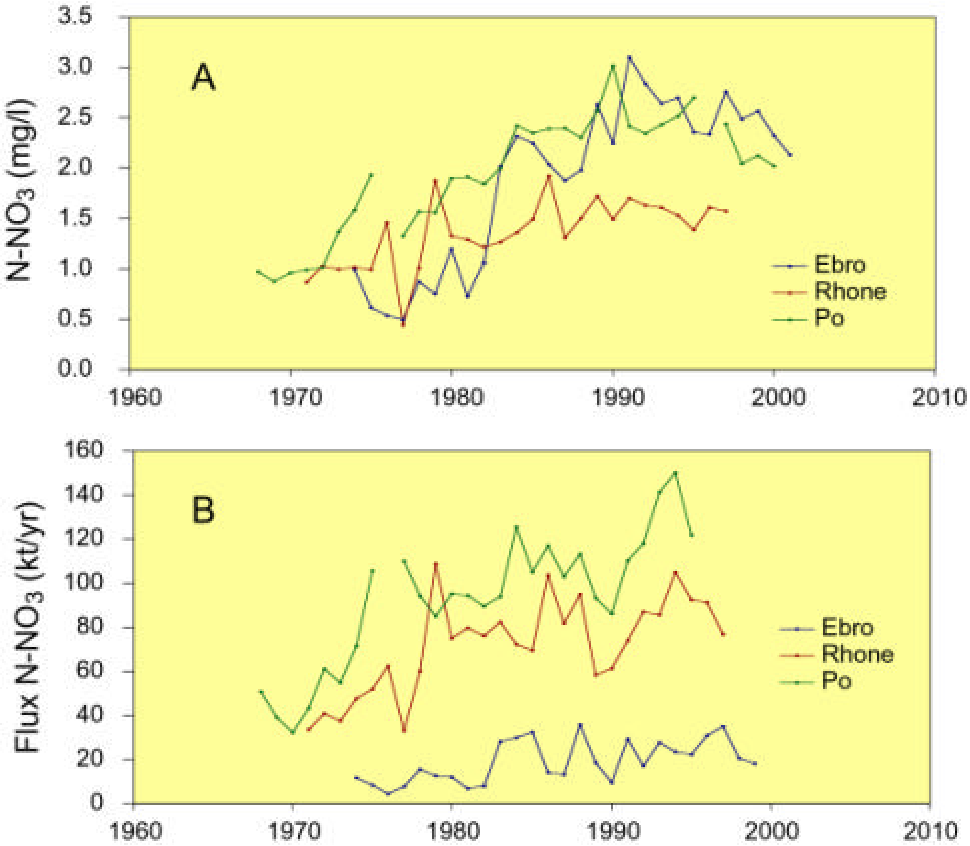


Figure 4.4 Evolution of the average nitrate concentrations (A) and the annual nitrate loads (B) in the Po, Rhone and Ebro rivers during the last decades

The Po River data are from Camusso et al. (2000) for 1968 - 1995 and from the Po River Authority for 1997 to 2001. The Rhone River data are from Moutin et al. (1998) for 1971 - 1981 as well as from the French monitoring Agency "Agence de l'Eau Rhône - Méditerranée - Corse" (http://www.rdbrmc.com/) for 1981 - 1997. Finally, the Ebro River data are from Ibanez et al. (1995) for 1974 - 1986 and from the "Confederación Hidrográfica del Ebro" (http://www.oph.chebro.es/#).

These trends are in good agreement with the situation in other European rivers. At many sites, annual concentrations are approaching a steady state, after two decades of rapid increase. This may reflect the use of nitrogen fertilisers and other changes in agricultural practices (see section 4.3).

For phosphate, the trends are more diversified. There is also a strong increase of the phosphate concentrations in the Po, Rhone and Ebro rivers at the beginning of the 70's, even more pronounced than in the case of nitrate. But about 10 to 20 years later, this evolution stops and the values started to decrease again. It is remarkable that in all three rivers, the phosphate concentrations at the end of the 90's meet again the values that have been encountered at the beginning of the 70's. When taking the mean of the phosphate loads in the three rivers, one can estimate that phosphate loads from 1975 to 1985 increased on average by about 15% per year. From 1985 to 1995, they then decreased again to about the initial values.

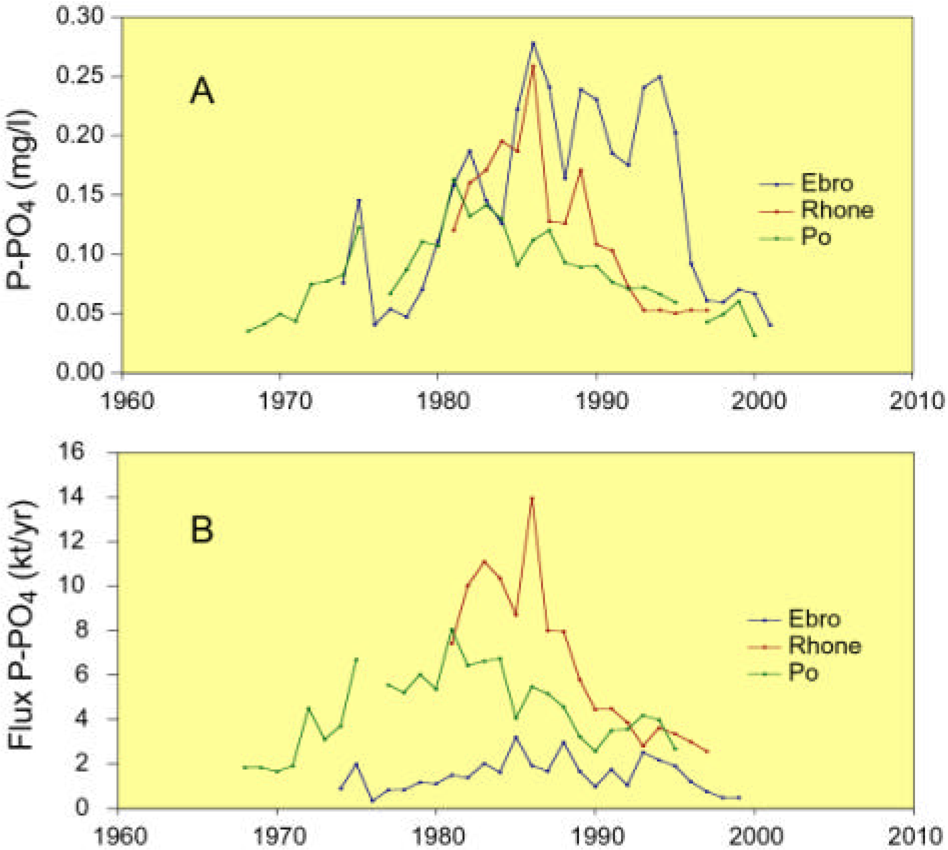


Figure 4.5 Evolution of the average phosphate concentrations (A) and the annual phosphate loads (B) in the Po, Rhone and Ebro rivers during the last decades**.**

But the evolution is not completely in phase between the three rivers, since the start of the decrease is different. This can be seen best when looking at the phosphate loads. The decline started earliest in the Po River (about 1980), followed then by the Rhone River (around 1985) and finally by the Ebro River (around 1993). The differences in the starting point of the phosphate decline may reflect the time lags in the launching of measures to defend phosphorus pollution in the different countries, such as the interdiction of the use of phosphorus detergents, and/ or differences in the upgrading of waste water treatment plants. In the case of the Ebro River, it is also possible that the improvement of the water quality in this river has been delayed by the multitude of reservoirs in this basin, which may have retained older phosphorus loads. Nevertheless, it has to be stated that the severe reduction of the riverine phosphorus loads is a widespread phenomenon in Europe.

Finally, it is worth being pointed out that, since the nitrate and phosphate concentrations did not follow the same evolutions, the composition of the riverine nutrient input to the Mediterranean Sea may have considerably changed during the last decades. Especially the nitrate to phosphate ratio changed remarkably (Figure 4.6). Whereas the weight ratio was about 10 to 20 during the 70's and the beginning of the 80's, it climbed up to values >40 in recent years. It is not excluded that this may not have had an impact on the biological systems in the marine environment.

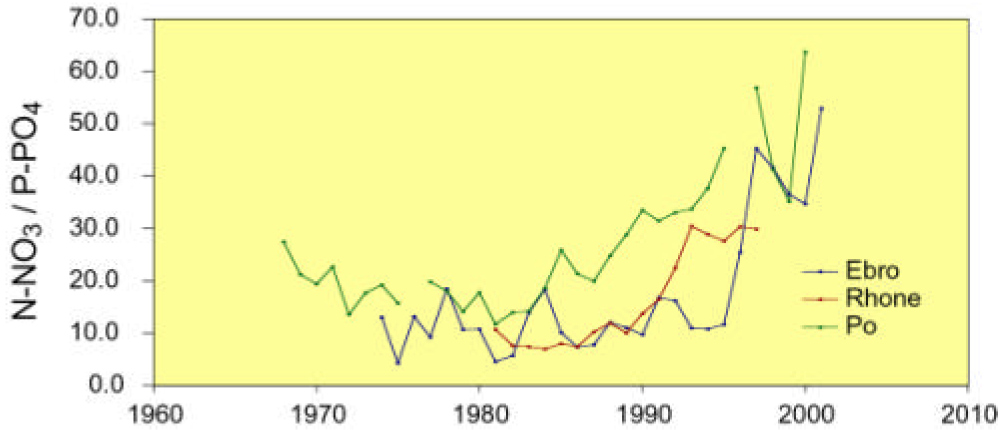


Figure 4.6 Evolution of the average nitrate to phosphate weight ratio in the Po, Rhone and Ebro rivers during the last decades
(For the data sources, see Figure 4.4.)

Other Mediterranean rivers

Additional data for the annual evolution of the nitrate and total phosphorus levels in some Greek, Italian and Croatian rivers are presented in the Table 4.24.

Table 4.24 **Evolution of the average nitrate and total phosphorus concentrations in some Mediterranean rivers**
(data from Kristensen, 1997)

River	**Neretva**	**Nestos**	**Axios**	**Aliakmon**	**Pinios**	**Acheloos**	**Tiber**	**Arno**	**Adige**
Station	Opuzen	Drama	Saloniki	Kozani	Larissa	Agrinion	Ripetta	Calcinaia	Badia Bolesine
Country	Croatia	Greece	Greece	Greece	Greece	Greece	Italy	Italy	Italy
Year	Average nitrate concentration (mg $N\text{-}NO_3/L$)								
1981	0.174								
1983	0.027	1.039	1.093	0.321	1.501	0.099			
1985	0.123	1.152	1.524	0.208	1.438	0.106			
1987	0.410	1.836	1.734	0.585	1.847	0.129			1.576
1989	0.728	1.594	1.628	0.336	1.231	0.172			1.355
1991		0.856	1.891	0.764	2.003	0.246		2.549	1.336
1993		0.703	2.084	0.480	1.423	0.228		2.558	1.374
1995					0.421			0.488	1.710
Year	Average total phosphorus concentration (mg P/L)								
1981	0.062								
1983	0.022	0.150	0.410	0.010	0.070	0.005	0.300		
1985	0.037	0.150	0.610	0.030	0.080	0.005	0.300		
1987	0.111	0.170	0.540	0.020	0.070	0.020			0.150
1989	0.028	0.110	0.500	0.010	0.050	0.010	0.300	0.380	0.100
1991		0.080	0.541	0.016	0.071	0.061	0.256	0.233	0.050
1993		0.065	0.988	0.008	0.079	0.015		0.118	0.043
1995								0.167	0.049

These data are annual arithmetic means, stretching over the period of 1980 to 1995. Since the corresponding annual water discharge was not available for all of these rivers, the corresponding nutrient fluxes cannot be calculated.

For nitrate, most of the rivers evolved towards greater nitrate concentrations (e.g., the rivers Neretva, Axios, Acheloos), or do not show any clear trend (e.g., the rivers Pinios, Adige). Only in the Arno River, nitrate decreased considerably from 1990 to 1995. The average concentrations were the highest in this river, indicating that a considerable part of the nitrate load may originate from point source pollution. Nitrate decrease can therefore be related to the general improvement of the water quality in this river.

For total phosphorus, most of the rivers depict decreasing values over time (e.g., the rivers Neretva, Nestos, Arno, Adige) or have no trend (e.g., the rivers Aliakmon, Acheloos). The decrease is the most significant since the second half of the 1980 for the Italian rivers, which is in good agreement with the evolution in the Po River. The only river where the total phosphorus concentrations increased is the Axios in Greece. It is also this river that depicts the highest phosphorus level. Apparently, no measures to limit phosphorus pollution were undertaken for this river in Macedonia, where most of the Axios drainage basin is situated. This confirms the general picture that, although phosphorus pollution is broadly reduced, the improvement is not uniformly progressing in the different countries of the Mediterranean.

<u>Budgets</u>

Global N and P inputs to the Mediterranean Sea

Even if the above-presented nutrient data are incomplete with respect to the spatial and temporal variability of the riverine nutrient loads, they are sufficient to allow a general estimation of global budgets for the nitrogen and phosphorus inputs to the Mediterranean Sea. To this end, the median N and P concentrations considered representative for the Mediterranean rivers on the whole may be 1.25 mg N/L, 0.1 mg P/L and 0.25 mg P/L for the mean N-NO_3, P-PO_4 and TP concentrations, respectively (Table 4.23). The year 1985 was attributed to these values as corresponding reference period, which means that the overall water discharge may have been in the range of 375 km^3/yr. The resulting fluxes were hence 469 kt N-NO_3, 38 kt P-PO_4 and 94 kt TP (Table 4.25). For the other N and P species, we did not attribute any flux estimates because of the scarceness of our data. But one may retain that the other inorganic nitrogen species (NO_2 and NH_4) are normally only about 10% of the nitrate concentrations, and the total DIN flux for 1985 should be in the range of 520 kt N.

When combining these estimates with the trends discussed above, it is also possible to reconstruct the temporal evolution of these nutrient fluxes. For this, it can be assumed that the trends in the Po, Rhone and Ebro rivers are representative for the entire Mediterranean area. This means that the nitrate fluxes may almost have doubled from about 1975 to 1995, whereas the phosphorus fluxes increased rapidly from about 1975 to 1985, and decreased then again to about the initial values. The Table 4.25 summarises the corresponding total nutrient fluxes for these periods. Because of the lack of data, it can also be assumed that the evolution of total phosphorus entirely followed the evolution of phosphate, although this has, of course, not necessarily to be the case.

Table 4.25 -**Estimated evolution of the total riverine nutrient fluxes to the Mediterranean Sea**

	Flux N-NO_3 (kt N/ yr)	**Flux P-PO_4** (kt P/ yr)	**Flux TP** (kt / yr)	**N-NO_3/ P-PO_4**
<1975	333	14	36	23.4
1985-90	469	38	94	12.5

>1995	605	14	36	42.4

These estimates are not very different from others reported in the literature (Seizinger and Kroetze, 1998; Béthoux et al., 1998).

- *Heavy metals*

The list of metals considered of major concern for the marine environment and their main effects on biota is given in Table 4.26.

Table 4.26 **Harmful effects of some heavy metals on the environment**
(according to the web-site http://heavy-metals.gpa.unep.org/).

Cadmium	Critical effects of cadmium contamination on plants are a decrease in productivity, reduced rates of photosynthesis and transpiration, and altered enzymatic activities. In sea waters, cadmium levels greater than 7 mg/L can initiate toxic effects for animals, including growth retardation and decrease survival of invertebrates, and kidney damage and decalcification of the skeleton for higher marine animals and seabirds.
Mercury	The major toxic action of mercury is the inhibition of enzymatic processes, which can affect the reproduction and the nervous system of birds and mammals. In fish, the effects of mercury also include a decreased of sense of smell, damage to gills and blindness. High concentrations of mercury lead to reduced growth of plants. One important hazardous effect of mercury in the aquatic environment is that it biomagnifies in the food chain.
Lead	Effects of lead on plants are limited to areas where relatively high concentrations of lead are found, like areas near mines or smelters. For animals, the signs for lead poisoning are central nervous system disorders, high excitivity, motor abnormalities and blindness. In fish, lead accumulates primarily in gills, liver, kidney and bones, causing blackening of the tail, damage to the spine and reducing larvae survival.
Zinc and copper	Zinc and copper constitute hazard to aquatic life in polluted waters where other much more hazardous metals like lead, mercury, cadmium are also present because its toxicity with the other metals is additive. It has been reported that sublethal concentrations of Zn impair the reproduction of salmon and some marine invertebrates.

The abundance of heavy metals in a river depends not only the natural and anthropogenic sources in the watershed, but also on the chemical and physical properties of the river, such as acidity (pH), oxydo-reduction conditions (Eh), turbidity (suspended load), colloids and organic matter particles. These factors may drastically change along the watercourse due to the season or other climatic effects (storm, dryness).

Under the usual pH conditions in rivers (pH range of 7 - 8.5), the main part of heavy metals (>80%) is adsorbed on the surface of the suspended particles. The distinction between the dissolved and adsorbed fractions of an element is important in addressing the problems of transport, biodavailability and remediation.

An assessment of the average metal contents and loads in Mediterranean rivers is more difficult for heavy metals than for other pollutants, such as nutrients, because it can hardly rely on the data regularly collected by national monitoring programs. Two reasons are responsible for that. On the one hand, many monitoring programs only measure total metals without filtering the sample, although the utility of his information is restricted. As we have seen above, by far most of the heavy metal transport occurs in the particulate phase, and a spatial and temporal inter-comparison of data requires a sampling strategy that is representative for the total suspended sediment transport. This is almost impossible with the sampling frequency normally applied by national monitoring agencies. Including one high-turbid sample or not in a data set may completely change the resulting averages.

On the other hand, one has also to point out that the contamination problem is still a major problem for the analysis of heavy metals. National monitoring agencies usually charge public laboratories for the analytics, doing in routine great number of samples of different origins. In fact, the analysis of drinking or surface water may be followed by the analysis of waste water or sewage sludge in the same place with the same instrument, which can lead to a great deal of invalid data and misinterpretation of the environmental process (Bortoli et al., 1998).

In the following sections, only data for dissolved and particulate metals (in µg/L and µg/g, respectively) will be presented, avoiding data for total metals. The variability of this parameter is often too large for being representative for one river. Referring the particulate metal content to one gram of suspended sediments is a better mean to assess the pollution state of a river than referring it to one litre of water. This does, of course, only allow flux calculations if the corresponding fluxes of total suspended solids are known.

Particulate metals

The average heavy metal contents in the total suspended solids for 17 different Mediterranean rivers are presented in Table 4.27. The median concentrations for all rivers are about 1, 51, 0.3, 68 and 212 µg/g for the elements Cd, Cu, Hg, Pb and Zn, respectively. These values witness a general impact of pollution in the Mediterranean rivers: when dividing them by the averages for the composition of continental crust most of the ratios are much greater than 1, indicating that these elements are mostly derived by anthropogenic pollution. However, the values are lower than those of the highly industrialised river basins in northwestern Europe.

For individual rivers, certain particularities can de detected in the relative abundance of the trace metals. Elevated concentration from pollution sources may be present in the following rivers for the following elements: Acheloos (Zn) Adige and Bradano (both Cd), Ebro (Cr, Cu, Cd), Goksu (Cr), Herault (Cu, Pb), Orb (Cu), and Tiber (Cd, Cu, Zn). For the Martil River in Morocco, only few elements were analysed, showing highest pollution levels for Pb and Zn. It is evident that not in all cases, pollution alone must be responsible for elevated heavy metal concentrations. The values should be interpreted together with the geological and lithological patterns of the rivers drainage basins, which is, of course, beyond the scope of this study. In the Po and Rhone rivers, the heavy metal concentrations are elevated for almost all of the elements (Cd, Cr, Cu, Hg, Zn (Po), Pb (Rhone)), with generally greater values for the Po than for the Rhone. The lowest values were found in the Var and Argens rivers in France. Here, the natural background levels probably mainly control the heavy metal concentrations in the sediments.

Table 4.27 Average concentrations of particulate trace metals (µg/g) in some Mediterranean rivers
(for source indexes, see reference list)

Rivers	Country	Cd			Cr			Cu			Hg			Pb			Zn		
		µg/g	period	source	µg/g	period	source	µg/g	period	source	µg/g	period	source	µg/g	period	source	µg/g	period	source
ADIGE	Italy	1.6	88-90	91.109				50.0	88-90	91.109				49.0	88-90	91.109	270	88-90	91.109
		1.9	85	91.110				75.0	85	91.110				72.0	85	91.110			
		1.2	95-96	98.003	60.7	95-96	98.003	76.6	95-96	98.003				72.7	95-96	98.003	212	95-96	98.003
AKHELOOS	Greece							50.5	82-90	97.021				40.4	82-90	97.021	470	82-90	97.021
ARGENS	France	0.1	94-95	97.006	15.6	94-95	97.006	3.2	94-95	97.006	<0.03	94-95	97.006	19.6	94-95	97.006	38	94-95	97.006
ARNO	Italy				159.0	88-90	91.109												
BRADANO	Italy	2.6	85	91.110															
BRENTA	Italy													145.0	85	91.110			
CEYHAN	Turkey							<10.0		94.066									
EBRO	Spain	1.8		91.105	215.0		91.105	71.0		91.106				60.0		91.106			
GOKSU	Turkey	0.5		92.063	270.0		92.063	16.8		92.063				5.0		92.063	27		92.063
HERAULT	France	0.7	94-95	97.006	33.6	94-95	97.006	57.2	94-95	97.006	0.14	94-95	97.006	129.0	94-95	97.006	279	94-95	97.006
MARTIL	Morocco				91.0		97.020							517.0	94-95	97.020	438	94-95	97.020
ORB	France	0.1	94-95	97.006	37.5	94-95	97.006	132.0	94-95	97.006	0.29	94-95	97.006	68.4	94-95	97.006	138	94-95	97.006
PO	Italy	1.7	88-90	94.001	124.0	88-90	94.001	75.0	88-90	94.001	1.54		91.109	75.0	88-90	94.001	342	88-90	94.001
					31.2	92-95	97.016												
RHONE	France	1.8		91.105	102.0	94-95	96.032	41.6	94-95	96.032	0.47	94-95	96.032	32.9	94-95	96.032	108	94-95	96.032
		0.7	94-95	96.032	155.0		91.105	125.0		91.105	0.30		94.068	120.0		91.105	230		94.068
		0.7		94.068	110.0		94.068	80.0		94.068	1.14	94-95	97.006	80.0		94.068	95	94-95	97.006
		1.0	94-95	97.006	39.6	94-95	97.006	26.0	94-95	97.006	0.48		96.022	30.0	94-95	97.006			
SEYHAN	Turkey							<10.0		94.066									
TIBER	Italy	2.0	88-90	89.109				100.0	88-90	89.109				130.0	88-90	89.109	280	88-90	89.109
VAR	France	0.1	94-95	97.006	19.8	94-95	97.006	17.1	94-95	97.006	0.04	94-95	97.006	11.9	94-95	97.006	47	94-95	97.006
		0.4		92.063				25.0		92.063				5.6		92.063	68		92.063

Dissolved metals

Table 4.28 represents the average dissolved trace metal concentrations for 13 Mediterranean rivers. Elevated levels were mainly found in some Italian rivers, such as the Po (Cd, Cu, Zn), the Tiber (Pb, Zn) and the Arno rivers (Cd), although a direct comparison is not always possible because of the differences in the reference periods corresponding to the values. Also the Ebro River seems to have somewhat elevated Cd values. By far the lowest values were found in the Krka River in Croatia, confirming the pristine state of this river.

It is worth being noted that, contrarily to the particulate metals, there is no fundamental difference between the Mediterranean and the northwestern European and American rivers. Since the concentrations can be strongly controlled by the chemical and physical properties of the river water (pH, Eh, etc.), it is possible that the dissolved metals may be less indicative for an assessment of the pollution state of a river.

Table 4.28 **Average concentrations of dissolved trace metals (µg/L) in some Mediterranean rivers**

(data in backets: ultraclean techniques doubtful; for source indexes, see reference list)

Rivers	Country	Cd			Cr			Cu			Hg			Pb			Zn		
		µg/l	period	source	µg/l	period	source	µg/l	period	source	µg/l	period	source	µg/	period	source	µg/	period	source
ADIGE	Italy	0.032	88-90	*91.109*				2.39	88-90	*91.109*				0.74	88-90	*91.109*			
		0.040	95-96	*98.003*	0.17	95-96	*98.003*	1.05	95-96	*98.003*				0.19	95-96	*98.003*	2.53	95-96	*98.003*
AKHELOOS	Greece							0.33	82-90	*97.021*				0.29	82-90	*97.021*	(2.6)	82-90	*97.021*
ALIAKMON	Greece							(10.5)	86-88	*90.001*				(7.5)	86-88	*90.001*	(50.5)	86-88	*90.001*
ARNO	Italy	0.020	88-90	*89.109*				2.00	88-90	*89.109*	0.07	88-90	*89.109*	1.00	88-90	*89.109*			
		0.100		*89.116*				1.75		*89.116*				0.21		*89.116*			
AXIOS	Greece							(7.0)	86-88	*90.001*				(8.0)	86-88	*90.001*	(67.3)	86-88	*90.001*
BRADANO	Italy	0.076	85	*91.110*															
BRENTA	Italy							2.54	85	*91.110*				0.50	85	*91.110*			
EBRO	Spain	0.015		*91.106*				1.30		*91.106*				0.025		*91.106*	0.55		*91.106*
		0.061		*92.065*				1.80		*92.065*				0.030		*92.065*	0.60		*92.065*
		0.120		*89.116*				0.97		*89.116*				0.155		*89.116*			
KRKA	Croatia	0.005		*92.065*				0.10		*89.116*	0.0004		*96.022*	0.010		*92.065*			
		0.010		*89.116*										0.083		*89.116*			
NILE	Egypt	0.008		*89.116*				0.95		*89.116*				0.034		*89.116*			
PO	Italy	0.110	88-90	*94.001*	1.10	88-90	*94.001*	2.07	88-90	*94.001*	0.009	88-90	*91.109*	0.260	88-90	*91.109*	6.65	88-90	*94.001*
		0.065		*92.065*	1.40	93-95	*97.016*	1.63		*89.116*				0.148		*92.065*			
								1.50		*92.065*				0.150		*89.116*			
														0.280		*94.001*			
RHONE	France	0.028		*92.065*	0.274	94-95	*96.032*	0.02	94-95	*96.032*	0.001	94-96	*96.032*	0.045	94-95	*96.032*	1.14	94-95	*96.032*
		0.050		*89.116*				1.93		*89.116*	0.018		*92.065*	0.083		*92.065*	1.30		*92.065*
								2.20		*92.065*	0.001		*96.022*	0.090		*89.116*			
TIBER	Italy	0.080	88-90	*91.109*				0.90	88-90	*91.109*	0.020	88-90	*91.109*	0.40	88-90	*91.109*	5.30	88-90	*91.109*
		0.015		*89.116*															

- *Pesticides and persistent organic chemicals*

As for other pollutants, most rivers are not adequately monitored for persistent organic chemicals in order to assess loads, even though they are very important. High pesticide concentrations have been found in some specific studies and are believed to occur in many small rivers which are affected by intensive agriculture. The type of pesticides may vary from one river to another and from one country to another.

- *Chlorinated pesticides*

Cyclodiene pesticides (dieldrin, aldrin, endrin, heptachlor) have been reported in river water samples collected during the 80's from Spain, Turkey, Slovenia, Egypt, Cyprus and Greece in a wide range of values (<0.1 – 228 ng/L, and even in the µg/L in some Turkish rivers) (Aya et al., 1997). Lower levels of these pesticides were observed in few recent studies. For example, 3.5-8.1 pg/L for heptachlor in the Nile River (Yamashita et al., 2000), 0.4-1.6 ng/L for total cyclodiene pesticides in the Ebro watercourse (Fernandez et al., 1999), 0.2-0-6 ng/L in the Rhone and Seine rivers (France) (Tronszynsky et al., 1996) and in only 2% of the samples from the major dams and rivers in Cyprus (max. 11 ng/L) (Michaelidou et al., unpubl.).

Surveys of DDTs have also been performed in several rivers, although only in France as part of a continued monitoring activity (Table 4.29). Extensive studies have also been performed in Egypt along the River Nile, with values ranging between 26 and 103 ng/L of total DDTs.

Table 4.29 **Concentration of DDTs in freshwaters of the Mediterranean region**

Country	Location	Sampling	S DDTs conc. (ng/L)	References
Spain	Ebro River	1983-1987	pp'-DDE, 0.3-0.9 (d +p)*	Cid et al., 1990 & unpubl.
		1995 - 1996	3.1 ± 1.3 (d + p)	Fernandez et al., 1999
	Guadalquivir River		7 (d+p)	Hernandez et al., 1992
France	Rhone River	1995	pp'-DDE, 3.6 (d)	Tronszynsky et al., 1996
	Seine River	2000	pp'-DDT, 0.2-0.8 (d)	Romaña, pers. com.
Egypt	Nile River (Kafr El Zayat)		0.02-0.04	Dogheim et al., 1996
Cyprus	8 dams (84% of surface waters)	1996 - 2000	4 - 49	Michaelidou et al., unpubl.
	12 contributing rivers	1996 - 2000	0 – 4	

* p = particulate phase ; d = dissolved phase

Hexaclorocyclohexanes, and particulalry lindane, have been identified in river waters. In France, lindane was detected, in a wide range of values (5-95 ng/L), in 23% of the river and estuarine water samples collected within the national monitoring network (Bintein and Devillers, 1996). More recently, the mean values found in the Rhone (n=34) and the Seine rivers have been of 5.6 and 7.0 ng/L, respectively (Tronszynsky and Moisan, 1996; Carru et al., 1997).

In Spain, the values found in the Ebro River for a- and γ-HCH were in the range of 0.7-2.7 ng/L (d + p) (Fernandez et al., 1999), but values one order of magnitude higher were reported in certain sites of the Guadalquivir (54 ng/L) and Llobregat (10-30 ng/L) (Hernandez et al., 1992; Planas et al., 1997).

Relatively high concentrations of γ-HCH (39-360 ng/L) have been reported in water samples collected during the 80's from the Nile River (El-Gendy et al., 1991). In a study carried out in 1993-1994 (Yamashita et al., 2000), levels decreased to the range 0.05-0.5 ng/L in the Nile River and Manzala Lake.

Hexaclorobenzene was found in water samples collected during the 80's at the lower course of the Ebro River (Spain) with levels in the range 0.2-3 ng/L (Cid et al., 1990). Similar low levels (0.2-0.6 ng/L) were reported more recently in the Rhone (Arles, France) and the Seine River at Rouen (Tronszynsky and Moisan, 1996; Carru et al., 1997). Lower concentrations were reported in 1993 for the Nile River (Egypt) and in the coastal Manzala lagoon (Yamashita et al., 2000).

- *Nitrogen and phosphorus herbicides*

The new pesticides generation (atrazine and others) are not much transported by rivers, as their persistence is lower than the chlorinated ones. Only 0.2 to 3 % of the products applied to cultivated land are exported. Examples of detection of these residues in the main Mediterranean rivers are presented in Table 4.30.

Table 4.30 **Pesticide residues in Mediterranean rivers**

Herbicides Rivers	**Atrazine** (µg/L)	**Simazine** (µg/L)	**Alachlor** (µg/L)	**Metolachlor** (µg/L)	**Molinate** (µg/L)
Po (Italy)	0.021-0.118	0.06-0.08	<0.03-0.11	<0.03-0.605	<0.03-1.750
Rhone (France)	0.022-0.386	0.018-0.372	<0.001	-	-
Ebro (Spain)	<0.001-0.190	0.010-0.138	<0.001- 0.267	<0.001-0.554	0.001-0.568
Evros (Greece)	Nd-0.63	Nd-0.32	Nd-0.37	-	-
Axios (Greece)	<0.05-0.70	<0.06-0.30	<0.05-1.30	<0.10-0.50	<0.001-0.90
Aliakmon (Greece)	Nd-0.74	Nd-0.06	Nd-1.20	Nd-0.63	Nd-0.94
Nile (Egypt)	<0.001	<0.001	<0.001	<0.001	<0.001

- *PCBs*

Most studies were performed in the 80's, including urban waste and river waters, although an accurate assessment of levels is precluded by the different units used. Concentrations of 5-110 ng/L eq. Phenochlor DP 5/6 were found in the wastewaters of Marseille, Toulon and Nice (Marchand et al., 1989), and of 120 ng/L Σ7 cong. in Barcelona (Bayona et al., 1991). Few measurements performed in the Ebro (Spain), Kupa (Slovenia) and Nile (Egypt) Rivers showed values (dissolved +particulate) in the range of 2-3, <1.5-5.0, and 17-653 ng/L of Aroclor 1254, respectively (Cid et al., 1990; Picer et al., 1995; El-Gendy et al., 1991). More recent studies are reported in Table 4.31. In this respect, a steady downward trend (by a factor of ten) has been found from 1989 to 2000 in Cyprus in the major dams and rivers of the island.

Table 4.31 **Concentration of PCBs in fresh and wastewaters of the Mediterranean region**

Country	**Location**	**Sampling**	**PCBs conc. (ng/L)**	**References**
Spain	Ebro River	1983-87	76.3 ± 23.4	Fernandez et al., 1999
Egypt	Ismailia canal		Max.77	Badawy, 1998
	Mahmoudia canal		Max.39	Badawy, 1998
	Nile Delta	1995-97	570 -1000	Abbassy et al., 1999
Cyprus	7 dams 12 rivers	1996-2000	Max: 60 (S14 cong) Max: 31 (S14 cong)	(Michaelidou et al., unpubl.)
Croatia	Ground water	1997 – 2001	0 – 26	Divkovic and Nikolic, 2002
Serbia and Montenegro	Danube river	1999	Median: 10.5 (S7 cong)	UNEP/UNCHS, 1999
	Lepenica River	1999	18.7 (S7 cong)	UNEP/UNCHS, 1999

- *Coastal discharges*

An analysis of general trends in concentrations of some pollutants over a decade reveals a marked stability in measured levels, with irregular tendencies to improvement and deterioration. Compared with the situation during the 1970's, progress in the reduction of sources of domestic and industrial pollution has, for example, reduced the impact of the Rhône. This should also be the case in the next few years for the Seine, the Ebro and the Po.

During MEDPOL Phase I (1975–1980), it was attempted through the project MEDPOL X to estimate the quantity and nature of riverine inputs in the region. The project met with considerable difficulties. Country responses were geographically almost restricted to the northern Mediterranean. Among 68 rivers registered, only 30 were adequately monitored but not for PTS.

Due to the difficulties and the uncertainties involved in the complex computations and extrapolations carried out, the results could not be better than rough estimates reliable within an error margin of one order of magnitude. Some of these results were proved, at a later stage, to be even worse. Only a comparative assessment of the regional contributions to the pollution load could be made. The results showed that the heaviest loads are discharged into the northwestern basin with one-third of the total pollution load. The Adriatic Sea receives about one-quarter of the total load. Moderate pollution loads are encountered in the Tyrrhenian and the Aegean Seas, as they receive each about 10% of the total load. The other six Mediterranean Sea areas each account for no more than 5% of the total.

More recently, accurate estimates have been obtained for some French rivers using linear regression and average weighted flow models. A survey was carried out during 1994-95 at the lower course of the Rhone River, far from the any marine influence. An important conclusion was that the large supply of fresh water (>70%) and consequently of dissolved species, corresponds to the medium-low flow regimes, whereas the contribution of large flows (>5000 m^3/s) represents less than 10% of the total input. On the contrary, these regimes contribute with about 80% of the total input of suspended particles. All pollutants, and notably PTS attached to the particles, are carried to the sea in such episodic events.

The calculation included dieldrin, endosulfan, heptachlor, HCB, α-HCH, γ-HCH, pp'-DDE and PCBs (Σ7 congeners) and are reported in Table 4.32. The load of lindane was consistent with the use of this compound in the preceding years (1500 tonnes/year) but the DDE is reflecting the leaching of the existing environmental stock.

Table 4.32 **PTS inputs (in kg/year) of the Rhone River into the Mediterranean (1994-95)**

	HCB	α-HCH	γ-HCH	pp'-DDE	PCBs	Dieldrin
Dissolved	14	124	360	230	-	-
Particulate	157	23	21	51	304	33

Similar calculations performed in the Ebro River in early 90's gave values one order of magnitude lower, consistent with the difference in water inputs. In any case, the determination of river inputs requires an optimisation of the sampling strategy and statistical evaluation of data (modelling) due to the large variability of hydrologic regimes of the Mediterranean rivers.

As mentioned before, contaminated coastal sediments arise from freshwater discharges. However, beyond the zone of influence of these discharges, concentrations drop rapidly reflecting the enhanced sedimentation processes which take place at the freshwater-seawater interface. In fact, 80% of the terrestrial sediments are trapped on the continental shelf, and only the finest particles are transported by currents to deep sea sediments. Indeed, atmospheric transport may be the main route by which pollutants enter the open sea basin

- *Temporal trends*

Decreasing trends have generally been observed for persistent organochlorine insecticides (a-HCH, ß-HCH, lindane, aldrin, dieldrin, heptachlor, and heptachlorepoxide, o,p'-DDE, p,p'-DDE, o,p'-DDT, and p,p'-DDT) in surface streams during the 80's and 90's (UNEP, 2002).

In the Nile River waters (Egypt), for example, levels decreased by 100-200 fold in the period 1982-1993. Although this difference can be partially attributed to the accuracy in the analytical methods, a certain decline exists, despite a limited use of DDT in the country.

Accurate trends have been obtained for several chlorinated pesticides in French rivers. In Figure are shown the profiles exhibited by aldrin, DDT and lindane, from 1978 to 2000 in the seine River. The temporal trend clearly reflects the pattern of use of these compounds in the country.

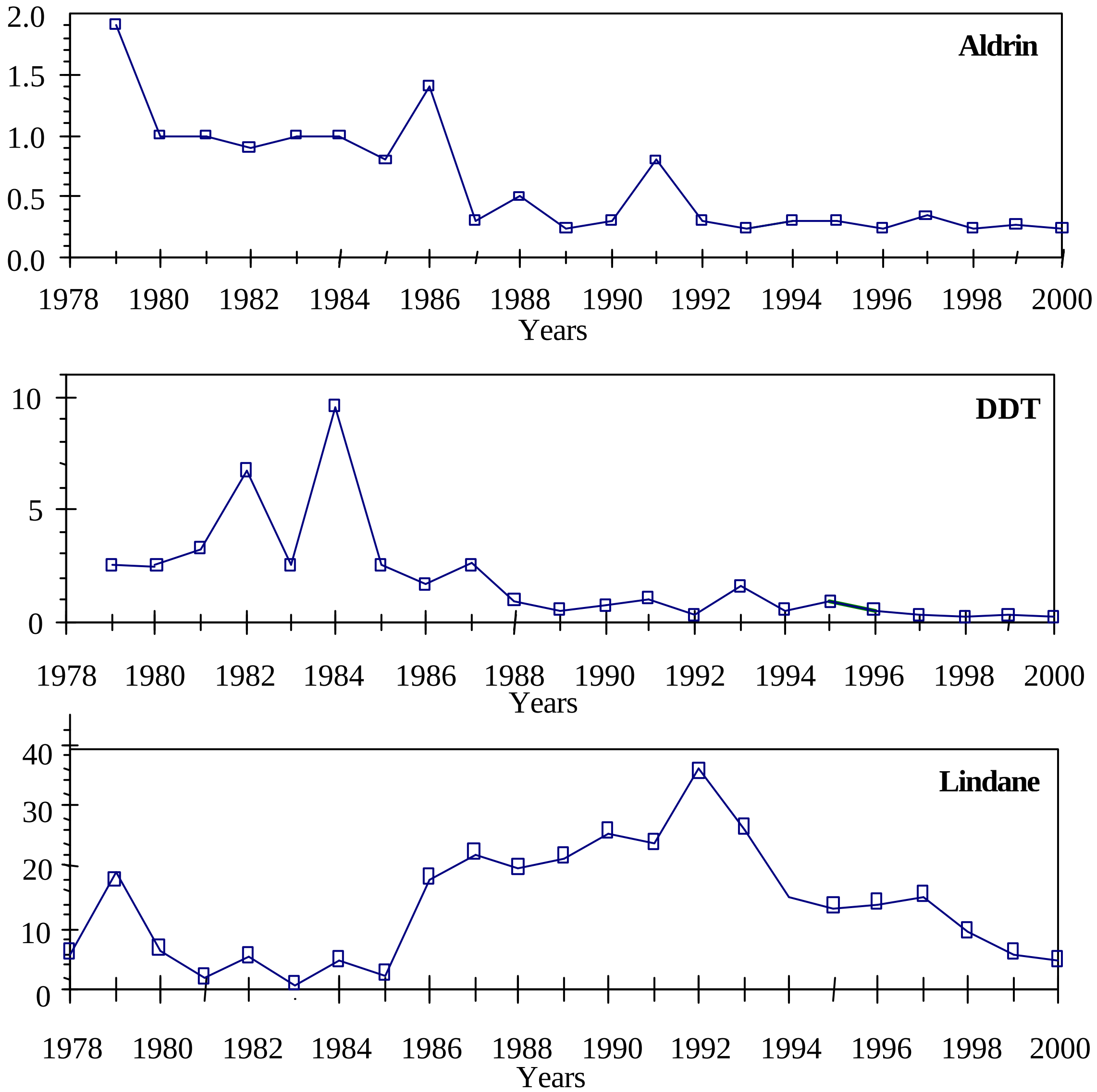


Figure 4.7 Temporal trends of concentrations (in ng/L) of some pesticides in the Seine river

o *Agriculture runoff*

- <u>*Agriculture runoff entering the Mediterranean*</u>

In the Mediterranean Basin, agricultural land is one of the resources where the pressures of development are the strongest (Table 4.33), particularly on a narrow coastal strip bordered by desertic regions on the Southern coast. Moreover, urbanization and infrastructures absorb an increasing part of arable land, and agricultural pressure is strong on ever more vulnerable soils. In the North Mediterranean highly yielding specialised monocultures have appeared, inducing gradual abandonment of marginal lands. In the Southern and Eastern Mediterranean, where demographic pressures are intense and constantly increasing, cultivated surfaces continue to progress at the expense of forests and grazing land, increasing the risk of soil degradation. In the North of the Basin, abandonment of terrace cultivation land, without reforestation or erosion control policies, as well as intensive agricultural cropping systems can have the same effect.

Non-point pollution from agriculture is related to that part of the Mediterranean Sea that drains into the Mediterranean Basin. The basins draining into the Mediterranean cover a total of about 1.9 million km^2 not counting the upper Nile basin and include 24 countries (UNEP/MAP, 1997a).

As the Mediterranean basin is receiving waters from the Black Sea there is also a remarkable effect of the Black Sea in the Eastern Mediterranean, mainly the Aegean Sea. The fluvial input of Black Sea into the Mediterranean sea is 210 km^3/year and 20 tonnes of pollutants per km^3 are carried through by the movements of the water masses. Eutrophication due to nitrogen and phosphorus has been attributed to different sources such as industry, agriculture and sewage. It is estimated that the contribution from nitrogen and phosphorus ranges from 25 to 40% for nitrogen and 10 to 20% for phosphorus.

Surface water eutrophication, one of the major impacts of continental runoff in coastal waters, is attributed to a combination of urban sewage (50%), industrial waste (25%) and 25 % agricultural activities (Rossi et al., 1992). Fertilisers can be disposed into the marine environment through the rivers or a non-point pollution. As agricultural activities, a number of farm practices are considered such as land use, irrigation, cultivation, pasturs, dairy farming and aquaculture. Water runoff resuspends sediment and carried into the marine environment nitrogen, phosphorus, metals, pathogens, salts and trace elements.

Flushing of fertilisers into the Mediterranean basin depends also on climatic conditions since there is a great variability in the Mediterranean climate, as discussed in section 3.1.

The distributions of nutrients and soils from the Mediterranean region is rather uneven along the 3000 km coast. The North African coastline is not exposed to nutrient inputs from agricultural sources as the rainfalls do not exceed 300mm per year as well as some areas in Italy, Greece and Turkey due to plain topography. The highest degree of nutrient transport is connected with soil erosion in agricultural regions.

Agriculture in the coastal zone has generally declined in the face of urbanization and farm industry. However, agriculture continuous at an intensive rate in inland parts of the countries and the amounts of fertilisers have been assessed.

Table 4.33 **Land use in the Mediterranean Region**
(Source: CIA World Factbook 1994)

Country	Arable	Permanent crops	Meadows pastures	Forests woodland	Others	Irrigated lands	Land area	Irrigated/ land area	AGR/GDP
	%	%	%	%	%	ha	ha	%	%
Albania	21	4	15	38	22	4230	27400	15.4	55
Algeria	3	0	13	2	82	3360	2381740	0.1	12.8
Bosnia Herzegovina	20	2	25	36	17	na	51233		9
Croatia	32	20	18	15	15	na	56538		na
Cyprus	40	7	10	18	25	350	9240	3.8	7
Egypt	3	2	0	0	95	25850	995450	2.6	20
France	32	2	23	27	16	11600	545630	2.1	4
Greece	23	8	40	20	9	11900	130800	9.1	15
Israel	17	5	40	6	32	2140	20330	10.5	7
Italy	32	10	17	22	19	31000	294020	10.5	4
Jordan	4	0.5	1	0.5	94	570	88884	0.6	10
Lebanon	21	9	1	8	61	860	10230	8.4	33
Libya	2	0	8	0	90	2420	1759540	0.1	5
Macedonia	5	5	20	30	40	na	24856		12
Morocco	18	1	28	12	41	12650	446300	2.8	14
Slovenia	10	2	20	45	23	na	20296		5
Spain	31	10	21	31	7	33600	499400	6.7	5
Syria	28	3	46	3	20	6700	184050	3.6	30
Tunisia	20	10	19	4	47	2750	155360	1.8	16
Turkey	30	4	12	26	28	22200	770760	2.9	16

- *Quantitative assessment of fertilisers*

The continuous use of fertilisers are a source of pollution not only for the aquifer but also for the marine environment. Ammonia nitrate, ammonium sulfate and urea are the common used fertilisers among the nitrogenous fertilisers. Hyperphosphate compounds and potassium phosphate are the most widely used phosphorus fertilisers. It is difficult to assess the consumption of fertilisers for the Mediterranean countries as data acquisition is rather difficult. Some data have been given in a previous report (UNEP, 1996). These data are shown in Table 4.34.

Table 4.34 **Consumption of fertilisers in Mediterranean countries**
(Source UNEP, 1996).

Country	Fertiliser consumption			
	T (10^3 t/yr)		Per cropping area (10^3 kg/ha/yr)	
	1968-1970	1988-1990	1968-1970	1988-1990
Albania	39	102	66.8	143.3
Algeria	83	138	12.2	18.2
Cyprus	26.0	22.2	163.6	142.5
Egypt	347	990	122.9	381.9
France	4300	5929	223.7	309.9
Greece	325	674	83.1	171.3
Israel	52	106	127.8	244.4
Italy	1243	1897	82.6	157.8
Lebanon	34	25	105.3	83.7
Libya	10	81	5.2	37.9
Malta	1	1	37.7	47.7
Morocco	93	315	12.5	34.8
Spain	1132	2041	55.0	100.3
Syria	33	278	5.7	49.9
Tunisia	34	96	7.7	20.8
Turkey	419	1766	15.4	63.4
Serbia and Montenegro	589	893	71.5	115.2

The countries of the Table 4.34 can be classified into three groups according to the fertiliser consumption. The highest consumption of fertilisers was observed in France, Italy and Spain, these countries having a consumption rate higher than 1 million tonnes per year. There is a second group of countries Egypt, Greece, Turkey and Serbia and Montenegro with fertiliser consumption varying between 0.5 and 1.0 million tonnes per year but also with a strong upward trend. The third group includes the remaining groups, that is Northern Africa and Middle East countries with annual consumption of fertilisers about 0.1-0.3 million tonnes per year. It is also important to notice that these countries have at least double the fertiliser consumption within two decades from 1970 to 1990.

On the contrary, consumption per cropping area shows intensified farming in Cyprus, Egypt, France, Israel and Lebanon during the period 1968-1970 with annual consumption more than 1 tonne per ha per year. The consumption of fertilisers per unit of cultivated area showed significant increase in 1990. The highest increase was observed in countries with very low consumption as Libya, Tunisia and Syria which is an indication of significant improvements in their farming practices.

EUROSTAT was a good source of data for the Mediterranean countries members of the European Union to trace the temporal trend in fertliser consumption. These countries are Spain, France, Italy and Greece; the consumption of fertilisers is given in Table 4.35. The consumption of fertilisers in the Mediterranean countries members of European Union showed an increase until 1980 and after that it was stabilised. France seemed to be first in consumption of fertilisers followed by Italy; Greece and Spain showed the lowest consumption. The consumption of nitrogen fertilisers is also given in Table 4.35. The trend is similar to the one observed for the global data. Spain showed a steady increase whereas, France, Italy and Greece showed more or less a steady pattern of fertiliser consumption during the last decade.

The consumption of phosphorus fertilisers in EU followed a downward trend Italy and there was a steady state for the other three countries as a result of application of composite fertilisers.

The consumption of fertilisers per unit area is rather low. The prevailing climatic conditions that is the limited rainfalls during the growth period do not favor nutrient runoff into the sea.

Table 4.35 **Consumption of fertilisers in European countries (kg/acre)**

Country	**Year**		
	1970	1980	1990
Spain	15.58	21.73	26.65
France	58.63	72.57	76.26
Italy	27.06	49.2	47.56
Greece	15.17	23.37	30.75
Average	29.11	41.72	45.31
Nitrogen fertilisers			
Spain	7.38	11.89	14.35
France	18.45	27.88	33.21
Italy	11.89	23.37	21.32
Greece	9.02	14.76	19.37
Average	11.69	19.48	22.06
Phosphorus fertilisers			
Spain	5.33	6.15	7.38
France	22.96	22.96	18.04
Italy	10.66	17.63	15.58
Greece	5.33	6.97	8.2
Average	11.07	13.43	12.25

Source: EUROSTAT (1995) Europe's Environment Statistical Compendium for the Dobris assessment

- *The MED POL programme*

The MED POL programme played over the last 30 years an important role in assessing the inputs of nutrients to the Mediterranean. A data base (UNEP, 2001) was organised during the MED POL phase II and nutrient values are available for a number of Mediterranean countries. In the present report seven thematic maps are given on nutrient and chlorophyll concentration in the Mediterranean. Station locations are shown in Figure 4.8. Ammonia concentrations (Figure 4.9), nitrite concentrations (Figure 4.10), nitrate concentrations (Figure 4.11), phosphate concentrations (Figure 4.12) and total phosphorus concentrations (Figure 4.13) are given.

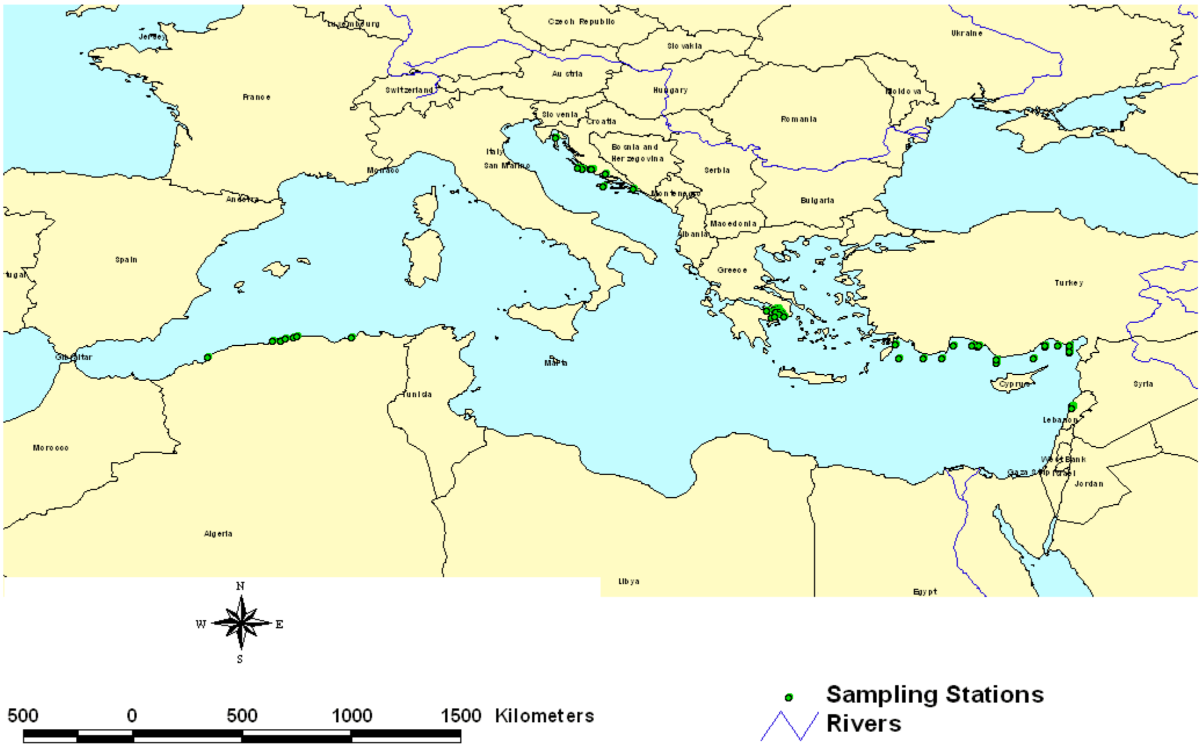


Figure 4.8 Station locations for nutrients in the Mediterranean for the MED POL programme

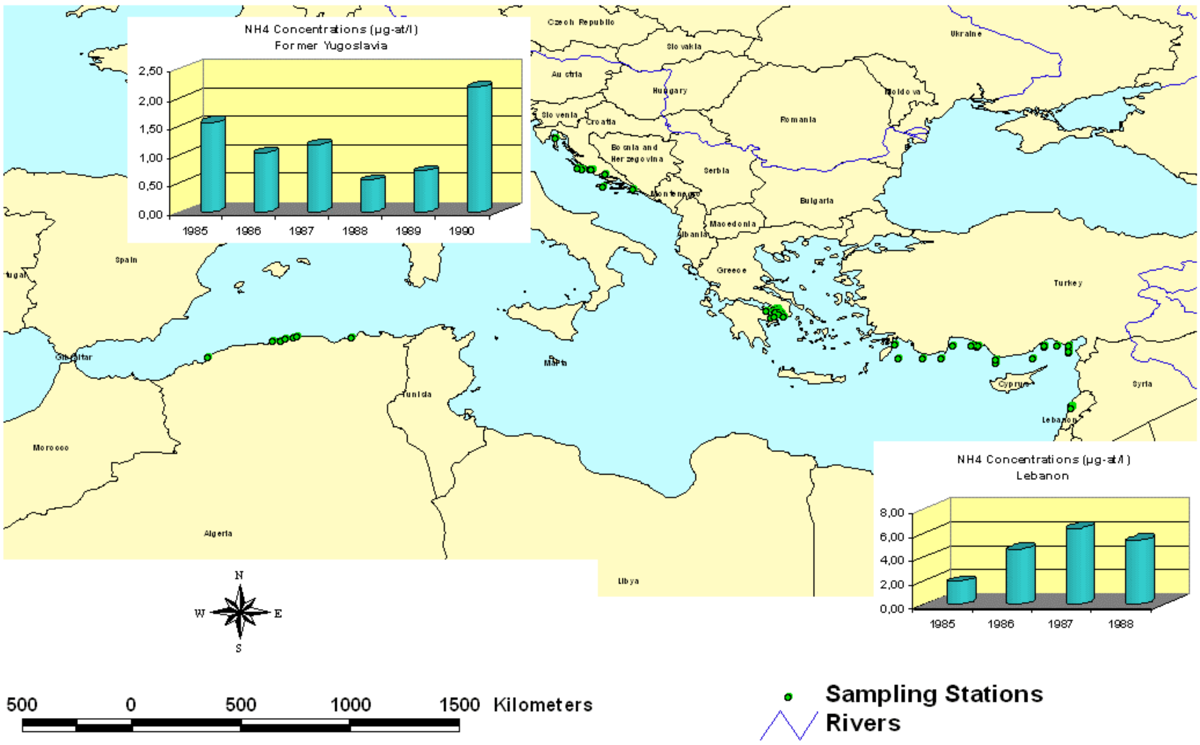


Figure 4.9 Station locations for ammonia in the Mediterranean for the MED POL programme

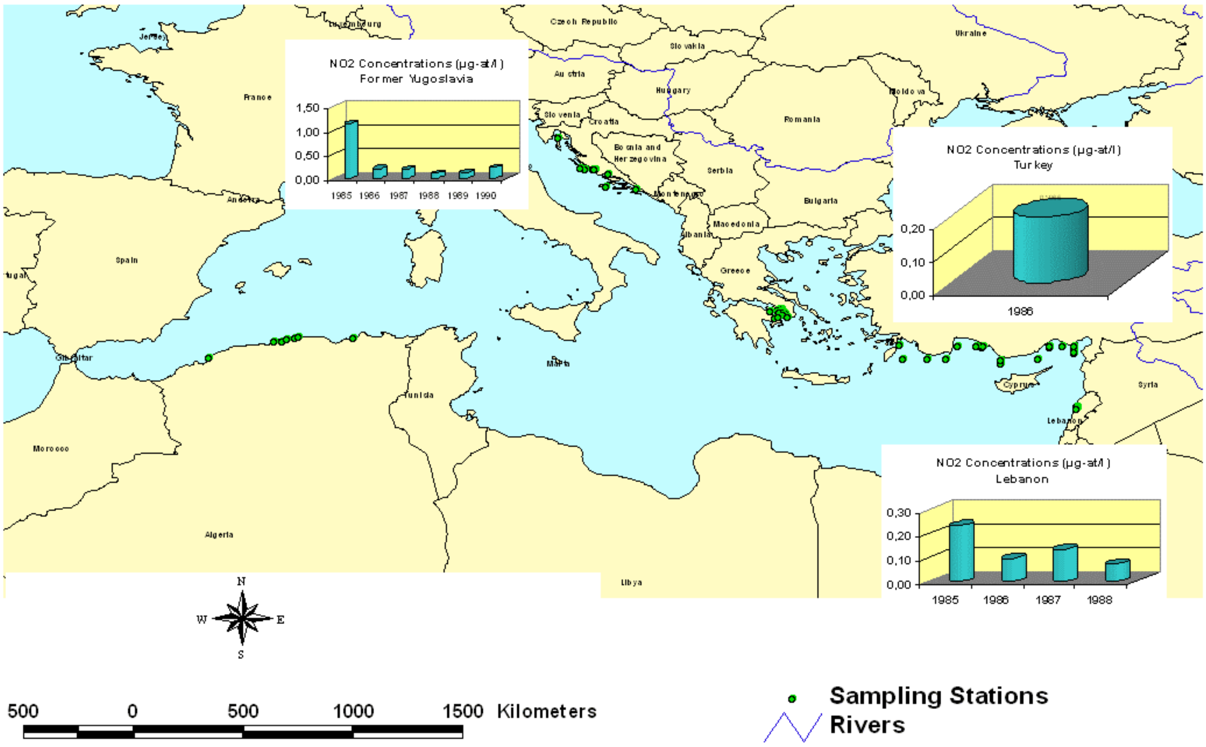


Figure 4.10 Station locations for nitrite in the Mediterranean for the MED POL programme

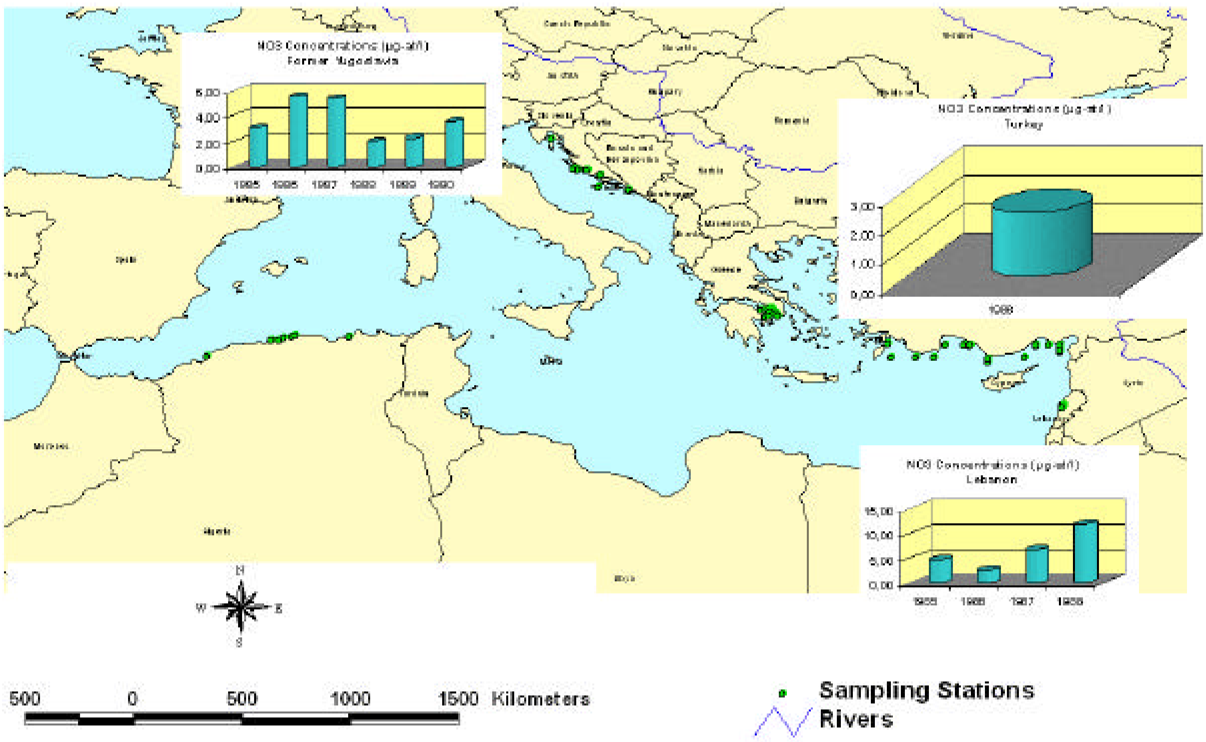


***Figure 4.11** Station locations for nitrate in the Mediterranean for the MED POL programme*

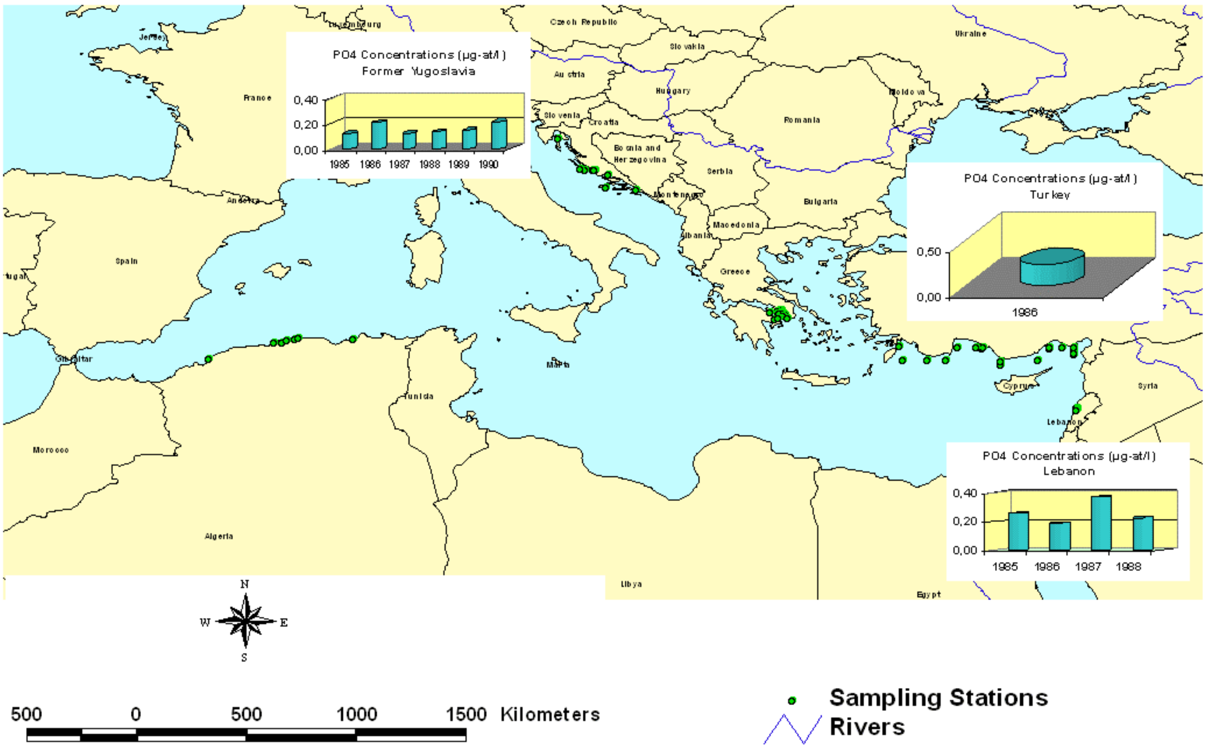


Figure 4.12 Station locations for phosphorus in the Mediterranean for the MED POL programme

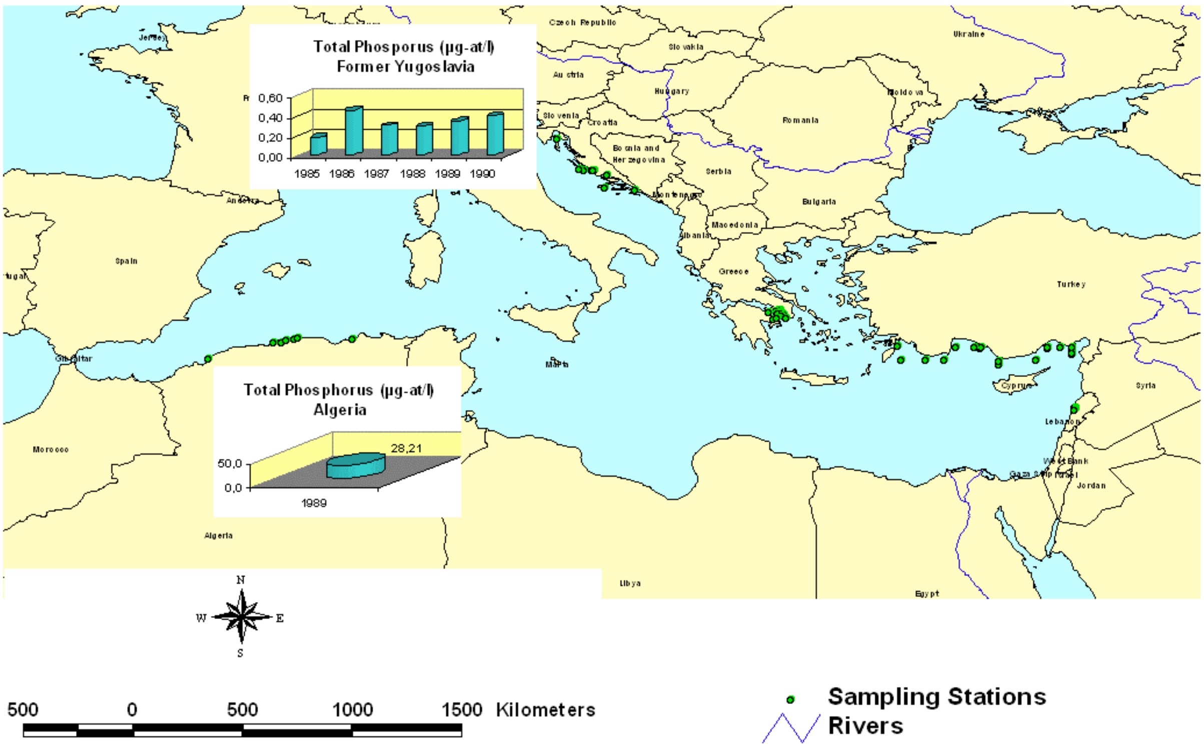


Figure 4.13 Station locations for total phosphorus in the Mediterranean for the MED POL programme

A summary of the agricultural discharges to the Mediterranean Sea is shown in Table 4.36.

Table 4.36 **Discharge to Mediterranean from agricultural land**

Country	Area	Soil	P 10^3 t			N 10^3 t			Org C 10^3 t			Soil t ha^{-1}			P kg ha^{-1}			N kg ha^{-1}			Org. C kg ha^{-1}			Erosion		
	Km2	106 t	Tot	Max	Min	Tot	Mx	Mn	Tot	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Av	Mx	Mn
Albania	30400	6.8	3.7	1.4	0.08	6.7	2.5	0.2	74.1	23.0	2.3	2.24	5.93	0.74	1.22	5.32	0.28	2.21	9.21	0.61	24.4	70.4	8.5	I	I	I
Algeria	99100	55.8	15.9	4.8	0.23	41.4	5.8	0.8	387.6	58.8	4.8	5.63	40.7	1.55	1.61	18.4	0.27	4.18	22.3	0.95	39.1	106.	5.3	I	II	I
Cyprus	9100	14.1	6.9	3.4	0.15	20.3	9.0	0.6	161.1	90.8	6.1	15.4	23.7	2.40	7.55	11.3	1.19	22.2	30.0	8.71	177.	302.	39.9	II	II	I
France	26800	10.8	7.5	2.0	0.29	19.2	6.7	0.4	240.0	84.0	10.0	4.03	14.3	1.00	2.81	7.11	0.70	7.16	20.9	1.00	89.6	262.	23.8	I	II	I
Corsica	7600	22.9	15.3	8.2	0.70	26.9	14.	1.5	269.0	142.0	15.0	30.1	57.1	6.84	20.1	39.0	3.68	35.3	67.6	7.89	353.	676.	78.9	II	III	I
Rhone	95600	4.5	2.8			5.6			56.0			0.47			0.29			0.59			5.9			I		
T.France	13000	38.2	25.6			51.7			565.0			2.94			1.97			3.98			43.5			I		
Greece	98000	183.3	129.	16.8	0.6	240.	34.	1.5	2205.	331.0	14.3	18.7	55.0	3.09	13.2	42.0	0.72	24.4	86.5	3.95	225.	827.	26.3	II	III	I
Crete	8100	24.2	16.7	6.2	3.0	28.7	1.5	5.2	287.0	105.0	52.0	29.8	50.0	22.8	20.6	34.4	15.9	35.4	60.0	26.9	354.	600.	269.	II	II	II
T.Greece	10610	207.5	146.			268.			2492.			19.5			13.8			25.3			234.			II		
Israel	10300	3.8	1.3	0.4	0.11	3.2	1.1	0.5	33.0	11.6	4.6	3.69	8.12	2.68	1.26	2.79	0.63	3.10	6.75	1.62	32.1	72.4	16.0	I	I	I
Italy pen.	15630	226.1	170.	29.2	0.30	325.	46.	0.8	3557.	367.0	8.0	14.4	59.2	2.67	10.9	58.4	2.00	20.8	93.4	4.30	227.	951.	43.7	II	III	I
Po	70000	12.0	14.0			21.0			210.0			1.71			2.00			3.00			30.0			I		
Sardinia	20700	61.8	64.7	22.0	4.4	105.	34.	7.5	1041.	360.0	75.6	29.8	45.0	15.0	31.2	61.1	17.0	50.7	95.2	21.5	503.	1000	251.	II	II	II
Sicily	32300	110.1	92.7	31.0	0.8	167.	55.	2.1	1765.	546.0	21.0	34.0	44.9	7.04	28.6	80.0	4.44	51.9	90.0	13.3	546.	1000	125.	II	II	I
T.Italy	27930	410.0	341.			619.			6574.			14.6			12.2			22.1			235.			II		
Lebanon	7800	25.7	6.5	4.8	1.7	17.4	14.	3.0	196.4	165.7	30.7	32.9	49.7	6.00	8.33	10.0	5.67	22.3	30.0	10.0	251.	345.	102.	II	II	I
Morocco	62800	43.7	9.1	4.3	0.24	29.7	15.	0.8	502.0	285.0	8.8	6.96	51.9	1.75	1.45	10.2	0.37	4.72	36.4	0.95	79.9	678.	13.5	I	III	I
Spain	18030	116.1	103.	51.6	0.45	177.	86.	0.9	1801.	932.0	8.2	6.44	37.7	2.09	5.72	27.7	2.07	9.84	47.7	3.00	99.9	237.	36.8	I	II	I
Syria	5700	34	14.8			27.4			267.9			59.6			26.0			48.0			470.			III		
Tunisia	34400	54.9	28.7	15.5	0.9	56.5	31.	2.3	571.0	314.1	30.0	15.9	56.1	9.71	8.34	28.4	4.09	16.4	52.3	10.4	166.	521.	130.	II	III	I
Turkey	15370	296.9	129.	31.0	2.6	250.	55.	4.7	3315.	780.0	40.0	19.3	52.6	8.89	8.39	23.3	3.88	16.3	53.3	5.92	215.	766.	59.7	II	III	I
Serbia/Montenegro	49900	43.9	30.9	13.0	0.76	72.0	26.0	3.0	723.5	214.0	21.5	8.80	45.45	1.88	6.20	39.39	1.58	14.44	78.79	5.52	145.0	648.5	44.8	I	II	I

▪ <u>*Impact of agricultural runoffs in the marine environment*</u>

- *The problem of eutrophication*

Eutrophication has been a problem along the coastal areas of Mediterranean, bays, gulfs and estuaries. The growth of human population along the coastal zone and the increase of agricultural production through the use of fertilisers have made the problem more acute in recent years (Gray, 1992). Eutrophication varies in severity and therefore in symptoms concerning negative effects on the marine ecosystem. A summary is shown in Table 4.37.

The impact of the initial phase (nutrient enrichment) is limited to enhanced growth of different species. The initial effects are referred to changes in species composition of the marine community. Further algal growth, results (secondary effects) into the shading of sea bottom, development of toxic algae and effects on zooplankton fish behaviour. Further development of algal biomass causes species mortality and toxicity on other groups of organisms. Growth of seaweeds such as *Ulva* and *Cladophora* are usual. The ultimate effects are the establishment of anoxic conditions allowing growth only to some anaerobic bacteria (methane and hydrogen sulphide production).

Table 4.37 **Effects of eutrophication on the marine ecosystem**
(Gray, 1992)

Phase of eutrophication	Impact of eutrophication			
Enrichment phase	Macroalgae growth	Phytoplankton Growth	Benthos Growth	Fish Growth
Initial effect	Changed species composition			
Secondary effect	Shading Depth reduction	Toxic/nuisance Blooms	Behavioural Effects	
Extreme effects	Mass gowth of Macroalgae	Toxic effects	Mortality of species	
Ultimate effect	Anaerobic conditions and mass death			

These phases are quantified according to a simple classification system based either on prediction variables such as nitrogen and phosphorus concentrations or response variables (chlorophyll, phytoplankton) or even combination of them if eutrophication assessment is attempted at a multivariate level. Depending on the nutrient / chlorophyll load the marine waters are classified into oligotrophic, mesotrophic and eutrophic water types. Two additional classes can also be considered; the ultra oligotrophic and the hypertrophic waters.

Reviews on eutrophication of the Mediterranean (UNEP/FAO/WHO 1996) support the view that Mediterranean will be seriously threatened by eutrophication over the next few decades; the oligotrophic character of the sea may also be pronounced if scenarios on climatic changes will be proved to be true (Sestini, 1998).

The oligotrophic character of the Mediterranean is the result of lower nutrient inputs into the basin compared to the outputs. The outflow/ inflow ratio is approximately 3 (5.7:1.9). Terrestrial inputs account for 29% of the inflowing water the remaining 71% is attributed to surface water inflow.

Different views have been proposed by Bethoux et al. (1992). They maintain that terrestrial and atmospheric inputs are more significant and they have found an increase in nutrient budgets in the deep sea of the western basin. Higher deep sea nutrient concentrations have also been found in the sea of Crete over the last ten years have also been found by Souvermezoglou et al. (1996). This is only indicative of the mechanisms involved in nutrient distributions since the effects of eutrophication in the deep Mediterranean waters is negligible as there is no light or upwelling that would enrich surface waters.

There is a long going debate as concerning the limiting nutrient. Early work (Berland et al., 1987) has supported the view that Mediterranean is different from most other ocean basins in that P seems to play a more important role in phytoplankton. More recent work (Krom et al., 1991) based on experiments carried out in the southeastern Mediterranean suggest that the area is strongly phosphorus limited, The degree of P limitation increases from west to east across the entire basin. Similar views have been expressed by Mingazzini et al. (1992) for the Emilia-Romana area of Adriatic.

- *Eutrophication in coastal areas*

In spite of the oligotrophic character of the Mediterranean, eutrophication seems to be a problem in many coastal areas and sometimes severe eutrophication events occur. This is the problem with enclosed coastal areas, estuaries, coastal areas with urban development and areas with intense agricultural activities.

The sites in the Mediterranean coastal areas with eutrophication problems have been identified and they are given in Figure 4.1. It must be noticed that for the north African and eastern Mediterranean coastal zone area, data are not available. In addition, it has to be emphasised that most of the designated areas are connected with industrial and urban activites. Furthermore, it is difficult to discriminate between phosphorus and nitrogen derived from agricultural runoffs on nutrients derived from discharges of domestic and industrial wastewaters. However, an attempt to calculate the nutrient load to the Mediterranean Sea from agriculture and aquaculture (in tonnes/year) has been attempted (EEA, 1999). The data are given in Table 4.38

Table 4.38 **Nutrient load to the Mediterranean Sea from agriculture and aquaculture in tonnes/year.**

Source: UNEP (2001).

Activity	**P**	**N**	**C**	**BOD**	**COD**
Agriculture	976000	1570600	16941000		
Domestic and Industrial	75234	259691		804244	1729853
Aquaculture	394	8678	38225		

Chlorophyll variations over a period of 6 years based on satellite imagery from CZCS is given in Figure 4.2. It is obvious that the chlorophyll distributions that the eastern Mediterranean is more oligotrophic than the western basin. The highest concentrations have been observed in coastal areas and especially in areas near river deltas, estuaries, urban and industrial areas. It must be noticed that although the northern shores are affected, there are also eutrophic areas in the south which are not illustrated in Figure 4.1 due to lack of data. These eutrophication problems can have serious impacts not only on marine life but they can also have serious impact on socio-economic effects and impact on tourism, aquaculture, fisheries and recreation. Similar patterns concerning spatial distribution of primary production in the Mediterranean are given in Figure 4.3. Coastal eutrophication is also observed in the Tunisian coasts and the delta area of Nile River.

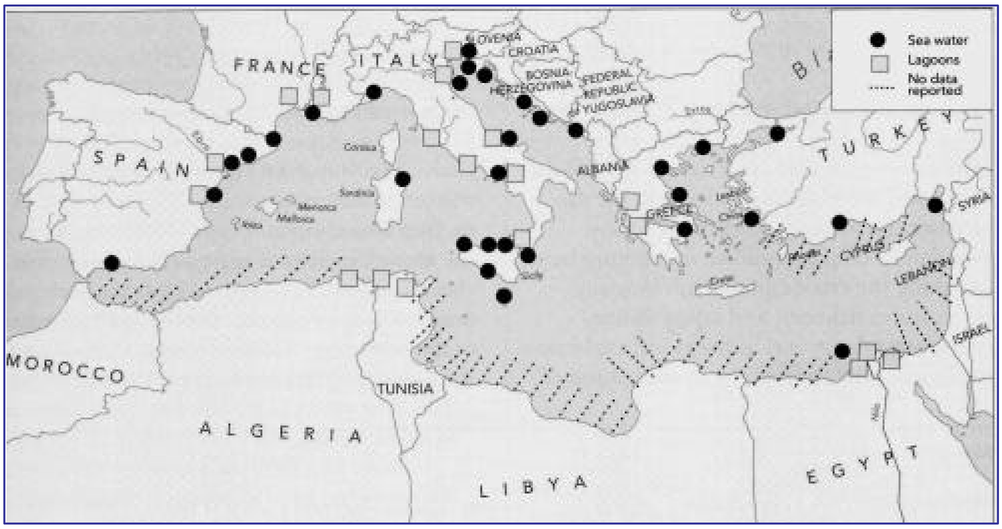


Figure 4.14 Mediterranean areas where eutrophication phenomena were reported
Source UNEP/EEA/1999

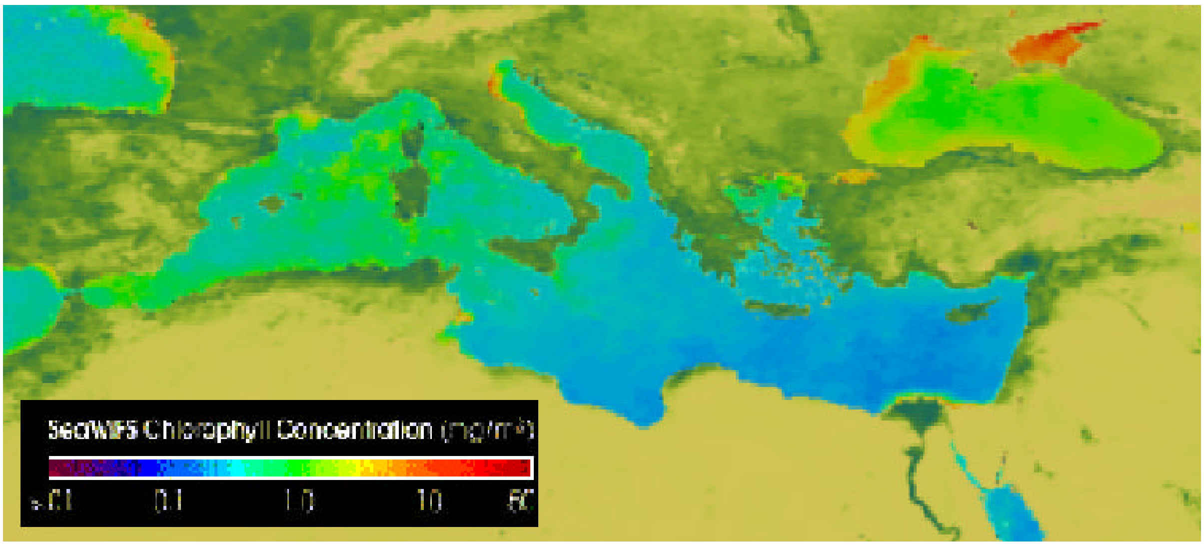


Figure 4.15 Chlorophyll distribution in the Mediterranean Sea
Chlorophyll a content has been estimated from SeaWifs satellite images over the period 1998-2000.

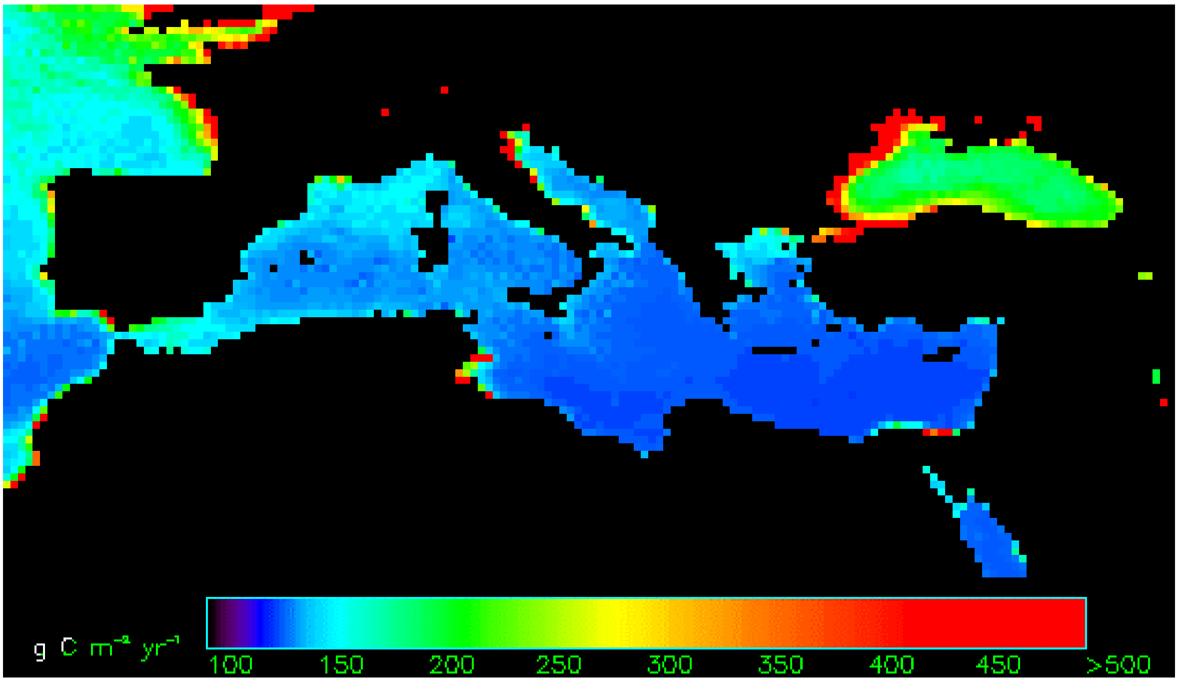


Figure 4.16 Distribution of primary productivity in the Mediterranean Sea
MODIS Ocean Primary Productivity: Data Products and Services K.R. Turpie and W.E. Esaias, AGU Spring Meeting: Tools and Systems for EOS Data, Boston, MA, May 29, 2001 http://opp.gsfc.nasa.gov/

In addition, to the adverse effects on the marine ecosystem caused by high nutrient and chlorophyll concentrations there are also adverse effects caused by algal blooms. Table 4.39 provides information on algal blooms recorded in Mediterranean. Toxins identified and dominant species involved in the algal blooms are also provided.

Table 4.39 **-Algal blooms and serious eutrophication incidents reported in Mediterranean countries**
Source: UNEP (1999)

Countries		**Hypoxia/ Anoxia**	**Algal Blooms and other effects**	**Dominant species**	**Cell number (cells/L)**
Croatia		Yes	AB, red tides, fish and bottom fauna mortality	7,12,15,28,31, 34,41,42,53	
Egypt	Costal waters and ports	Yes	AB, water discoloration, HS	17	
	Lagoons in the Nile Delta	Yes	AB, water discoloration, HS		
Greece	Saronikos Gulf	Yes	AB, water discoloration, fish mortality	7,11,16,32,34 46,55	$3x10^5$ – $6x10^7$
	Gulf of Thermaikos	Yes	AB, water discoloration, fish mortality	1,3,8,10,12 14,15,16,39 41,42	$1\text{-}7.5x10^7$
	Other Aegean Gulfs and bays	No	AB, water discoloration	5,6,11,20,28 33	$12x10^6$-10^7
France	Western Zone	Yes	AB,	24,30,34,35 42,54	
	Eastern Zone	Yes	AB, DSP, PSP	24,30,34,35	

				42,54	
Italy	Tyrrhenian Sea, Lagoons	Yes	AB, PSF, fish mortality, mucus	33	$6x10^6$
	Gulf of Naples	?	AB	2, 9, 15, 48	$3.5-112x10^6$
	Sardinia	Yes	AB, fish & molluscs mortality	13, 14	
	Sicily	Yes	AB, DSP, fish mortality	23, 24, 49	
	Ionian Sea	?	AB	52	
	Southern and Central Adriatic	Yes	AB, putrefaction, bottom fauna mortality	34, 37, 52	
	Emilia-Romana	Yes	AB, DSP, PSP, fish and bottom fauna mortality, mucilage, poor transparency, smell	4, 11, 15, 16, 18, 24, 25, 26, 27, 28, 34, 36, 41, 44, 45, 46, 52, 53	$1-230x10^6$
	Gulf of Venice	Yes	AB, HS, hypertrophy	4, 9, 13, 14, 15, Ulva	$36x10^6$
	Gulf of Trieste	Yes	AB, bottom fauna, mortality	28, 38, 40, 46, 53	$5-7x10^6$
Spain	Alboran Sea		AB, PSP, toxins	33, 53	$>3x10^3$
	East Coast & Balearics		AB, PSP, toxins	4, 16, 17, 21, 33	$7.2x10^6-2.8x10^7$
	Lagoons, Bays Estuaries	Yes	AB	52, Ulva	$10-2x10^6$
Tunisia	Lagoon of Ichkeul		AB		
Turkey	Western Coasts	Yes	AB, bottom fauna mortality, PSP	17, 28, 29	

AB: Algal Blooms; PSP: Paralytic Shellfish Poisoning; DSP: Diarrheic Shellfish Poisoning; the numbers of the dominant species refer to the Table below (Annex)

Table 4.40 **Algal species reported to cause algal blooms in Mediterranean Waters**

A. Microalgae		
Diatoms		
1. Cerataulina bergoni	7. Leptocylindrus ssp.	13. Rhizosolenia firma
2. Chaetoceros sp.	8. L. minimus	14. Rh. fragilissima
3. Ch. socialis	9. L. danicus	15. Skeletonema costatum
4. Ch. simplex	10. Nitzschia closterium	16. Thalassiosira sp.
5. Cyclotella sp.	11. N. delicatissima	
6. Cyclotella subtilis	12. N. seriata	
Dinoflagellates		
17. Alexandrium minutum	27. G. quadridens	37. Peridinium depressum
18. A. tamarensis	28. Gonyaulax sp.	38. P. ovum
19. Amphidinium curvatum	29. G. spinifera	39. Prorocentrum dentatum
20. Cachonina niei	30. G. polyedra	40. P. lima
21. Chattonella subsalsa	31. Gymnodinium sp.	41. P. micans
22. Dinophysis acuminata	32. G. aureolum	42. P. minutum
23. Dinophysis ssp.	33. G. adriaticum	43. P. scutellum
24. D. sacculus	34. G. breve	44. P. triestinum
25. Glenodinium foliaceum	35. G. catenatum	45. Protogonyaulax tamarensis
26. G. lenticula	36. Katodinium rotundatum	46. Scrippsiella trochoidea

Coccolithophores		
47. Coccolithus pelagicus	48. Emiliania huxlei	
Other flagellates		
49. Chlamydomonadacae	52. microflagellates	55. Pyramimonas sp.
50.Cryptomonas sp.	53. Noctiluca miliaris	56. Spirulina jenneri
51. Cyanobacteria	54. N. scintillans	
B. Macroalgae		
57. Ulva sp.		

- *Effects of nutrient runoff on fishery production in the Mediterranean*

Early studies in biological oceanography established the low biological productivity of Mediterranean waters compared with oceanic areas elsewhere, and up to the 70's fisheries production figures per shelf area were also much lower than the world's average. Evidence has been accumulating for the Mediterranean (Caddy *et al*, 1995), and for semi-enclosed seas elsewhere (Caddy, 1993), that fisheries production in inland seas has been showing a steady rise, even after fish stock assessments have shown that the key stocks are fully exploited. This phenomenon has been tied to runoff of nutrients from catchment basins; and in particular for the Mediterranean, predominantly due to the influence of the rivers Rhone, Po, Ebro, and for the Aegean, to nutrient rich outflow of water from the Marmara Sea. In the case of the Nile, the opposing effect has demonstrated the rule, through a significant decline in sardine landings following construction of the Aswan Dam, and more recently a recovery of production around the Nile Delta and associated lagoons, due to increased inputs of domestic wastes and fertilizers. In the Black Sea, a previous GEF-sponsored Transboundary Analysis summarised evidence for the impact of nutrient runoff, in causing progressive anoxia of shelf bottom waters, especially in the NW Shelf under influence of the Danube and Russian rivers to the north. Episodes of anoxia in the Northern Adriatic have led to localized fish kills, and illustrate that under certain conditions, high oxygen demand due to high nutrient inputs from the River Po, if not diffused, may cause summer kills, suggesting that in this area at least, we may expect further increases in nutrient inputs to lead to declines in production, as has also happened for demersal fish in the Baltic sea.

Evidently, fishery production is positively influenced, like other biological production, by moderate levels of nutrient inputs, even if these inputs can also lead to negative and noxious effects close to the coast, such as harmful algae blooms, and health and aesthetic impacts, which are of particular concern to tourism and aquaculture, and are likely to damage critical habitats and have effects on biodiversity.

It nonetheless emerges from an objective analysis of GFCM fishery statistics that fishery production per shelf area, especially in the Northern Mediterranean, which is under the predominant influence of incoming rivers, has been increasing. Evidently there is a risk, especially for the high value demersal fish and invertebrates, that in semi-enclosed basins, estuaries and lagoons an excessive level of nutrient runoff will lead to drops in demersal and benthic commercial production, with extremely serious consequences. Judging from experience in the Black Sea, the impact of high nutrient inputs on pelagic fish is not negative, unless eutrophication allows jelly predators such as ctenophores to dominate the pelagic ecosystem, as occurred there, with drastic consequences on the anchovy fishery.

Although it is not possible to separate quantitatively the effects of fishing and of eutrophication on marine fisheries in the Mediterranean, it seems likely that a significant proportion of yield increases since the 70's, especially in the Northern Mediterranean, are due to nutrient inputs, since evaluations performed since the mid 1970's suggested that we were close to, or at, Maximum Sustainable Yield (MSY), especially for the demersal fish.

The first conclusion therefore is that it would be misleading to consider nutrient runoff as a purely negative phenomenon from the perspective of fisheries, even though this impact is certainly negative for some other sectors. The focus should probably be on placing upper limits to nutrient runoff, and focusing elsewhere in this diagnosis more particularly on severely reducing non-biodegradable and toxic waste discharges, pesticides, organotin residues and other toxic by-products of industry and agriculture.

As noted, an exact quantification of nutrient impacts is not possible, but it may be concluded from existing fisheries statistics which show a plateau of landings, that current levels of nutrification have reached or recently exceeded optimal levels in the Adriatic and Gulf of Lions. We are probably approaching these optima also for the Aegean and directly off shore from the Nile Delta. Judging from satellite imagery of ocean colour, other areas such as the Levant and much of the southern Mediterranean, can still be considered strongly nutrient limited, and may show further increases in fishery yield if coastal runoff of domestic and agricultural nutrients continue. Over the long term, given the long period (quoted as of the order of 80 years), of nutrient accumulation and recycling of land runoff is likely to complete the conversion of the northern Mediterranean from an oligotrophic system to a eutrophic one some time in the 21st century. The implications of this obviously go beyond issues related to fishery production, and are not dealt with further here.

- *Pesticides*

Pesticides in agriculture are used for pest control (insecticides), as weed killers (herbicides) as well as for fungal diseases. This is why the intensive use of these compounds is a threat to groundwater, surface water, ecosystem stability and human health.

Organochlorines accumulate in fatty tissues and their presence in seafood is a risk for carcinogenesis, PCBs inhibit plant growth. They also affect invertebrates and the young stages of fishes. The thinning of the egg shells of seabirds is also another symptom of organochlorines on marine organisms.

DDT has significant effects on invertebrates. It can also affect the mortality rate in fish eggs and cause premature pupping in seals. It may also affect species composition in phytoplankton community. Phytoplankton photosynthesis has also been affected by thiazines. On the contrary the effects of herbicides and organophosphorus compounds on marine organisms seem to be negligible.

Part of the pesticides applied in aquaculture find their way into the Mediterranean through the atmosphere and the river water. The amounts of pesticides used in Mediterranean countries are given in Table 4.40.

Table 4.41 **Active ingredients of pesticides applied in agriculture in Mediterranean countries**
(Source: UNEP, 1999)

Country	Tonnes (year)	Country	Tonnes (year)
France	36000 (1990)	Italy	33000 (1987)
Spain	23700 (1989)	Greece	8080 (1989)
Algeria	5950 (1993)	Egypt	13200 (1990)
Turkey	34400 (1989)	Morocco	9400 (1989)
Serbia and Montenegro	3300 (1992)		

It is observed that the largest amounts of pesticides were recorded in the north western part of Mediterranean. In addition to the non-point pollution of the Mediterranean used in agriculture there is also a number of point sources: River Rhone in France, River Ebro in Spain, River Po in Italy, River Nile in Egypt and rivers Axios, Loudias and Aliakmon in Greece that have been discussed in detail in section 4.2.7.

A third source of pesticide pollution is the aerial transportation of these compounds. Volatilisation and wet/dry deposition may also contribute to contamination of rivers.

- ***Fishery and mariculture***

  - *Fishery*

    - *Main characteristics of the Mediterranean fishery*

The extent of international waters in the Mediterreanean makes it inevitable and essential to address fisheries on an international level, at least in the field of highly migratory stocks. This task is complex in the Mediterranean as there are a high number of riparian states of varying stages of development in the management of fisheries. Future progress in terms of fisheries management however will be based on the ability to build a multilateral dimension into national practices.

Although fishing on international waters is the exception rather than the rule in the Mediterranean, the perception of shared stocks and fisheries has been advancing rapidly. This is due both to clearer scientific opinions and to the development of new fisheries extending their operative ranges outside national waters. The number of shared fisheries has increased in several areas like the Alboran Sea, the Gulf of Lions, the Northern Tyrrhenian Sea, the Adriatic Sea, the Ionian Sea, the Aegean Sea, the Sicily Strait and the Gulf of Gabes. In addition to the highly migratory species, that can be found in the whole Mediterranean basin, a minimum list of shared stocks has been agreed both within the GFCM framework and FAO subregional programs. The list might be expanded in the future while a sample of shared fishery resources is shown in Table 4.41. However, the number of shared fisheries identified already at this stage justifies common action to be taken for those stocks at international level.

According to FAO a temporary slump in 80's Mediterranean fish landings gave way to recovery and in the 90's fish production picked up by more than 30 per cent. However, recovery in catchings masks the underlying problem of long term depletion in Mediterranean marine catches. In fact, most of the Mediterranean fishery resources, being demersal, small pelagic or highly migratory species, have long been considered over-exploited.

In regard to highly migratory species, the eastern bluefin tuna stock has been assessed in the past by the International Commission for the Conservation of Atlantic Tunas (ICCAT), which has indicated heavy over-exploitation. Although the thoroughness of these evaluations is arguable due to considerable uncertainties resulting from the lack of data, there is little doubt that the stock is over-exploited. The level of bluefin tuna being caught and put in cages in the Mediterranean area for rearing purposes and often outside a framework of regulated and reported catches, is also a source of concern. This fishing activity is believed to increase the pressure on the stocks.

Similar considerations on over-exploitation apply to swordfish in the Mediterranean where there is evidence of an exploitation pattern, which results in large quantities of juveniles and recruits of the year present in the catches. Major efforts in data collection are required to get a clear picture of the status of the key stocks, although indications based on current data paint an extremely negative picture.

Catch statistics on demersal and small pelagic species show a negative trend in the 90's for the most important species or groups of species. Daily catch rates per vessel have fallen dramatically when compared to catch rates of some decades ago despite the fact that power and efficiency of fishing vessels has increased in recent times. Also the catch quality, both in terms of species and size composition have been changing over time. Long life-span species and bigger size specimens have practically disappeared from demersal catches in several areas and fisheries.

The current evaluations of demersal, small and large pelagic fisheries, carried out within the GFCM and ICCAT frameworks confirm this picture of over-exploitation of several resources and highlight the need to reduce the mortality on juveniles as well as the overall fishing effort by about 15-30 per cent for those fisheries focused on over-exploited stocks.

Table 4.42 **Some shared stocks and fisheries in the Mediterranean**

Common and scientific name	**Areas**	**Countries sharing the resource**
Albacore, *Thunnus alalunga*	All Mediterranean	Several countries
Anchovy, *Engraulis encrasicholus*	Adriatic Gulf of Lions Aegean Sea	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Gulf of Lions: Spain, France Aegean Sea: Greece, Turkey
Blackspot seabream, *Pagellus bogaraveo*	Alboran Sea	Spain, Morocco
Bluefin Tuna, *Thunnus thynnus*	All Mediterranean	Several countries
Blue whiting, *Micromesistous poutassou*	Adriatic	Albania, Croatia, Serbia and Montenegro, Italy, Slovenia
Common Pandora, *Pagellus erythrius*	Tyrrhenian, Corsican and Sardinian Seas Adriatic	Tyrrhenian, Corsican and Sardinian Seas: France, Italy Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia
Common spiny lobster, *Palinurus elephas*	Tyrrhenian Corsican and Sardinian seas	France, Italy
Deepwater rose shrimp, *Parapenaeus longirostris*	Adriatic Strait of Sicily	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Strait of Sicily: Italy, Libya, Malta, Tunisia
Dolphinfish, *Coryphaena* spp	All Mediterranean	Several Countries
Eel, *Anguilla anguilla*	All Mediterranean	Several Countries
European hake, *Merluccius merluccius*	Adriatic Aegean Sea Gulf of Lions Strait of Sicily Tyrrhenian, Corsican and Sardinian Seas	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Gulf of Lions: Spain, France Aegean Sea: Greece, Turkey Strait of Sicily: Italy, Libya, Malta, Tunisia Tyrrhenian, Corsican and Sardinian Seas: France, Italy
Flounder, *Platicthys flesus italicus*	Adriatic	Croatia, Italy , Slovenia
Great scallop, *Pectin jacobeus*	Adriatic	Croatia, Italy , Slovenia
Large pelagic elasmobranches, *Isurus oxyrinchus, Lamna nasus, Prionace glauca*	All Mediterranean	Several Countries

Common and scientific name	Areas	Countries sharing the resource
Norway Lobster, *Nephrops nervegicus*	Adriatic Strait of Sicily Tyrrhenian, Corsican and Sardinian Seas	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Strait of Sicily: Italy, Libya, Malta, Tunisia Tyrrhenian, Corsican and Sardinian Seas: France, Italy
Red mullet, *Mullus barbatus*	Adriatic	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia
Red mullet, *Mullus surmuletus*	Tyrrhenian, Corsican and Sardinian Seas	Tyrrhenian, Corsican and Sardinian Seas: France, Italy
Red shrimps, *Aristeus antennatus*, *Aristeomorpha foliacea*	Alboran Sea Ionian Sea Strait of Sicily Tyrrhenian, Corsican and Sardinian Seas	Alboran Sea: Morocco, Spain Ionian Sea: Greece, Italy Strait of Sicily: Italy, Libya, Malta, Tunisia Tyrrhenian, Corsican and Sardinian Seas: France, Italy
Sardine, *Sardina pilchardus*	Adriatic Gulf of Lions Aegean Sea	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Gulf of Lions: Spain, France Aegean Sea: Greece, Turkey
Sparids, several species	Tyrrhenian, Corsican and Sardinian Seas	France and Italy
Sprat, *Sprattus sprattus*	Adriatic	Albania, Croatia, Serbia and Montenegro, Italy, Slovenia
Sturgeons, *Acipenser* spp, *Huso huso*	Adriatic, Ionian and Aegean Seas	Adriatic: Albania, Croatia, Serbia and Montenegro, Italy, Slovenia Ionian: Italy and Greece Aegean: Greece and Turkey
Swordfish, *Xiphias gladius*	All Mediterranean	Several Countries

Despite the recognised over-exploitation of several resources, there are few scientifically reported cases of stocks at risk of collapse, like anchovy in the Northern Spanish coast, black spot bream in the Alboran Sea and hake in the Gulf of Lions. This long term resilience of Mediterranean fisheries, without so far detected dramatic collapses of target resources, except for anchovy in the mid-80's, is usually explained by the fact that some proportion of adult stocks have most probably remained consistently unavailable to small mesh trawling. This feature of Mediterranean fisheries, as determined by fishing practices, has led to the creation of enclaves within the normal range of distribution of several species which allows a proportion of the stock to survive to maturity, thus preventing the collapse of the population. However, the situation has changed rapidly in the last decade, with the increasing efficiency of fishing methods both in terms of vessel engine power, the size of gear and vessel characteristics and above all, the development of fixed gear fisheries targeting spawners of several long lived species in so far untrawlable areas. Furthermore, widespread illegal trawl fisheries in coastal areas have reduced the refuge effect, resulting from the poor enforcement of the current regulation limiting the use of towed gears at depth greater than 50 meters or at a distance from the coast greater than 3 miles if depth is less than 50 meters.

- *Intercations of fishing with environmental conditions*

Besides decline of target species some of which are becoming rarer, fishing interacts with the environment in a number of adverse ways. High numbers of by-catches of non-target migratory or wide-ranging species is a major cause of decline of fishery populations. Discard rates as high as 60 per cent are regular practice reflecting the pronounced role fishing plays in the decline of Mediteranean fishery resources. Moreover, lack of selective fishing gear means that species of high conservation status may be included in the by catch making fishing responsible for loss of biodiversity. Cetaceans seen to be in competition and being killed by fishermen adds more complexity to the issue of fishing as a cause of decline in Mediterrranean fishery resources.

Decline in fisheries also occurs locally as a result of eutrophication incidents. The effects of nutrients runoff on fishery production in the Mediterranean has already been disussed in section 4.3.3. While fishery production is positively influenced by moderate levels of nutrient inputs a risk of fish-kill arises at excess levels of eutrophication. Red tides and lack of oxygen both linked to high nutrient input are two ways in which eutrophication may lead to a decline in fishery resources. Shellfish poisoning in Spain in 1993, for instance, caused by red tides was responsible for drastic drop in mussel production from a 247,000 mt in 1986 to 90,000 mt in 1993.

The presence of persistent pollutants in the marine environment, both organic and inorganic, may also induce sub-lethal long-term effects, and represent a true hazard for marine biota. However, the Mediterranean Action Plan assessed the risks associated with current levels and loads of organohalogen compounds in marine biota (UNEP/FAO/WHO/IAEA, 1990) and the main conclusions were that based on the limited data available it is unlikely that present levels of these compunds would adversely affect marine organisms, particulalry on reproduction. An overview of these potential threats is presented below, in section 5.1.2.

- *Interactions of fishing with non-commercial resources*

Mediterranean fishing grounds are usually found quite close to the coast where the highest biodiversity is located and there is an increasing awareness and concern about fishing impact both on habitats and non-commercial resources.

Apart from legal obligations concerning environmental protection, there is a clear interest to ensure the conservation of the target species but also of species belonging to the same ecosystem or associated with or dependent upon the target species. This approach is basic to preserve the biodiversity and integrity of marine ecosystems and hence, the production of essential fish habitats for the sake of the fisheries sector too.

The main pressures to marine resources posed by fisheries in the Mediterranean may result in damages to biodiversity and damages to habitats, as discussed in detail in sections 5.1 and 5.2.

To the first group belongs the widespread use of small mesh size fishing gears as well as excessive fishing of commercial species. As for other resources, sustainable use by curtailing catches is bound to have a positive impact on the environment.

Nowadays many non-target species are under threat, such as sea-mammals, birds, reptiles and non commercial stocks. Very high by-catch and discard rates are the main sources of threat for these populations. Due both to the low selectivity of small mesh size trawl gear and to mismatching between legal mesh size and minimum landing size by catch rates as high as 60 per cent are known to occur. Given also that about half of discarded species constitute edible biomass with commercial value, the inefficiency of current fishing practice is large. Estimates computed in the Aegean and the Greek Ionian Seas pointed out that bottom trawl discards range between 13,000 to 22,000 tons annually, that is about 12 per cent of the total landings.

In some cases the main threats come from non fishing activities such as the reduction of nesting sites of sea turtles and birds and fishing is seen to impact the marine resources in an indirect way.

The widespread use of dredges and bottom trawl gears have been identified as the main causes both of the decline of shallow meadows of marine phanerogams and deterioration of benthic communities in rocky areas.

High impact techniques such as the St Andrews' cross for red coral (*Corallium rubrum*) or the exploitation of European date mussel (*Lithophaga lithpphaga*) and common piddock (*Pholas dactylus*) by destroying the rocks inhabited by these bivalves have long been forbidden but there are indications that the prohibition is not well enforced. Furthermore, there are warning signals that the illegal use of explosive and poisonings is still taking place.

As far as damage to habitats is concerned there is need to protect sea-grass beds (Phanerogams such as *Posidonia* sp., *Zoostera* spp and *Cymodocea* sp), ham mussel beds, deep water white corals and hard bottom biocenosis in coastal areas, irrespective of depth, from the effects of trawling, dredging and similar activities. The impact of dredges fishings for bivalves must also be controlled since it may reduce the capacity of soft bottoms to maintain diversity in benthos.

As far as by catch of protected species is concerned conservation of the few remaining monk seals is of major importance. Protection of turtles and seabirds from longlining may in some cases be of special concern. Catacean by-catch will be of less importance following the recent ban of driftnets, although action at the international level would be beneficial to extends the protection to all Mediterranean fisheries. However, the interaction between cetaceans and fishing activities beyond the by-catch phenomenon, is a problem of growing concern that deserves careful consideration.

- *Interaction of fisheries with mariculture*

Mariculture is a relatively new source of pressure on the marine environment and fisheries, as will be discussed below. The overall impact of maricultures on the Mediterranean sea environment is so far limited compared to other pollution sources, however, in view of the probable expansion of these activities their impacts are included in this report.

Mariculture is in direct competition with other uses of coastal areas, including fisheries' breeding grounds. Maricultures are concentrated on the coastal zone and therefore particular attention must be payed to site selection in order to ensure that local ecosystems can absorb impacts without harmful lasting effects. The effects of introducing aquaculture activities in a marine or brackish environment vary according to an area being closed, semi-closed or open. The effects of phpsphorus and nitrogen released from aquaculture in the form of animal excreta or uneaten feed are estimated to be relatively small compared to total discharges from agriculture, urban and industrial sources. However, discharge from intensive mariculture often represents a localized, point source pollution form whose impact on oligotrophic waters could be significant. The consequences for fisheries could include eutrophication and resulting depletion of oxygen levels which if severe, could lead to fish kills in the vicinity of aquaculture stations.

In addition, mariculture presents a source of chemical contamination through release of pesticides. Toxicological effects on non-target species may be associated with the use of organophosphate ectoparasites for instance. Use of antibiotics by aquaculture may also affect the fitness of fish populations by stimulating antibiotic resistance in microbial communities (see section 4.4.2.5).

Further the risk of introducing new organisms and alien (exotic) species into the sea increases with the expansion of mariculture. As breeding and biotechnological techniques are increasingly used to produce varieties for mariculture purposes there is a serious potential of escape of cultured stocks into the open sea. This presents unforeseen risks to the health and survival of wild stocks as shown by the cases of the Asian clam (*Tapes semidecussatus*). Production of this clam increased rapidly in the North Adriatic in the period 1985 – 1996. Owing to its rapid growth and resistance to anoxic conditions, this species undermined the autochthonous species (*Tapes decussatus*) so much that it could also be fished in other coastal areas.

The kuruma shrimp (*Penaeus japonicus*) that was introduced to the Mediterranean, due to its rapid growigh in aquaculture provides a similar example. Nowadays, owing to its presence in natural stocks, and because entering the Suez Canal, it can be considered a Mediterranean species.

- *Mariculture*

Marine aquaculture and in particular intensive fish farming, has shown a large expansion in most of the Mediterranean countries during the last 10 years. This has caused conflicts with other activities of the coastal zone and raised significant public concern over environmental issues. Among them are the high organic and nutrient loading of the coastal zone as well as the use of chemicals (therapeutic products, vitamins and antifouling agents), the introduction of pathogens and new generic strains.

These problems may be overcome by improvement in technology related to aquaculture practices and interventions through integrated coastal management plans. In this respect, Mediterranean mariculture should be sustainable with practices that are environmentally no degrading, technically appropriate, economically viable and socially acceptable.

- *Main characteristics and features of the Mediterranean mariculture*

Aquaculture has been the world's faster growing food production system for the past decade (Tacon, 1997). Aquaculture production increased from 16.8 million tonnes in 1990 to more than 42 million tonnes in 1999 valued at over US$ 53 thousand million (FAO, 2001). Aquaculture in the Mediterranean represents about 5% of the world total production.

- *Recent evolution of mariculture in the Mediterranean.*

A new form of aquaculture has arisen over the past 20 years due to mastery of the reproduction of marine fish, the development of research in formulated feeds and technological innovations enabling installations to be located on land as well as in the sea. This type of aquaculture corresponds to the growth in the demand for fish quality products (seabass, seabream etc.) which generally cannot be met by traditional means because of the chronic overfishing of these species and the generally relative decline of fisheries production the last few years in the Mediterranean (Table 4.42).

Mean consumption of seafood around the Mediterranean basin is quite close to the levels of world consumption (appr. 18 kg per person/year), with very mark differences among different countries. It represents a total of nearly 3 million tonnes overall which is much more than the Mediterranean global levels of production from fishing and aquaculture. Italy, France and Spain have major deficit in the balance of sea products. Practically all Mediterranean countries are in the same situation. A growing demand that exists in this area led to a real explosion in the Mediterranean aquaculture production.

Table 4.43 **Total fish catch by Mediterranean countries for the years 1995 – 1999** *(FAOSTAT data base results 2000).*

Mediterranean and Black Sea (MT)	1995	1996	1997	1998	1999
Albania	1,46	2,058	923	1,968	2,136
Algeria	105,912	82,024	91,615	92,374	105,725
Cyprus	2,859	3,232	3,173	3,486	3,597
Egypt	45,078	53,932	56,815	77,535	98,877
France	70,636	56,316	61,473	61,555	65,636
Greece	169,838	175,129	194,824	156,673	185,811
Croatia	16,476	18,309	17,412	24,682	21,812
Israel	4,507	3,858	5,15	5,901	6,049
Italy	551,515	510,924	481,479	494,263	472,502
Lebanon	4,065	4,115	3,635	3,5	3,54
Libya	34	32	31	32	32
Malta	1,826	2,382	2,675	2,93	3,035
Morocco	40,993	40,98	32,663	29,582	38,416
Serbia and Montenegro	374	383	380	418	433
Slovenia	1,911	2,203	2,192	2,113	1,885
Spain	149,089	150,61	133,395	123,39	122,445
Syria	1,95	2,67	2,574	2,75	2,6
Tunisia	83,436	83,677	86,867	88,123	91,554
Turkey	594,486	493,467	426,843	456,61	550,137
AGG COUNTRIES	1,880,411	1,718,269	1,635,088	1,659,853	1,808,190

Figure 4.17 shows the production of aquaculture (fish and molluscs) in the Mediterranean over the last few years. Indeed, the production of fish has increased from a total of 220,000 tonnes in 1985 to 320,000 tonnes in 1995 and to 480,000 tonnes in 1998. Ferlin and Lacroix, 2000, provided the aquaculture production of the Mediterranean Sea and the watershed (fresh water species) in 1988 and 1998, as shown in Table 4.44.

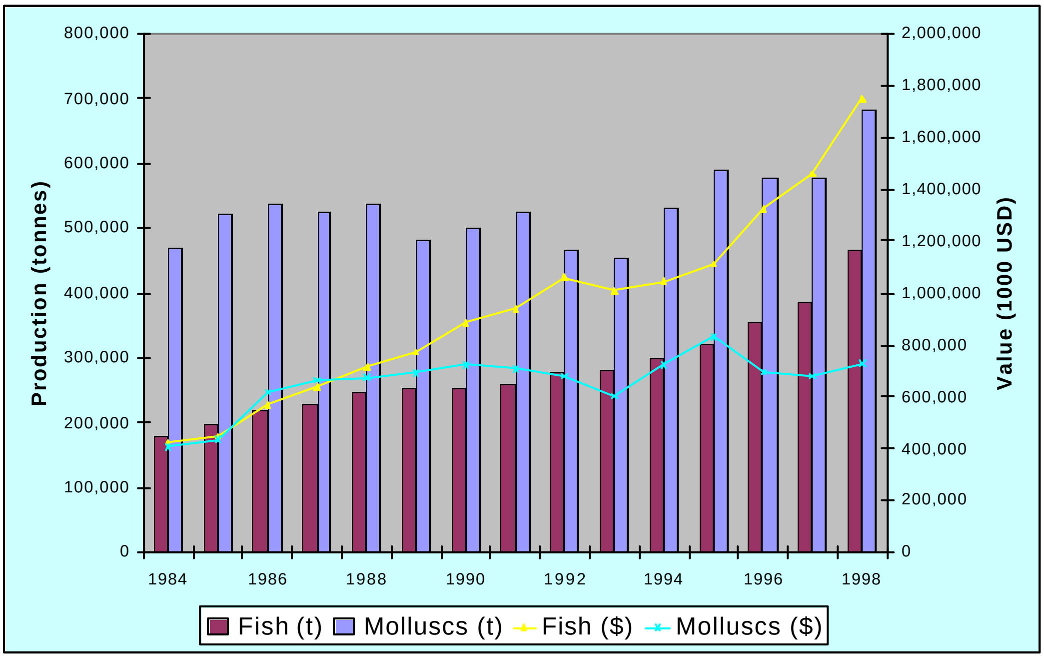


Figure 4.17 Fish and molluscs production and value of the Mediterranean countrie for the years 1984 to 1998 (Georgiou, 2001)

Table 4.44 **Aquaculture production of the Mediterranean Sea and the Mediterranean watershed (freshwater species) in 1988 and in 1998 (except the Black Sea). Data (in tonnes) from FAO, Sipam, Ifremer (Ferlin and Lacroix, 2000)**

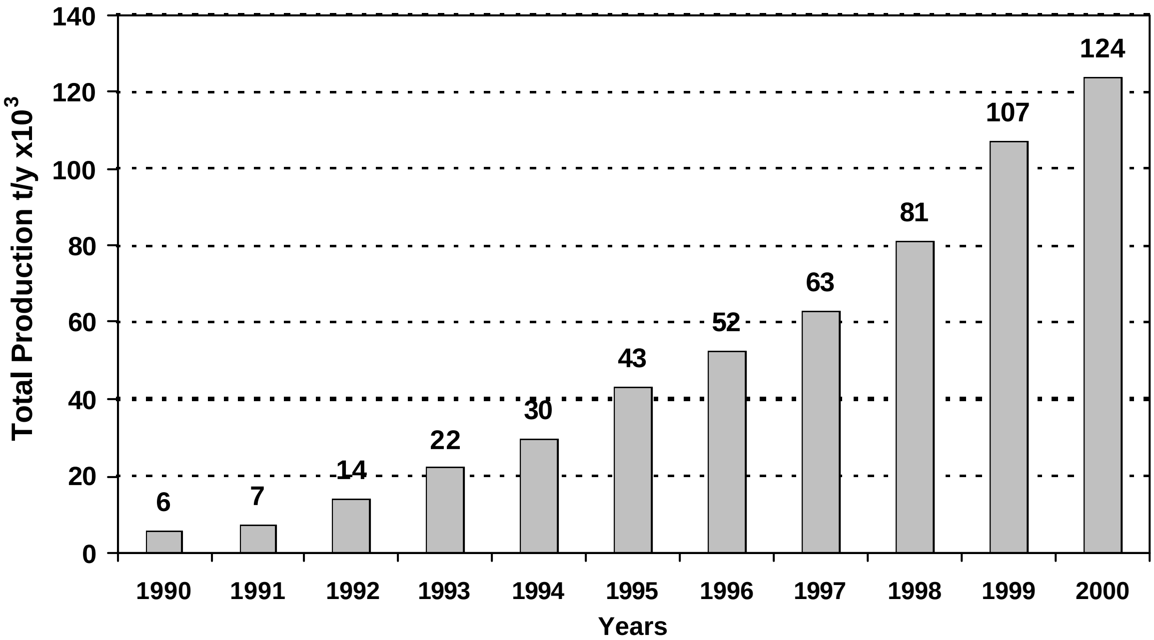
Species, or group of species	Production 1988	Production 1998	Variation: X factor	Variation: (%)
Seabass	1,600	32,000	X 20	
Seabream	1,600	40,000	X25	
Mullet	6,000	20,000	X 3,3	
Other marine fishes	400	6,500	X 16	
TOTAL MARINE FISHES	9,600	98,500	X 10	
Trout	46,000	93,000		+ 100 %
Carp	37,000	30,000		-19%
Tilapia	28,000	34,000		+ 21 %
Other freshwater fishes	3,300	9,000		+ 172%
TOTAL FRESHWATER FISHES	114,300	166,000		+ 45%
Oyster	26,000	25,000		-4%
Mussel	195,000	200,000		+ 2%
Clam	3,400	43,000	X 12	
Other molluscs	100	2,900	X 29	
TOTAL MOLLUSCS	230,000	271,000		+18%
CRUSTACEAN	1,300	300		-76%
ALGAE	0	5000		

GLOBAL TOTAL	350,000	540,000	+ 54%

The production of marine fishes has a remarkable increase from 9,600 tonnes in1988 to 96,500 tonnes in 1998. Among the species, the main dynamic trend originates from the seabass, *Dicentrarchus labrax* and seabream, *Sparus aurata*, which account for the bulk of marine aquaculture. As a direct consequence the greatest share of the Mediterranean hatchery output is farmed by these species.

In terms of type of marine aquaculture the intensive culture shows an exponential increase. Figure 4.15 shows the production of fish and crustaceans from intensive mariculture by Mediterranean countries for the years 1990 to 2000. Production from intensive mariculture has increased from about 6,000 tonnes in 1990 to nearly 124,000 tonnes in 2000.

Figure 4.18 Total production of fish and crustaceans from intensive mariculture in the Mediterranean for the years 1990-2000



- *Country by country situation*

The percentage of total production from mariculture in terms of type (intensive, semi-intensive and extensive) and group of species (fish, molluscs and crustaceans) by Mediterranean countries is shown in Table 4.44.

For the year 2000, Greece has the greatest share of about 47%. The number of mussel farms in Greece increased rapidly from five in 1980 to 346 in 1998. Molluscs production in the semi-intensive and extensive forms increased in Greece from 5800 tonnes in 1990 to 28,100 tonnes in 2000.

Table 4.45 **Percentage of the total production by each country for the year 2000**

Country	%
Croatia	2.02
Cyprus	1.37
Greece	47.25

Country	**%**
France	4.21
Israel	0.16
Italy	12.78
Malta	1.62
Morocco	0.65
Slovenia	0.08
Spain	8.98
Tunisia	0.24
Turkey	20.63

Molluscs with cupped oyster as the principal species, dominate marine aquaculture production in France which in 1999 has reached 205,000 tonnes. Molluscs production from semi-intensive mariculture has been quite stable over the last 10 years. On the other hand, fish production from intensive culture increased to 7,000 tonnes in 2000 from the 1410 tonnes of 1990; Crustaceans production is around 1,200 tonnes per year.

Aquaculture in Spain is dominated by semi-intensive and extensive shellfish farming, mainly mussels. Total production in 2000 was about 280,000 tonnes, although the main activity is found in the NW of the Iberian Peninsula.

During the last years finfish farming has been developed in a number of Mediterranean locations in Spain with turbot, seabream and seabass as the most important species. Fish production from intensive mariculture was about 11,100 tonnes in 2000. The last few years blue fin tuna production was also increase. The production of tuna in 1990 was 31 tonnes while in 2000 it has reached to 3,400 tonnes.

In 2000, Italian finfish production in marine waters exceeded the 15,800 tonnes mainly due to seabream and seabass production. Molluscs production in 1999 was about 141,000.

Turkey is the country where fish mariculture grew exponentially the last few years. Production of marine fish from intensive mariculture increased to 25,500 tonnes in 2000, from 1750 tonnes production in 1992.

A real evolution in mariculture occurs also in Cyprus, where marine finfish production in 2000 reached the 1700 tonnes, while in 1992 was only 70 tonnes. The main species cultivated are seabass and seabream. Cyprus has also a noticeable production of crustaceans, which in 2000 was of 60 tonnes.

Malta shows a similar picture than Cyprus. The production of fish from intensive culture was more than 2000 tonnes in 2000, while 1992 this was only of 300 tonnes.

Production from intensive and semi-intensive mariculture in Croatia shows no substantially increase the last ten years. Fish production mainly seabass and seabream in 1999 was about 2500 tonnes, while in 1992 was 685 tonnes. A slight decrease in molluscs production occurs the last few years being less than 1,000 tonnes per year. What is interesting in Croatia is the fast growth of tuna fish production, which started in 1998, with a production of 400 tonnes while today the production is more than double.

The only marine species produced until recently in Slovenia was that of molluscs with a production of about 50 tonnes. Since the early 1990 production of seabream and seabass has been established with very low production. Today the production is around 120 tonnes.

Albania has no intensive mariculture. The only production is that of molluscs in brackish waters with a production reaching to about 100 tonnes per year.

Egypt has always been the main aquaculture producer in Africa with a production of 73,500 tonnes in 1997. However, aquaculture production on the Mediterranean coast represents only the 12%. The most important marine species that are cultured are seabream and seabass. The average annual production during the years 1994 to 1997 was about 200 tonnes with an increase in 1999 to 940 tonnes.

Morocco is a country where mariculture production shows a decrease the last years. In 1992 production of intensive mariculture was about 200 tonnes. the production increased to 1200 tonnes in 1996 and the last 3-4 years has dropped to less than 800 tonnes.

A similar situation exists in Tunisia, where intensive mariculture showed an increased in production in the years 1996-97, reaching the 800 tonnes: the production dropped to about 300 tonnes in 2000.

There is no intensive mariculture in Algeria. The very low fish production of about 30 tonnes (1999) and 20 tonnes of molluscs, comes from extensive mariculture.

In Israel intensive mariculture, is a recent activity in Mediterranean coastline. One of the existing seabream farms with a production of 200 tonnes in 2000 was completely destroyed due to bad weather conditions in early 2001. The only farm which is operates today in Israel has a production capacity of 50 tonnes.

In Syria, Libya, Lebanon and Bosnia-Herzegovina there is no intensive mariculture.

Wastes/contaminants into the marine environment

The environmental load from marine fish farming is not a recent issue but it has been a subject of increasingly heated debate during the last few years. A perceived risk of pollution from fish farming in coastal waters relates to the generation of wastes (Gowen and Bradbury, 1987) and the release of chemotherapeutants (ICES, 1994). It has further been argued that coastal aquaculture is potentially harmful to indigenous biota through disturbances of wildlife (Whilde, 1990, Beveridge et al., 1994), influence on the behaviour of wild fish (Henriksson, 1991) and the genetic interaction between wild and farmed fish.

The range and amount of waste contaminants from aquaculture depend on the form of aquaculture activity. The distinction between extensive aquaculture (that relies upon the availability of natural food) and intensive aquaculture (that relies upon feeding the stock with processed diets) is useful when considering the inputs of aquaculture operation (Gowen et al., 1990).

Nutrients and carbon enrichment

There is a number of studies worldwide that have examined the nitrogen and phosphorus inputs from intensive fish farming, but only few for the Mediterranean. Most of these studies are using the mass balance estimates based on feed usage and different species.

Hakanson et al. (1990) estimated that 100 kg of nitrogen and 20 kg of phosphorus are released into the marine environment with each tonne of fish produced. In turn, Hall et al. (1992) indicate that the 67-80% of nitrogen added to the cage system is lost to the environment. If it is assumed that the nitrogen content in feed is 8% and that retained by fish is 21%, it is estimated that 84 - 100 kg of nitrogen enter the marine environment per tonne of fish produced. The conversion ratio is considered to be 2:1.

On the other hand, Holby and Hall (1991) showed that the environmental losses of phosphorus were 19.4 to 22.4 kg per tonne of fish produced, 34-41% of which was released in dissolved form, with the remaining being lost by sedimentation. They estimated that 4-8% of the sediment phosphorus returns to the water column per year. In a more recent survey, Gowen et al. (1997) estimated the nitrogen and phosphorus inputs from the seabream and seabass cage farming in Cyprus. To estimate waste output they used a mass balance model (Figure 4.19).

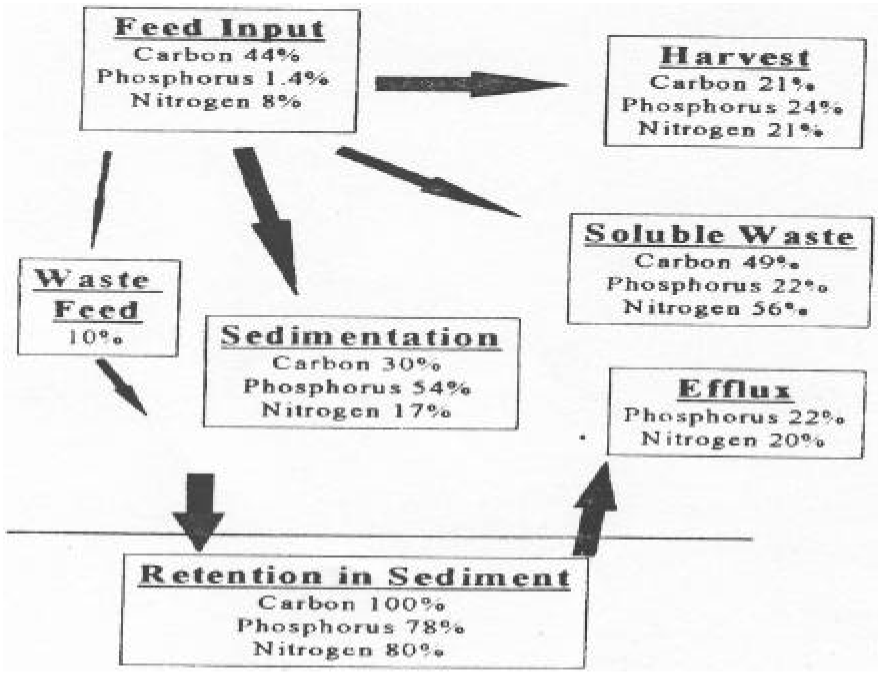


Figure 4.19 The mass balance model used to estimate soluble and organic waste output from each of the marine cage farms in Cyprus
(Gowen et al., 1997).

The model was derived from Hall et al. (1992) and Ackefors (1990) for nitrogen and phosphorus and from Hall et al. (1990) for carbon. A factor of 10% for uneaten food was introduced a suggested by Gowen and Bradbury (1987). This is an approximate value, but does not appear unreasonable given the feed conversion ratio in Cyprus farms to be of 2.6-2.7.

The estimated total annual (1996) inputs of soluble nitrogen and phosphorus were 116 kg and 12 kg per tonne of fish produced, respectively. Katavic (1997) reported, 96.5 kg of nitrogen and 11 kg of phosphorus annual inputs per tonne of seabass produced in cage farms (266 tonnes/y) in coastal waters of Croatia.

It should be noted that the above mass balance models are for the salmonid culture in northern European waters. It appears that these models can also used for warm water fish species (Baird and Muir, 1990) and are comparable with data derived from a gilthead sea bream farm (Dominguez et al., 1997)

Carbon inputs

In intensive fish culture, fish faeces are lost to the environment along with the wastage of uneaten food (processed fish meal and trash fish). Processed fish food is composed of a highly labile (digestible) mixture of protein, fat, carbohydrate and other minor components such as vitamins and pigments. As it is undigested, uneaten food has a much greater capacity (weight for weight) than faecal material to impact the environment both in terms of energy content and degradation rate.

Several published studies have examined the total amount of particulates released to sediments from fish cages (Hall et al., 1990, Ye et al., 1991, Findlay et al., 1995). Estimates of waste have varied between 29 and 71% of input carbon, depending on year (Hall et al., 1990) and 78% of input carbon (Ye et al., 1991).

In the mass balance model used by Gowen et al. (1997) to estimate waste inputs from seabream and seabass cage farms in Cyprus, carbon input was considered to be 79%. The estimated annual waste output of particulate C was 427 kg per tonne of fish produced.

Higher values were reported for seabream cage farms in Malta where the estimated annual waste output of particulate C was 570 kg per tonne of fish produced (Grech, 1999).

Estimated nutrients and carbon loads.

The estimation of the loads of nutrients and carbon entering the marine environment and their trends during the last ten years was based on the following criteria, facts and data:

- Main waste outputs come from intensive aquaculture and accurate estimates can be drawn only from intensive culture. Estimated waste outputs in this study are related to intensive mariculture.
- The nitrogen and phosphorus loads from semi–intensive mariculture are only the 5% and 10% respectively of those from intensive culture.
- Based on existing data, the following values were used for the purpose of this study:

  110 kg nitrogen output per tonne of fish produced
  12 kg phosphorus output per tonne of fish produced
  450 kg carbon output per tonne of fish produced

Nitrogen

Figure 4.17 shows the estimated inputs of nitrogen (t/y) from intensive mariculture by each country in the Mediterranean region for the years 1990-2000. As it is seen, the total inputs of nitrogen in 2000 has increased by 25 times from that of 1990. Total nitrogen input in 1990 was estimated to be about 630 tonnes while this was increased to 13600 tonnes for the year 2000.

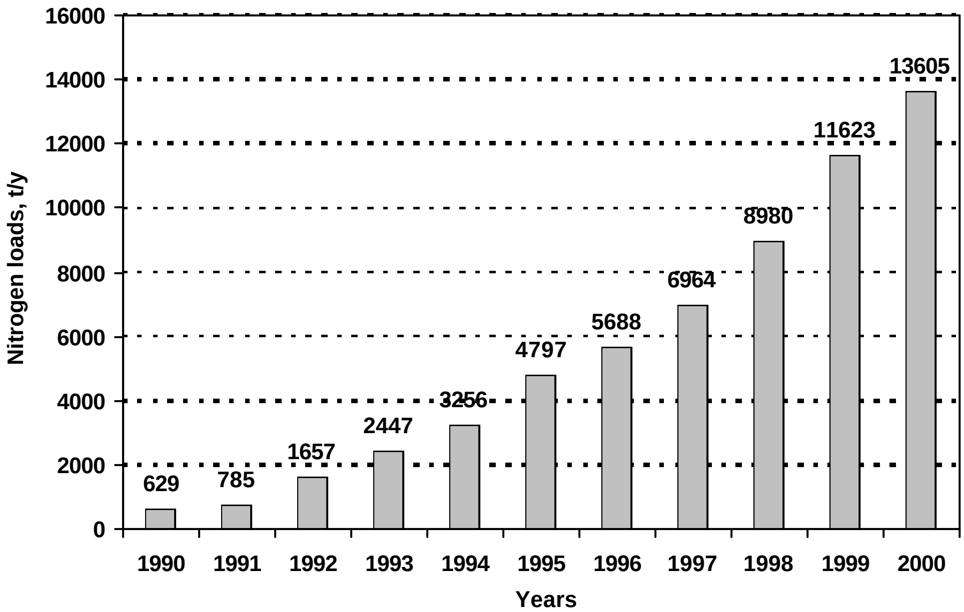


Figure 4.20 Estimated loads of nitrogen (N) from intensive mariculture for the years 1999 - 2000

The percentage contribution by each country to the total input of nitrogen for the year 2000 is shown in Table 4.45. Greece shares the 47% of the total input with Turkey having about 20%

of the total input, Italy having about 12% and Spain and France about 9% and 4%, respectively. The percentage contributions by the rest of the countries range from 0.09 to about 2%.

Table 4.46 **Percentage of the total nitrogen, phosphorus and carbon loads by each country for the year 2000**

Country	Nitrogen	Phosphorus	Carbon
Croatia	2.02	2.02	2.02
Cyprus	1.45	1.48	1.45
Greece	47.21	47.26	47.21
France	4.19	4.18	4.19
Israel	0.16	0.16	0.16
Italy	12.77	12.74	12.77
Malta	1.65	1.68	1.65
Morocco	0.60	0.61	0.60
Slovenia	0.96	0.07	0.10
Spain	8.97	8.97	8.97
Tunisia	0.23	0.20	0.23
Turkey	20.62	20.63	20.62

Phosphorus

Phosphorus input was estimated to be 69 tonnes in 1990 while this figure was increased to about 1500 tonnes for the year 2000 (Figure 4.21). The percentage contribution by the countries to the total inputs of phosphorus for the year 2000 is similar, as expected, with that of nitrogen (Table 4.46).

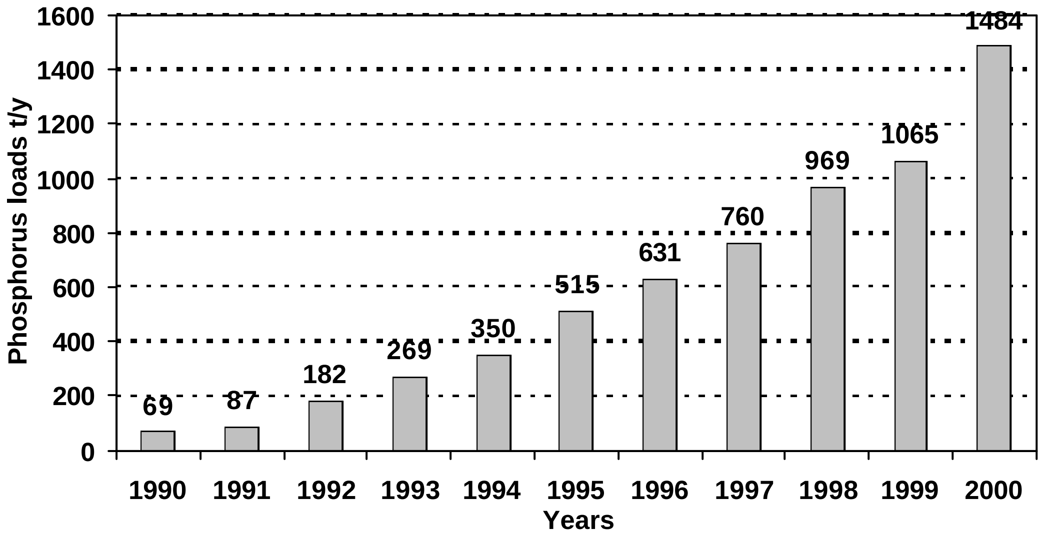


Figure 4.21 - *Estimated loads of phosphorus (t/y) from intensive mariculture in the Mediterranean for the years 1990 – 2000*

Carbon

The estimated input of carbon for each country for the years 1990 to 2000 is shown Table 4.44. In the year 2000 the estimated total carbon input was about 55700 tonnes compared with the 2600 tonnes for the year 1990 (Figure 4.19). The percentage contribution by each country is similar with those of N and P (Table 4.45).

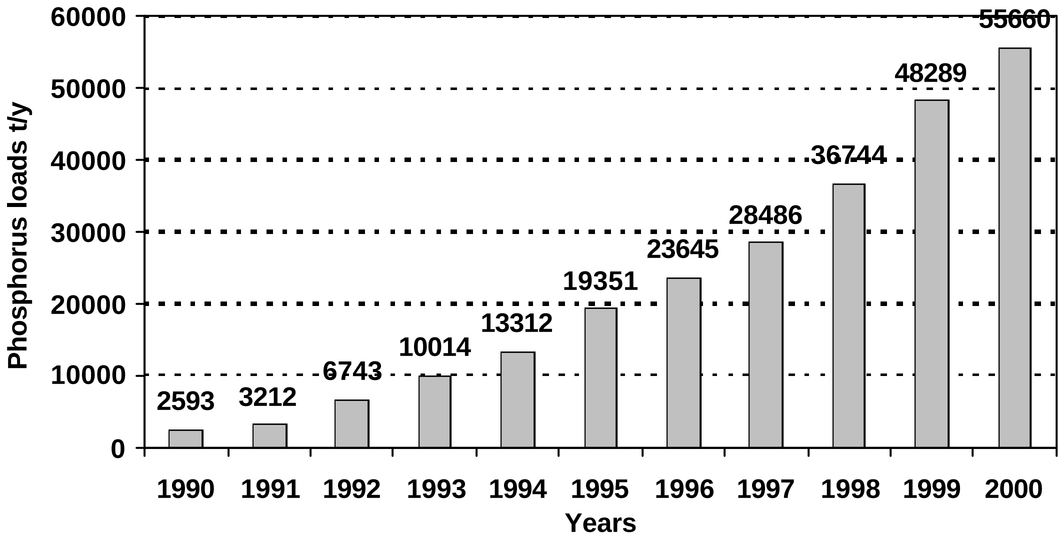


Figure 4.22 Estimated loads of carbon (C) (t/y) from intensive mariculture in the Mediterranean for the years 1990 – 2000

As mariculture is a coastal activity, the inputs of N, P and C were estimated in terms of the km of coastline for each country. The results are shown in Figure 4.23. As it is seen Malta has the higher inputs per km of coastline (with the others to be in the same range (1000 to 2000kg/y/km) with the exception of Tunisia and Morocco, which have lower inputs in this respect.

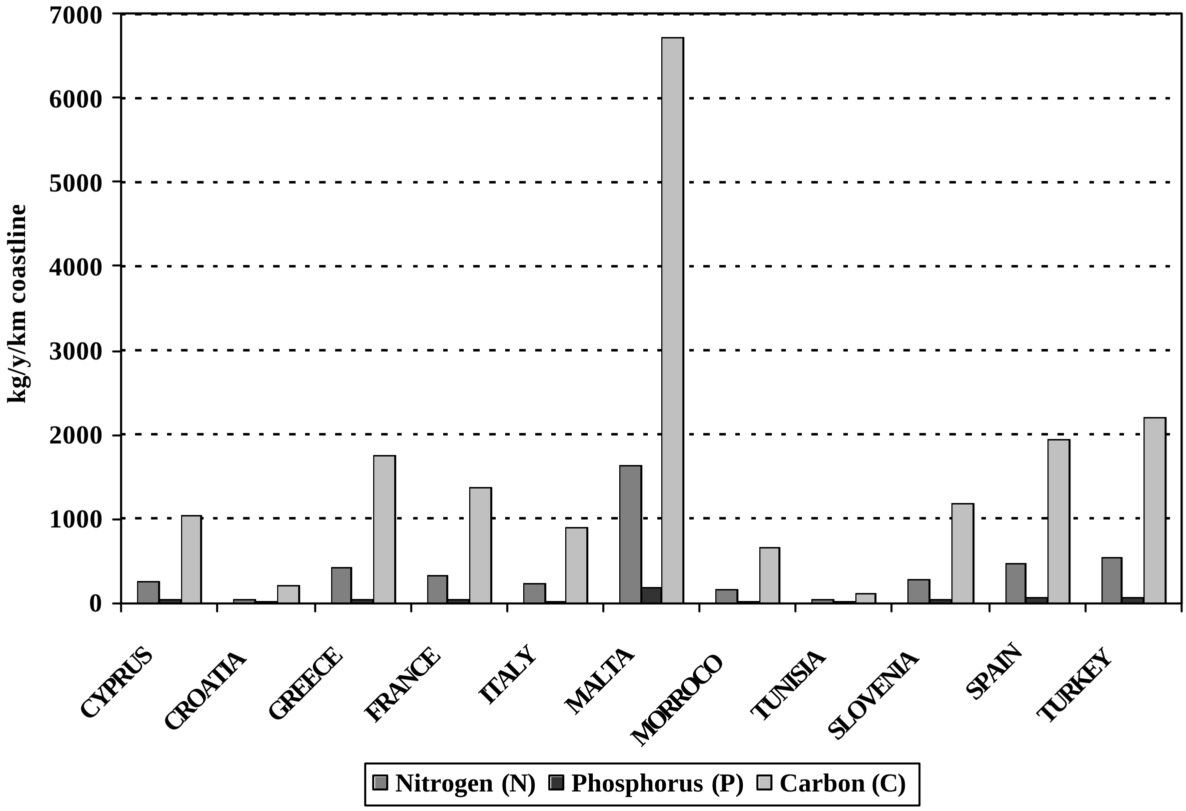


Figure 4.23 Waste outputs from intensive mariculture for the year 2000 (kg/y/km coastline)

Chemicals used in mariculture industry

The chemicals used in coastal aquaculture include those associated with structural materials, soil and water treatments, antibacterial agents, other therapeutants, pesticides, feed additives, anaesthetics and hormones.

The above chemicals can be grouped into three categories (GESAMP, 1997). The first consists of aquaculture chemicals that pose an inherently high level of hazard and on this basis their use should be curtailed. The second category includes chemicals that can be used safely if standard precautions are followed but poses a threat to the environment and/or human health if misused. The third category of chemicals, include those that may be environmentally benign under most situations but detrimental at specific sites because of the unique attributes of such sites.

In the literature, Alderman et al., (1994) is an important source of information for chemicals used in mariculture, while the ICES report (1990) on environmental impacts of mariculture provides information on the ICES countries.

Many Mediterranean countries engaged in mariculture have few regulatory controls and/or little documentation used by the industry. Even countries that maintain a list of approved chemicals and control their use no drugs were licensed for Mariculture and rarely have information on the quantities actually used (Silvert et al., 2001). Consequently, the compilation of a complete and quantitative listing of Mariculture chemicals used in the Mediterranean is at present impossible.

- *Impacts*

Impacts on the marine environment

The environmental impact of marine fish farming depends very much on species, culture method, stocking density, feed type, hydrography of the site and husbandry practices. In many instances there is little direct evidence of an impact and in such cases the impact must be regarded as potential, since the threat to the environment is derived from our current understanding of ecology or more broadly based on direct comparison with known effects of the farms of agriculture and industry. However, it should be pointed out that a lack of scientific validation of a perceived impact does not reduce its potential importance (Gowen et al., 1990). The possible environmental impacts of aquaculture activities in the coastal environment is shown in Table 4.46 (Chua, 1992).

Mediterranean marine ecosystems present an idiosyncratic combination of characteristics, which make them very different from north European conditions. These differences listed below, affect both the fish farming industry and the ecological processes as they determined the fate of wastes.

- High temperate conditions (annual minimum of 12^{o}C, reaching up to 25^{o}C during summer) includes high metabolic rates, thus affecting both the production of the farm fish and the activity of microbial communities.
- The microtidal regime (tidal range is typically less than 50cm) reduces the potential for dilution and dispersion of solute and particulate wastes, especially in enclosed bays where wind driven currents are relatively weak.
- Oligotrophy: low nutrient, low primary production and low phytoplankton biomass are typical of most Mediterranean marine ecosystems, particularly in the eastern basin (Bethoux, 1981; Azov, 1986). Low phytoplankton biomass induces high transparency of the water and light penetration deeper in the water column (Ignatiades, 1998), thus allowing photosynthesis at a greater depth.

- Primary production is considered to be phosphorus limited (Krom et al., 1991) as opposed to nitrogen limitation in the Atlantic and in most of the world's Oceans. In this context, eutrophication could be expected only when phosphate is released in adequate quantities.
- The biotic component of the ecosystems (i.e. the fauna and flora) is highly diverse particularly in the coastal zone and consist of a large proportion of endemic species as a result of the dynamic geological past of the Mediterranean (Tortonese, 1985, Fredj et al., 1992). It is of low abundance and biomass as a result of the prevailing oligotrophic conditions (Karakassis and Eleftheriou, 1997).

Finally, the morphology of coastal bays where most of mariculture is practiced is also very different from that of Scottish Lochs and Norwegian fiords. They are typically not associated with permanent fresh water supply.

Table 4.47 **Possible environmental impacts of aquaculture activities in the coastal environment.**

Aquaculture inputs/activities										
Environmental impact	Cultured organism	Feeds	Drugs	Pesticides	Hormone/ growth promoter	Faecal wastes	Siting physical structure	Exotic species	Ground water extraction	Antifouling compounds & plastic additives
Water enrichment	-	●	-	-	-	●	-	-	-	-
Marine food web	●	●	0	0	-	●	-	0	-	0
Oxygen consumption	●	●	-	-	-	●	-	0	-	-
Mangrove habitat	-	-	-	-	-	-	●	-	-	-
Biodiversity	-	●	●	●	0	0	-	●	-	0
Biofouling	-	-	-	-	-	-	●	-	-	●
Changes in benthic	-	0	●	0	-	0	-	0	-	0
Antibiotic resistance	-	-	●	-	-	-	-	-		-
Salinization of aquifers	-	-	-	-	-	-	●	-	●	-
Acidification of soil	-	0	-	-	-	●	●	-	-	-
Land subsidence	-	-	-	-	-	-	●	-	●	-
Wildlife	-	-	-	-	-	-	0	-	-	-
Salinizafion of	-	-	-	-	-	-	●	-	0	-
Hardening of seabed	-	●	-	-	-	●	-	-	-	-
Growth of undesirable	-	●	-	-	-	●	-	-	-	0
Eutrophication	-	●	-	-	-	●	-	-	-	-
Toxicity to marine	-	-	-	-	-	-	-	-	-	●

●Significant impacts. O— Likely impacts. -—No relationship.
(After: Chua, 1992).

Nutrients enrichment

Enrichment of marine ecosystems.

It has been argued that the quantities of phosphorus and nitrogen released from aquaculture operations are small relative to the total discharges from human activity. The estimated loads of phosphorus and nitrogen to the Mediterranean sea from agriculture were 976,000 t/y and 1,570,000 t/y, respectively (Izzo, 2001). In the same study the loads of phosphorus and nitrogen from aquaculture were reported to be 394 t/y and 8,678 t/y respectively. Estimated loads of phosphorus and nitrogen for the year 2000 from intensive mariculture in this study were 1484 t/y and 13,600 t/y, respectively.

However, discharge from intensive mariculture often represents a localised point source discharge of waste into unpolluted, oligotrophic (nutrient poor) waters and such one impact could be significant. Large proportion of nitrogen and phosphorus are released in dissolved form into the water column (Holby and Hall 1991, Hall et al., 1992). Thus, the discharge of dissolved inorganic nitrogen (ammonia, nitrate and nitrite) and phosphorus from intensive mariculture (cage and land-based fish farming) could lead to eutrophication.

Furthermore, the pattern of nutrient release presents a significant deviation from the natural fluctuation of nutrient concentrations in the water column (Pitta et al., 1999). In temperate regions, such as the Mediterranean, phytoplankton presents seasonal maximum growth during spring and autumn as a result of nutrient availability due to mixing and other physical processes as well as adequate light conditions. By contrast, the released of nutrients by fish farms is a continuous process throughout the year, reaching maximal values during summer when high water temperature imposes the need for higher feeding rates.

Despite the rapidly expanding marine fish culture industry very little information has been published regarding the impacts from nutrients in the Mediterranean. A seasonal survey of the water column characteristics (physical, chemical and biological) was carried out in three Mediterranean farms (Pitta et al., 1999). A significant increase in concentration of phosphate and ammonium was detected within the cages but without significant effect on chlorophyll concentration. Analysis of variation within the data set identified location and season as the major factors of variability in most of the variables examined except phosphate and ammonium for which variability induced by fish farming seemed to be of major importance.

Plankton abundance for the major groups, microplankton species diversity and community structure were also determined by the effects of season and location rather than by fish farming.

Similar data were obtained in a series of baseline studies conducted for the main fish farms in Cyprus (Andronikou and Apostolidou, 2001). In three farms of capacity range from 200 to 300 tonnes of fish, there were not significant differences in chlorophyll and other phaeopigment concentrations neither in the control nor in the stations close to the farms.

Beveridge (1996) reviewed a wide range of information sources including papers and technical reports and concluded that in marine waters, several studies have failed to establish a relationship between nutrient concentrations and phytoplankton growth.

The inconsistency between nutrient enrichment and the lack of a significant increase in chlorophyll may be attributed to the limited utilisation of the excretory wastes due to rapid flashing time, so that phytoplankton are not present long enough to capitalise on the high production of nutrients as has also been suggested by Gowen et al. (1997). Mesocosm experiments in the Eastern Mediterranean (Pitta, 1996) have shown that there is a time delay of 3 to 8 days (depending on season) between nutrient enrichment and the peak of phytoplankton biomass.

Benthic enrichment

The general picture emerging from the existing studies indicates that the impact from intensive culture is on the seabed and that the most widely known effect is benthic enrichment beneath the sea farms. The existing studies for the Mediterranean, although small in number, have covered the different Mediterranean areas. Delgado et al. (1999) studied the effects of fish farming on a seagrass (*Posidonia oceanica*) meadow at Fornells Bay, Minorca (Balearic Islands, Spain). Changes in plant and meadow features (e.g. shoot morphology, shoot density and biomass) were observed in the stations closest to the fish cages. The same picture appeared in an inshore seabass cage farm in Croatia, producing around 200 t/y, over almost 15 years. The well developed *Posidonia oceanica* beds have almost disappeared beneath the cages and they were in regression in the entire bay (Katavic and Antolic, 1999).

A seasonal survey combining sediment geochemistry and macrofauna was carried out in three fish farms in Greece (Cephalonia, Ithaki and Sounion), situated at a depth of 20-30m, in areas with different types of substratum and with varying intensity of water currents (Karakassis et al., 2000). The results of this study indicated that the impacts of fish farming on the benthos in the Mediterranean could vary considerably depending on the specific characteristics of the farming site. At the sampling stations under and near the cages, redox potential was found to decrease but reached negative values only out the silt site. The organic carbon and nitrogen content of the sediment near the cages was found to increase by 1.5 to 5 times and ATP content by 4 to 28 times. No azoic zone was encountered in any of the stations, but the macrofaunal community was affected at a distance of up to 25m from the edge of the cages. At the coarse sediment sites abundance and biomass increased by more than 10 times and at all sites diversity indicated that the ecotone was in the vicinity of 25m from the cages.

In the eastern Mediterranean, environmental impact studies on three fish cage farms, in Cyprus situated at depths of 25 to 30 meters shown that the areas below the cages displayed a gradient of biotic enrichment being reflected in changes of macrofauna diversity and abundance (Adronikou and Apostolidou, 2001).

The result of a study on benthic communities of soft bottom has shown that they have been subjected to environmental disturbances by floating cages situated in the Gulf of Olbia, northeastern Sardinia, as reported by Martinelli et al. (1995). The zoobenthos appears to be sharply modified in the area below the cages; the community was sharply dominated by *Capitella capitata*, a species typical of organic enriched and polluted bottoms.

The environmental impacts of extensive and semi-intensive mariculture is difficult to evaluate since the incorrect balance between available foods, food supplement and fish yield could result in either impoverishment or enrichment. However, a number of studies describing the impact from these activities have been published.

Bivalve cultivation can be broadly split into three main processes, namely seed collection, seed nursery and on-growing, and harvesting. A growing number of studies of the ecological effects of mechanical collecting devices have demonstrated direct mortality on non-target species and the distraction of suitable settlement substrata and habitats (Kaiser et al., 1998).

The impact of suspended oyster culture on oxygen and nutrient fluxes has been studied in situ in a coastal lagoon (Thau, France). Ammonia and nitrates were released into the water column at a rate of 11,823 m/h. Phosphate released was low (Mazouni et al., 1998). Another study for the same lagoon (Casabianca et al., 1997) concluded that maximal shellfish farming results to the growth of red macroalgae, especially *Gracilaria.*

A number of studies have also been performed in Italy. Sdrigotti et al. (1999) reported that the diatom community living at the water-sediment interface has been influenced, by the presence of suspended mussels culture in the Gulf of Trieste, Italy.

One of the main causes of outspreading of dystrophic conditions which endanger the Marsala Sound (Italy) is the aquaculture plant constructed near the northern mouth at the beginning of the eighties (Giani et al., 1999).

The Comacchlo Lagoon system (Northern Adriatic Sea), is still recovering after the intensive farming of eel and fish has stopped in 1992. The increased release of organic matter from fish farming resulted in a bloom of Cyanobacteria and an almost elimination of eukaryotes at both the planktonic and benthic level (Crema et al., 2000).

Impacts from used chemicals

Evaluation of environmental impacts of the chemicals used in mariculture must be based on the following issues;

- Their fate and persistence in the marine environment and their longevity in animal tissues and
- The development of transfer of resistance in microbial communities.

Many mariculture chemicals degrade rapidly in aquatic systems. For example formalin, has a half-life in water of 36 hours (Katz, 1989). The half life of dichlorvos is in the range of 100-200 hours and the degradation of oxytetracycline proceeds also rather rapidly (Samuelson et al., 1992). However, most oxytetracycline become bound to particulates and is deposited at the bottom of (or beneath) the fishfarm cage sites. Within the sediments, oxytetracycline may remain in concentrations capable of causing antibacterial effects for 12 weeks after the cessation of treatment (Jacobsen and Berglind, 1988). In anoxic fish-farm sediments the compound may be very persistent (up to 419 days). However, this was not biologically available in this case (Bjoerklund et al., 1990).

Salmon net –cage culturists, in the USA use oxytetracycline and to a lesser extent Romet® and amoxycillin to prevent or treat bacterial disease. Capone et al. (1996) examined the fate of these chemicals in three farm sites. The area of sediments containing measurable oxytetracycline residues was very localised, with residues detectable only under the cages and to a distance of 30 meters.

Crabs and oysters from the over surrounding the farm area were collected. No more than trace oxytetracycline residues were found in oysters, but about half of the rock crabs collected under the cages during and within 12 days after the treatment contained oxytetracycline in meat at concentrations of 0.8 to 3.8 mg/g. Oxytetracycline concentration was determined in samples of blue mussels collected in the vicinity of Atlantic salmon farms during and after the treatment (Coyne et al., 1997).

Although oxytetracycline is the most commonly used antibiotic in seabream and seabass cage culture, there are no reports for its fate for the Mediterranean.

Toxicological effects of non-target species may be associated with the use of chemicals. Among the pesticides that may have toxicological effects on the surrounding invertebrate fauna are the organophosphate ectoparasites. Organophosphates bath treatments result in the release into the surrounding waters of significant quantities of toxic material liable to affect crustaceans particularly at larval stages (Egidius and Moster, 1987). The use of carbaryl pesticides to eliminate burrowing shrimp from oyster beds in the North-Western United States results in the unintended mortality of Dungeness crab, a commercially exploited species (WDF/WDOE, 1985).

The environmental effects of pigments and vitamins are poorly known. Biotin has been shown to simulate growth of certain phytoplankton species and is implicated in the toxicity of the dinoflagelate G*ymnodinium aureoles* (Gowen and Bradbury, 1987). Vitamin B12 has been shown to be one of the growth-promoting factors of the alga *Chrysochromulina polylepis* and the dinoflagellate, *Heterosigma alashivo* (Graneli et al., 1993, Honjo, 1993).

Indiscriminate use of drugs, especially antibiotics to control or prevent fish diseases in coastal fishfarms has shown that some native aquatic microbial communities develop antibiotic resistance (GESAMP, 1991) and the possibility of transfer resistance to human pathogen has also raised concern (Aoki, 1989, Dixon, 1991).

The development of resistant bacteria population in the sediment has been documented. For example, up to 100% of oxytetracycline resistant bacteria have been recorded from marine sediments near fish farms after medication and resistance persisted for more than 13 months afterwards (Torsvik et al., 1988, Samuelson et al., 1992).

Interaction between escaped farmed stock and wild species

The rapid development of marine cage farming of salmonids has raised concerns about the impact of escaped fish on natural populations. There is a number of studies (McGinitty et al. 1997, Hutchinson, 1997) with reference to the possible genetic impact of escaped cultured Atlantic salmon on native populations. The demonstration that farmed and hybrid progeny can survive in the wild to the smolt stage, indicates that escaped, farmed fish can perhaps produce long-term genetic changes in the natural population. However, there is insufficient available information to judge whether this interaction is a serious ecological impact. Some countries have initiated studies to address this issue and in recognition of the potential problem Norway prohibits the sitting of salmon farms within 30km of important salmon rivers.

Regarding the Mediterranean region this problem has received none or little attention. It seems that the tremendous increase of cage farming in the Mediterranean, along with the fact that the number of escapes can be large, is an issue to be considered. Frequency analysis of the damages of Greek mariculture Industry during the period 1986-1994, (Report on SELAM, Network, Montpellier – France, 1995) showed that the loss of 70 cages, with loses valued of 1.76 million US$ which in terms of production is about 3000 tonnes of fish, was due to bad climatic conditions. Very recently, February 2001, the full production of a cage farm in Israel with about 200 tonnes was lost to the open sea due to very bad weather conditions, while in December 2001, due to extreme weather conditions, tonnes of fish escaped to the open sea in Cyprus.

Introduction and transfers of species

A number of fish, invertebrate and seaweed species have been transferred or introduced from one region to another for aquaculture purposes. A distinction has been made between the two kinds of movements, which differ in their purpose, and potential effect (Welcomme, 1988)

Transfers take place within the same geographical range of a species and are intended to support stressed population, enhance genetic characteristics or re-establish a species that has failed locally. Introductions are movements beyond the geographical range of a species and are intended to insert totally new taxa into flora and fauna.

The problem associated with transfers and introductions have been well studied and recorded (Rosenthal, 1976, Welcomme, 1988, Murno, 1988, Turner, 1988). This movement can pose risks to human health the integrity of ecosystem, aquaculture and related primary industries.

Example of the type of disease problem which have arisen in the past from such movements are illustrated by the transfer of salmon moults from Sweden to Norway and Finland and of Japanese oysters (*Crassostrea gigas*) to France (Murno, 1988).

<u>*Human health impacts*</u>

The major public health concern associated with mariculture is the consumption of products raised in unhygienic conditions. Many fish farms located near the coast are often contaminated with human pathogens (eg. bacteria and viruses). Some of these pathogen belong to such genera as *Salmonella, Shigella, Vibrio* and *Escherichia.*

Many outbreaks of human diseases are associated with the consumption of fish products that are raw or well cooked. It was clear from the result of major cholera epidemic in Italy during 1973 that contaminated molluscs could be effective vectors of *Vibrio cholerae* (Baine, 1974). The cholera epidemic in Naples, the coastal regions of Campania and Puglia and in Sardinia resulted in 278 confirmed cases.

Although such episode has not been reported since then in the Mediterranean, Naples-type outbreaks could occur anywhere, especially as El Tor cholera is pandemic and airline travel permits the rapid dissemination of pathogens through susceptible populations. It has been estimated that human cholera patient may excrete 10^3 organisms/day. These organisms could contaminate shellfish beds via improperly treated sewage (GESAMP, 1991).

The occurrence of toxic species of phytoplankton represents a considerable threat to the economic sustainability of coastal aquaculture development in many countries. A relatively small number of algal species produce a range of toxins. Human illness and death have resulted from the consumption of phycotoxin-contaminated shellfish during red-tide (toxic algal blooms) outbreaks (Hallegraeff and Maclean, 1989, Shumway, 1990).

Several toxins are responsible for paralytic shellfish poisoning (PSP) (Sullivan, 1988), which is perhaps the most well documented group of phycotoxins. The toxins are produced by several dinoflagellates, including *Alexandrium tamarense, Gymnodinium catenatum* and *Pyrodinium bahamense.*

Human illness has also been attributed to the consumption of fish containing saxitoxin. There is however, no evidence of human illness as a result of consumption of farmed fish containing phycotoxins.

A group of toxins are responsible for diarrheic shellfish poisoning (DSP). Diarrheic shellfish poisoning which is caused by another group of dinoflagellates (*Dinophysis* and *Procentrum*) has been reported in many parts of the world.

Amnesic shellfish poisoning (ASP) recorded for the first time 1987 in eastern Canada (Bernoth, 1990) affects the nervous system. The chemical compound for ASP is domoic acid a neuroexcitatory aminoacid produced by the pennate diatom *Nitzschia pungens*.

In some coastal regions the occurrence of toxic species and toxicity in bivalves is almost an annual event and this has necessitated the establishment of extensive programmes to monitor bivalve stocks. Most European countries have routine monitoring programmes for PSP and DSP.

The wide application of drugs (antibiotics and other chemicals) in intensive fish farming can pose healthy hazards from drug residue in produce destine for human consumption. In Taiwan, 8% of eels and 3% of shrimp (*Penaeus japonicus*) have measurable amounts of drug residues (ADB/NACA, 1991).

While therapeutant residues resulting from aquaculture treatments may not appear to be so significant hazard to human when considering the extremely small number of cases reported, producers must be alert to the significant public concern created by potential residues (Armstrong, 1997).

There is potential for some compounds used in mariculture to also pose health risks to site workers. Some chemicals such as organophosphates must be handled with respect especially those in concentrate form. If proper health and safety precautions for handling aquacultural compounds presenting significant health risk to humans are enforced, the operators' risk will be minimised.

Increasing attention, particularly in the developed Mediterranean countries has been given to assuring food safety in the consumer. Legislative and institutional measures have been developed to provide food that is hygienic and free of pathogens and contaminant substances that could cause ill health.

Issues such as BSE (Bovine Spongiform Encephalitis) and dioxin contamination have contributed to higher public awareness of this topic. However both of these issues have an additional dimension that of the procedures used in farming. In these examples, the very nature of the components of the feeds has been highlighted, raising doubts as to the viability of the materials used and to the integrity of livestock feed manufacture.

Additional complex issues are entering the debate nowadays, for example, the potential use of genetically modified feed materials and fish is being discussed and questioned by many different interests (Hough, 2001).

o ***Urban centres***

- *Municipal waste waters in coastal cities around the Mediterranean Sea*

The major problems identified as related to uncontrolled waste discharges into the sea are:

- deterioration of the quality of marine ecosystems due to eutrophication, resulting from the extended release of nutrients and other organic and inorganic pollutants.
- toxic effects on aquatic fauna and flora - and subsequent effects on human beings, due to various substances reaching the marine ecosystem.
- the dispersion of pathogenic agents, generating risks for public health.

• *Contamination due to organic matter, potential consumer of oxygen*

In coastal areas, the discharge of degradable organic matte is considered to be a cause of degradation through the excessive consumption of dissolved oxygen, leading to low oxygen levels, but only in a number of cases which are undoubtedly specific. Certain tidal estuaries, for which the catchment basin is subject to a very high level of urbanization and the waste from a high population density, have very low levels of dissolved oxygen. The role of the tide is important, firstly due to the morphology that it gives to estuaries, which are fairly confined environments, and secondly due to the formation of a muddy barrier which traps organic material and heterotrophic and nitrifying bacteria, thereby permitting the development of an intense level of biological oxygen consumption. This type of impact is clearly of low significance in the Mediterranean, where there are only a few deltas (such as the Ebro delta) in which the waters are anoxic. This is due to the long periods spent there by saline water, polluted by discharges upstream and confined by the presence of a sandy barrier at their outlet. Certain lagoons subjected to urban discharges may suffer the same effects depending on their hydrology, in the same way as port areas and very enclosed coves.

One of the consequences of organic pollution in the marine environment, and particularly of particulate organic pollution, is also the marked deterioration of the local environment close to outfalls of untreated or only slightly treated waste waters. Organic particles and other debris may totally cover the bottom and the flora, which evidently profoundly perturbs the ecosystem.

• *Eutrophication and dystrophies, the consequences of excessive discharges or imbalances in nutrient salts*

The problems of eutrophication in the coastal environment are widely studied throughout the world in view of the increase in outbreaks of dangerous or merely noxious species. There are still many uncertainties with regard to the conditions for the occurrence of these blooms, with many influential factors coexisting in relation to the nutriments present, as well as the physical characteristics of the environment (intensity of the vertical mix, down-wellings, the luminosity of the water column). Although considered to be oligotrophic, the Mediterranean Sea is not exempt from these problems.[1] They have existed for a long time, are located in coastal areas and may be very concentrated (particularly in ports). This tends to suggest that

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[1] The recent HAB2000 Conference (Harmful Algal Blooms, University of Tasmania, Australia), for example, noted many outbreaks of toxic algae in both the Eastern and Western Mediterranean over a long period (*Alexandrium minutum* was discovered in the port of Alexandria in 1956). The blooms appear to be confined to coastal areas that are rich in nutriments, with ports constituting areas that are very rich in these substances and have little turbulence, and are therefore very favourable to them. One general idea is that the development of dinoflagellates to the detriment of diatoms results in an N/Si imbalance, although much remains to be done in terms of identifying the relative significance of the various determining factors.

local sources, possibly urban, may play a determining role in the appearance of these blooms.

It should be noted that urban waste waters are not the only sources of nitrogen and phosphorus in catchment basins, just as they are not the only sources of degradable organic material. However, urban sources of pollution tend instead to be characterised by their geographical concentration in catchment basins or the coastal environment. A concentrated source is particularly harmful where it is liable to give rise to rapid effects before being dispersed by the processes of dilution and dispersion. For example, the impact of urban areas in terms of the deoxygenation of rivers rapidly became very evident. The impacts of urban areas on eutrophication are less clear cut, partly because other sources of nutrients also make a major contribution to trophic dysfunctions, and also because the pace of development of an algal bloom is slower than that of a bacteriological bloom (oxygen consumption), particularly since heterotrophic bacteria are themselves discharged with used waters. Therefore, the dilution and dispersion effects are more easily able to play a role in cases where there is a risk of eutrophication by weakening the impact of concentrated urban areas.

- *Micro-pollutants*

Urban waste waters also contain many micro-pollutants with widely varying characteristics, which have their origins in the whole range of human activities in urban areas. Reference may be made to metals (Pb, Zn, Cd, Cu), hydrocarbons (including PAHs), fuels, a great variety of cleaning products (surfactants and chelating agents), disinfectants and other intentionally toxic products (phytosanitary products, fungicides, …). Some of these are directly related to a specific industrial activity in a catchment area and this type of discharge cannot therefore be generalised for a whole series of cities. Others are related to generic activities, such as road traffic and transport (lead in petrol where leaded petrol is still used, as well as the corrosion of wearing parts, emissions from combustion), corrosion (copper and lead in pipes, zinc from roofs and from many urban and road signs), dusts (from urban heating, incinerators, …) and certain widespread small-scale commercial activities (solvents from laundries, mechanical workshops, …). These pollutants are rarely measured in urban waste waters, but rather in the sludge produced by treatment plants, which is the level at which technical and political issues tend to be focused (re-use, composting of sludge for agriculture, compared with incineration and/or discharge in a dump). Data on treated and untreated waters are therefore more dispersed and rarer. It should be noted that a large proportion of such pollution, which might be qualified as diffuse urban pollution, is transported by storm waters and is therefore directly evacuated to the receiving environment despite its toxicity, which has recently been confirmed.

- *Pathogenic pollution*

This last type of urban pollution, namely pathogenic pollution, is both the least well-known and the most sensitive. It is the most sensitive type of pollution because it directly affects human beings by facilitating the transfer of diseases both directly through water (drinking and bathing waters) and through the products of acquaculture and fishing (particularly shellfish). It is also the oldest, since it was the development of hygiene and the importance of water-borne diseases which lead to sanitation programmes in Europe. The chemical measurements made of water were mainly considered as indicators of contamination which could not otherwise be evaluated. Pathogenic pollution is also the least well-known because, except in the case of specific studies, we still today only use indicators of faecal, coliform and streptococcic contamination.

A very large number of pathogenic organisms may be found in waste waters, and particularly over 120 enteric viruses. Viral hepatitis and gastroenteritis are relatively frequent and often associated with the consumption of contaminated shellfish. Enteric protozoa can also cause diarrhoea, with *Giardia* and *Criptosporidium* being the most widespread. Finally, pathogenic bacteria (salmonella, pathogenic coli, …) are also present in large quantities. Diarrhoea is another symptom common to many of these infections, and can be fatal. The exact role played by municipal waste waters in the occurrence of these infections is not well-know insofar as many of these micro-organisms are also present in animals. However, experts believe that one of the principal issues in the Mediterranean is the micro-biological pollution of coastal waters and of shellfish due to the discharge of untreated or partially treated waste waters. The problem becomes even more serious when seen in the light of the constant increase in tourism and the corresponding demand for coastal waters fit for bathing.

The survival time of these pathogenic micro-organisms varies widely, which clearly raises the problem of the reliability of indicators. Indeed, the faecal coliforms used as indicators of pollution of faecal origin (which represents 90 per cent of the intestinal flora) have a much lower survival time than that of protozoans, which may survive several days, even in the marine environment, particularly through encystment, while 90 per cent of coli disappear in the marine environment in a few hours. It may be noted that sediments and shellfish themselves form an environment which in general extends the average life of micro-organisms.

- *Characterization of waste waters and treatment processes*

  - *Variability of waste waters*

One of the characteristics of waste waters is that their quality is very variable, as is the quantity of waste water produced per inhabitant. This variability has its origins in the diverse uses made of the land (the density of residential areas, artisanal activities, industry), individual and collective practices (whether arising from cultural and/or economic constraints) and the situation/organization of the sewage system. It is therefore necessary to be very cautious in making generalizations.

In general terms, it is difficult to obtain precise and statistically representative data on the quality of waste waters, or on the quality of the waters treated by plants. Table 4.48 shows the average concentrations of pollution indicators for waste waters in Mediterranean countries, which correspond fairly closely to physiological production levels, to which should be added a variable volume of pollution due to washing/cleaning type activities (Degrémont, 1989).

Table 4.48 **Average values of pollution indicators for waste waters in Mediterranean countries (kg/inhab/yr)**

	Egypt	**Italy**	**Turkey**	**France**
BOD_5[2]	10-15	18-22	10-15	24
SS	15-25	20-30	15-25	-
Total N	3-5	3-5	3-5	4.5
Total P	0.4-0.6	0.6-1	0.4-0.6	1.5[3]

Above and beyond these almost physiological discharges, one important source of variability is related to the use of detergents containing phosphates, which may multiply threefold the annual physiological discharge, which may attain 1.5 kg/inhab/yr. All industrial sources can clearly have a considerable effect on modifying loads. In particular, all industrial or artisanal activities based on vegetable or animal products can constitute dramatically important sources of organic pollution, and of other types of toxic pollution (tanneries, textiles/cotton, dye works, paper, slaughterhouses, catering, …).

[2] Ratio COD/BOD_5 of 2 to 2.5
[3] Presence of detergents containing phosphates: this value has been considerably reduced over the past ten years.

The other major source of variability is related to connections and the sewage system itself. The volume of leakages can be very significant in both of these respects, based on the piezometric level of the groundwater. It leads to a loss of dissolved matter to the groundwater or a dilution through the infiltration of groundwater, resulting in a decrease in pollution loads in the first case and mere dilution in the second. It may be noted that a leaky system may give rise alternatively to both types of discharge, according to whether the groundwater is above or below the level of the collector. These leaks may be compounded by intentional emptying (such as water from foundations, although this is not very likely in countries with a dry climate). Branch pipes are also a major source of variability, both in terms of the volume and quality of water.

The concentrations are therefore highly variable. Table 4.49 gives an overview of indicative levels of concentration based on both reference works and waste waters from major Western cities, as well as a number of specific cases in the Mediterranean region. This overview is evidently not intended to be exhaustive. Reference has been made above to the difficulties involved in producing a statistically significant synthesis. Nevertheless, generic data based on the technical experience of operators, combined with a number of specific cases, undoubtedly provide a picture that is fairly close to the real situation.

Table 4.49 **General characteristics of waste waters**

	Henze et al., 1996	Degrémont (1990)	Amman (Jordan)[a]	Boujaad (Morocco)[b]	Nice (France)	Istanbul (Turkey)[c]
BOD_5 (mg/L)	100-350	100-400	770	45	210	
COD (mg/L)	210-740	300-1000	1830	200	460	410-870
Total N (mg/L)	20-80	30-100	150	29	40	
Total P (mg/L)	4-14 (6-23 with detergents)	10-25	25	4	7	
SS (mg/L)	120-450	150-500	900	130	20	
Coli/100 mL	10^8	10^7-10^8				
E. coli or faecal coli per 100 mL	10^7	10^6-10^7			10^7	

[a] Pescod, 1992. [b] Hussein et al. 2002. [c] Ohron et al., 1997

In general, the metal content of waste waters is poorly documented. Measurements on sludges are considered more reliable and representative. Indeed, it is possible to obtain national average assessments of the metal contents of sludge from water treatment plants. Table 4.49 gives the values of the metal content of sludge for various countries. Unfortunately there are no data for the whole Mediterranean region. It should nevertheless be noted that several Mediterranean countries still use leaded petrol, undoubtedly resulting in more significant loads of lead, despite the differences in car ownership per capita.

Based on data for the tonnes of sludge produced by wastewater treatment plants in each country, it is possible to calculate the average production per inhabitant of metals in waste waters, taking into account the efficiency of wastewater plants in eliminating metals. The reference work by Henze et al. (1996) proposes indicative figures for concentrations in waste waters. Considering an average production of water per inhabitant of 200 L/day, figures are reached for the annual production of metals of 15g of zinc, 0.15 g of cadmium and mercury, 5g of copper and lead and 1.5g of chromium. These figures largely concord with the estimates based on sludge.

However, it should be noted that these estimates of metal loads in urban waste waters are highly dependent on the management of industrial waste in cities. The problems related to the management of sludge in Europe and water policies have lead cities to take measures to prevent the discharge of industrial waste into sewage systems, which have resulted in a drastic decrease in metal loads in sludge. The example may be given of the city of Paris, where the age of the treatment system allows retrospective comparisons. Table 4.50 shows changes measured over the past 20 years in Paris. The spectacular decrease in cadmium leads is clearly due to an industrial effect (establishment of pre-treatment processes in enterprises and certain delocalizations). While the role of industrial waste discharged into municipal systems on the level of contamination cannot be doubted for other metals, it is known that there have been other reasons for these decreases (such as the lead content of petrol).

Table 4.50 **Average metal content of sludge from treatment plants**

	Average content in sludge (France)	Annual production of metals in waste waters in France (g/inhab)	Decrease over 20 years City of Paris (mg/kg)	European national maximum
Mercury	2.7	0.05	12 to 5	3.2
Lead	133	2.5	1200 to 250	217
Copper	334	6	200 to 1000	473
Chromium	80	1.5	500 to 100	208
Cadmium	5.3	0.1	140 to 10	5.3
Zinc	921	20	5800 to 2200	1550

In conclusion, while the final findings of evaluations made in France of metal loads in discharges per capita for urban waste waters are being used, it is clear that only detailed analysis of the relevant industrial activities and the manner in which they are linked to the sewage system in each city can provide a basis for refining these assessments.

- *Types of treatment: Description and effectiveness*

The great variety of technical solutions currently used for the treatment of waste waters is due to differences in the local historical situation and to various technical and economic constraints (geo-technical, the cost that can be borne by the community, quality objectives for water, the availability of land, the destiny of sludge, …). Within a single technology, many variants may be proposed, leading to different levels of effectiveness (Table 4.51).

The quality objectives required would be another manner of addressing the issue, although it would be too uncertain because many treatment plants are undersized or badly managed (particularly in the case of small plants), while on the other hand many managers of plants have no hesitation in going beyond their objectives when they are able to do so. It is therefore necessary to confirm theoretical estimates through data collected on site.

The efficiency of these traditional treatment techniques for pathogenic pollution is much less known, since the plants are not designed for this purpose and are not therefore monitored for these parameters. Furthermore, they may be expected to vary in efficiency depending on the type of parameter used to assess pathogenic pollution (bacteria, viruses and protozoa). In practice, the two main treatment techniques used in these systems are sedimentation (for fixed or flocculable micro-organisms) and vibration ("broutage"), and the effects of these two processes on the various types of organisms are probably very variable. Reference may be made in this respect to the recent results of Pierre Servais in the PIREN-Seine research programme using a homogenous methodology and covering several representative plants using a broad range of techniques for faecal coliforms.

Table 4.52 below summarises the results obtained. It should be noted that these results consist of a count of faecal coliforms applying traditional techniques based on the use of agar. It would appear that two recent technologies, in which UV plays an important role, perform much less well in the case of non-cultivable bacteria.

Table 4.51 **Theoretical efficiency of the various types of treatment (Mémento Degrémont, 1989).**

	SS		BOD_5		COD		N_{total}		P_{total}	
	Effic.	Typ. conc.	Effic.	Typ. conc.	Effic.	Typ. conc.	Effic.	Typ. conc.	Effic.	Typ. conc.
PS	40-60		20-35		20-35		5-10			
PC	80-95	20	40-65	100	40-65	150	10-15	50	80-90	1
AS average load	90	30	90-95	30	80	90	15	50		
Extended aeration	90	30	95-98	20	80	90	90*	5		
PS and AS average load		30	90-95	30	80	90	15	50		
PS and AS low load	90	30	95	20	80	90	90*	5		
PC and bacterial bed	85	45	80	60	75	120	10-15	55		
PC and BF with nitrogen treatment	95	15	90	30	80	90	15	50	80-90	1
PS and AS average load and BF	95	10	95	10	90	50	90	5		

All figures for efficiency in percentages, concentrations are in mg/L
PS = primary sedimentation; PC = physical/chemical; AS = activated sludge; BF = bio-filter
*These performances concern “total” nitrogen from plants, that is to say reduced nitrogen. These performances attain 70 per cent only if “global” nitrogen is taken into account, including nitrates, where plants are equipped for denitrification.

Table 4.52 **Performance of the various types of treatment plants for faecal coliforms**

	Reduction (decimal log)
Primary sedimentation	0.2
Activated sludge	1
Activated sludge + nitrification	1.6
Activated sludge + nitrifying bio-filter	1.7
Activated sludge + nitrification + denitrification	2.5
Bio-filters, nitrification and denitrification	2.8
Placed in holding reservoirs	4
Activated sludge + filtration + ultraviolet disinfectant treatment	5.3

- *Urban storm waters*

The quantities of pollution released by urban storm water are increasingly a matter for concern. In practice, in relation to installed treatment plants and sewage systems, these sources of pollution, which were considered to be secondary a few years ago, are taking on relatively greater importance.

Urban waste waters in rainy weather are composed of the overflow from combined systems and direct discharges of urban storm water in the case of separate systems. In a combined system, all the waters are evacuated by the same system, which generally becomes saturated during rainy periods, making it necessary to have recourse to holding reservoirs to prevent the city being flooded by a mixture of waste waters and storm water in the system. In separated systems, the storm water drainage system must not receive waste waters, which is unfortunately too infrequently strictly the case, and the wastewater system must not be infiltrated by other waters.

Urban storm water is polluted by all the dusts and wastes accumulated on the road systems and may have very significant pollution loads. Moreover, as it is normally considered to be unpolluted or only slightly polluted, and with significant volumes, it is often discharged in the close vicinity in order to prevent flooding. As a result, rivers in cities are often directly influenced by these waters. Storm water raises real environmental and economic problems, as the bacteriological quality of the beaches is a major advantage in attracting tourists to a city. Considerable investments are therefore made to prevent such overflows, even for storm water in very wet periods. Furthermore, it is necessary in the management of storm water to reconcile the preservation of the quality of the coast and the elimination to the maximum possible extent of the risks incurred by the population in the event of violent rainstorms and flash floods, which are characteristic of the Mediterranean climate.

The quality of storm water has been studied in various European cities as a result of local initiatives or within the framework of national programmes. These are necessarily major studies, since the volumes and quality of the water are extremely variable during a single episode of rainfall, or between such episodes. Reference is made to the case of France, a Mediterranean country in which a national assessment has been undertaken through the QASTOR database (Saget et al., …). We have no knowledge of any other such initiative in other Mediterranean countries.

The following data (Table 4.52), drawn from the above database, show the great variability of values as a result of several factors, of which the precise significance is not yet known:

- the quality of the system, and infiltration, which is clearly a deterioration factor of primary importance;
- the existence of industrial or commercial areas, major road systems, transport in general and the number of cars (metallic dusts, used or unused hydrocarbons, …);
- the means used to clean roads;
- construction (corrosive materials, methods of heating, …); and
- the maximum intensity of rain and the duration of preceding dry periods.

Table 4.53 **Characteristics of water during periods of rainfall: Pollution loads**

Pollutant	Unit	Type of system		Water in dry weather (reference)
		Separate	Combined	
SS	kg. per active ha.	1300-6700	1700-3400	
	mg/L	160-460	240-670	100-500
COD	kg. per active ha.	670-4500	1550-4200	
	mg/L	80-320	350-570	250-1000
BOD_5	kg. per active ha.	100-450	810-1490	
	mg/L	13-130	90-270	100-400

The impermeable surface area per inhabitant is around 0.006 ha. in two case studies (Tunis and Marseilles). Based on this figure, estimates can be made for the run-off of storm water per inhabitant per year. These figures are merely indicative, partly because the ranges are wide, and also because climatic, urban, demographic and economic conditions, and the sanitation programmes in each city, lead to variations. As a final figure per inhabitant per year, the estimates range from 7 to 40kg of SS, 4 to 25 kg of COD and 0.5 to 2.5kg of BOD_5 for a separated system, and from 10 to 25kg of SS, the same for COD and from 4 to 8kg of BOD_5. It is clear that these loads are not systematically negligible when compared with those of treated waste waters.

Data on loads of metals, hydrocarbons and other micro-pollutants are extremely variable depending on the intensity of land use and, although indicative figures exist for specific surfaces such as roads and certain types of roofing, we are still far from being able to propose indicative figures for the loads released based on a complex pattern of land use.

The most widely used pesticides in urban areas are herbicides. These generally consist of non-specific herbicides acting on foliage or roots (and therefore remaining in the soil). The most common in urban areas, particularly in France, are diuron, glyphosate and aminotriazole. They are used both for the maintenance of green areas and private gardens, and for the maintenance of road systems. The two types of uses contribute to the pollution of storm water, as shown by specific studies undertaken on experimental catchment basins. In a city in which no programme has been established to limit the use of phytosanitary products, the concentrations obtained in storm water frequently exceed 1µg/L, and are comparable with concentrations for water basins of equal surface area of principally agricultural use. A good indicative figure for the transfer coefficients is around 3 to 5 per cent in typical peripheral urban housing areas. Other uses (road systems, protection of railways) are liable to give rise to higher volumes in storm water, but almost no data are available concerning catchment basins of significant size. A study on a catchment area with nearly 4 million inhabitants in the Parisian suburbs led to the conclusion that around 30g of herbicides are used per inhabitant and per year (for all uses in urban areas, of which 50 per cent is used by private individuals in their gardens), of which between 1 and 2g are likely to be found in storm water. This is the best indicative figure that it is possible to propose and corresponds to a situation in which no policy has been established to restrict their use.

Certain municipalities (particularly Algiers) also use insecticides in large quantities, especially during the summer, to keep down the numbers of flies and mosquitoes. This use of pesticides for health reasons is a significant additional source of pesticides, but no information is available on the real scale of this practice around the Mediterranean.

Data on hydrocarbons (particularly PAHs) are available for sludge from treatment plants. However, these micro-pollutants act in a much more complex manner than metals in water treatment systems and it is not therefore possible to use a mere indication of their loads in sludge to extrapolate the amounts produced by each citizen. Furthermore, their concentrations in waste waters are extremely variable, increasing significantly during rainy periods. Another source of variation is the absence of a unanimously recognised definition of the “sum” of PAHs. The United States Environmental Protection Agency recommends the use of the sum of 16 PAHs, while France for the composting of sludge from treatment plants focus on only three PAHs (evidently the most persistent PAHs). Comparisons are therefore very complex and general indications of concentrations in storm water provided by the literature are also very variable. It would therefore appear illusory to propose an indicative level applicable to the Mediterranean. It may merely be recalled that the indicative figures for the volumes produced by the sewage system in Paris are around 75kg a year for three PAHs (fluorine, B(a)P and B(a)F), and that these figures are confirmed by the loads discharged in sludge from treatment plants, which correspond to the discharge generated by around 5 million inhabitants for whom the storm water is connected to a combined system. This gives a value of 15mg per inhabitant and per year, which is a purely indicative figure and should not at this stage of knowledge be used for the purposes of extrapolation.

- *Evaluation of loads released by Mediterranean coastal cities*

This evaluation is based on the synthesis offered by UNEP (2000), providing estimates of the populations served by water treatment plants, the populations linked up to the system and the volumes discharged. The data are incomplete as it was not possible to obtain the necessary information from all countries. However, note should also be taken of the differences, as well as very discordant data. Before assessing the loads discharged by all these urban centres, an analysis will be made of the principal problems encountered.

- *Analysis of data made available by UNEP*

Spain and France chose not to indicate the populations connected to the treatment plants or to the sewage system, but inhabitant-equivalents. In the case of France, these inhabitant-equivalents are in practice the dimension of the treatment plant. This figure does not therefore bear any relation to the quantity of pollution actually treated and the two types of data are only equivalent when the plants are ideally sized, which occurs rarely and in any case only for a short time, as populations evolve.[4] In the case of Spain, the inhabitant-equivalents are given even for towns which do not have treatment plants, and these figures therefore relate to dimensions that are wished for or planned for treatment plants that are to be built. As in the case of France, these figures relate to the size of the treatment plants and not pollution loads.

Other countries only provide figures for the population served by treatment plants and the population linked up to the system. In these cases, the figures relate to the number of individuals and no longer consist of pollution-equivalents (which may include pollution of industrial origin).

The figures given for the volume of water discharged or treated are very uninformative. Table 4.48 recalls that the volumes discharged can differ greatly for cultural and technical reasons from one country to another, but also from one city to another in the same country, while the level of pollution released by a person in a city is less variable. A large proportion of the water entering the waste water systems may come from air-conditioning plants, street cleaning, infiltration (the drainage of groundwater or wells through the system) and water pumped out (for example, from underground parking lots and underground railways). Many of these not strictly domestic uses of water are more significant in the larger cities, thereby introducing a strong bias in the relationship between the quantity of pollution and the volume of water discharged. Pollution loads, even if the only parameter measured is BOD_5, constitute much more relevant data.

In certain countries, an inhabitant-equivalent is used in terms of water volume. One example is Algeria, which proposes an inhabitant-equivalent of 120 L/inhab/day to estimate volumes in many cities. In certain cities, more precise estimates are made. In other cases, the volumes of water reported do not appear to be a product of this type of standardised calculation. It is sometimes impossible to relate them either to the actual populations, to the size of the treatment plants (inhabitant-equivalents), or to the populations linked up to the system, as the volumes obtained per inhabitant and per day are either much too low (some tens of litres per inhabitant per day) or much too high (over $1m^3$ per inhabitant per day).

There remain inconsistencies with regard to the manner in which these estimates have been made. In this respect, there are three main possibilities: (i) either an estimate of the population, including seasonal increases which may be very significant, has been multiplied

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[4] The case study of Nice illustrates this point: the average daily load of BOD_5 is equivalent to 375,000 inhabitants (for around 350,000 real inhabitants) with an inhabitant-equivalent of 60g of BOD_5 a day according to European standards, whereas the treatment plant is designed for 690,000 inhabitant-equivalents.

by an inhabitant-equivalent; (ii) measurements have been made; or (iii) the volumes of water distributed and billed for are used to give an approximate volume. In the case of (i), a figure for the population used for the calculation would have been more informative. In the case of (ii), it would appear that if measurements of volume or discharges have been established, data for BOD_5 are very probably also available and it would be preferable to indicate a daily load of BOD_5 rather than a volume of water.

Seasonal variations are difficult to assess. In certain cases, cities with very wide seasonal variations have been mentioned, without it necessarily being possible to assess the number of inhabitants during the high period. In many cases, the populations linked up (to the treatment plant or the system) are higher than the total population, undoubtedly taking into account the seasonal population.

It is therefore proposed that the following elements should be considered in priority if a new survey or a more continuous monitoring process is launched. Table 4.54 is based on BOD_5, which remains the basic parameter for sanitation, although other parameters could be added. Nitrogen and phosphorus would be particularly important in the context of coastal eutrophication phenomena.

Table 4.54 **Proposed working basis for the establishment of assessments of coastal cities around the Mediterranean**

	Indicator	Comment
1	Population of the urban centre	
2	Population linked up (sewage system + plant)	
3	Population linked up (sewage system only)	
4	Indication of destination of waste water for population not linked to the system	
5	Additional load of industrial pollution in the sewage system (and the plant)	
6	Size (in European inhab.-equiv.[5], 60 g/inhab/day) of the plant, and type.	If possible indicate another inhabitant-equivalent that is more representative of the country or region – in this case, specify further.
7	Type of plant	Type = primary, secondary, physical/chemical, tertiary, etc…. Specify whether tertiary plants carry out nitrification, nitrification + denitrification
8	Outfall	Location
9	Pollution load entering the plant as annual average (in tonnes of BOD_5 per day)	Specify whether these are measurements or estimates based on the number of inhabitants linked up
10	Where possible estimate of percentage of load of industrial origin	

[5] It should be recalled that inhabitant-equivalents are primarily a unit for the measurement of pollution loads. This measure should be close to the pollution discharged per inhabitant in an urban centre (for all sources of pollution), but there is a wide variation between countries and between urban centres in the same country.

	Indicator	Comment
11	Pollution load discharged by the plant after treatment (in tonnes of BOD_5 per day)	Specify whether these are measurements or estimates based on the plant's theoritical efficiency
12	Pollution load entering the plant in the three heaviest months in case of tourism (in tonnes of BOD_5 per day)	Specify whether these are measurements or estimates based on the number of inhabitants who are linked up present during the three month period
13	Pollution load released by the plant during the heaviest three months (in tonnes of BOD_5 per day)	Specify whether these are measurements or estimates based on the theoretical efficiency of the plant

- *Loads released into the Mediterranean by coastal cities (waste water from treatment plants and direct discharges of waste waters)*

The information contained in "MAP technical reports series No. 128" has been used as follows.

1. For all countries except France and Spain, a calculation has been made of the volumes entering treatment plants from the populations linked up to the plants and the loads discharged directly from systems based on the populations linked up to the system. These data have been considered valid for a year (the discharges are therefore overestimated for cities for which the population figures provided are seasonal maxima). The inhabitant-equivalent has been determined as follows: 20 kg-BOD_5 per year for the countries of the European Union and Israel, and 12.5 kg-BOD_5 per year for the other countries; 4 kg of N per year; 0.6kg of P per year; and 0.02 kg of Zn per year. Industrialization, and particularly the level of treatment of industrial waste, are the two preponderant factors which can lead to variations in such indicative values. Based on the relationship between the concentration of faecal coli and BOD_5 in waste waters, an inhabitant-equivalent of faecal coli of $20x10^{12}$ colonising organisms per year has been determined. These figures are arbitrary and are dictated by the weakness of the information available.

2. In the case of France and Spain, the figures taken are for the real population and not inhabitant-equivalents, since the sizing of the treatment plants (the only information provided) may be based on many criteria other than the actual population. Major loads from peaceful industries and seasonal influxes may therefore have been underestimated.

3. The performances of treatment plants have been assessed on the basis of the data provided above (Tables 4.50). A performance of 80 per cent has been indicated for all metals, except for primary sedimentation (only 70 per cent). The assessments made for Zn may therefore be easily transposed to other metals based on the data on annual loads provided in Table 4.51

4. In the absence of a treatment plant or in the case of a planned treatment plant or one that is not in use, it has been considered that all the pollution is released directly (equivalent to being linked up to a system without a treatment plant).

The results of these indicative calculations are shown in the following tables. Clearly, the quality of these results is subject to the same reservations as those mentioned in MAP report No. 128, concerning the quality of the data and certain extrapolations or corrections which had to be made to them. Furthermore, they concern the installations as they were when the survey was carried out. Planned plants may subsequently have been constructed, plants which were out of service may have been rehabilitated or, in contrast, planned plants may have been abandoned.

No information is available concerning the type of sanitation network, whether separate or combined systems, in Mediterranean coastal cities. The case studies all show that the tendency is for combined systems in old city centres and for separate systems in the surrounding urban areas. Urban populations have therefore been split equally between combined and separate systems.

Clearly, the specific characteristics of storm water run-off through a combined network has no meaning except where there is a treatment plant, since it is by definition waste that is untreated by the plant for hydraulic reasons. These discharges have therefore only been calculated for the proportion of the population linked up to a treatment plant (Table 4.55).

The estimated average efficiency of treatment plants is 67 per cent, with this figure reflecting the mix of biological (secondary) and primary treatment plants in existence. The efficiency is the lowest in Slovenia, Lebanon, Turkey and Croatia, where the treatment plants installed consist exclusively of primary treatment plants. The average efficiency in Greece is lower than that of other countries in the European Union due to the high proportion of plants based on primary treatment. Other countries which have opted for secondary and tertiary systems in their great majority have average performances approaching 90 per cent. However, these countries are not for the most part in Europe. There is therefore a very surprising panorama of the existing treatment plants which probably reflects differences in the organization of programmes, but in which geographical and economic groupings are not clearly identifiable.

Table 4.55 **Structure of urban discharges by country for BOD_5. All BOD_5 figures are in ktonnes/year**

Country	Load	Treat. plant			Untreat. waste	Storm	Not collect.	Prop. collect.	Of total discharge, relative importance of		
	pop. x inhab.eq.	Input	Output	Av. effic.					Plant disch.	Direct disch.	Storm waters
Albania	0.0	3.3	3.3	0.0	1.0	1.0	0.0	0.2	0.2	0.0	5.2
Algeria	9.9	17.5	27.4	7.6	5.6	13.2	1.1	0.8	2.0	11.8	28.0
Cyprus	0.2	1.0	1.2	0.2	0.3	0.5	0.0	0.0	0.1	0.2	1.6
Croatia	3.0	4.4	7.4	1.1	1.4	2.5	0.1	0.2	0.4	3.6	7.0
Egypt	8.3	37.1	45.4	4.0	11.9	15.8	0.6	1.8	2.3	10.1	59.3
Spain	30.5	38.5	68.9	13.0	7.7	20.6	2.0	1.2	3.1	22.9	38.5
France	20.9	0.3	21.2	8.2	0.1	8.2	1.0	0.0	1.0	5.7	0.3
Greece	58.6	16.4	75.1	17.1	3.3	20.4	2.4	0.5	2.9	44.4	16.4
Israel	9.9	0.0	9.9	8.8	0.0	8.8	1.4	0.0	1.4	8.1	0.0
Italy	32.3	144.2	176.6	16.1	28.8	44.9	2.6	4.3	6.9	25.1	144.2
Lebanon	7.2	24.2	31.4	2.6	7.7	10.3	0.3	1.2	1.5	8.6	38.7
Libya	3.4	0.5	3.9	1.7	0.2	1.9	0.5	0.0	0.5	3.5	0.8
Malta	0.1	1.2	1.3	0.1	0.4	0.5	0.0	0.1	0.1	0.1	1.9
Moroco	0.1	8.4	8.5	0.0	2.7	2.7	0.0	0.4	0.4	0.1	13.4
Monaco	0.2	0.0	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Slovenia	0.4	0.4	0.8	0.1	0.1	0.3	0.0	0.0	0.0	0.5	0.7
Country	Load	Treat. plant			Untreat. waste	Storm	Not collect.	Prop. collect.	Of total discharge, relative importance of		
	pop. x inhab.eq.	Input	Output	Av. effic.					Plant disch.	Direct disch.	Storm waters
Syria	0.0	12.5	12.5	0.0	4.0	4.0	0.0	0.6	0.6	0.0	20.0
Tunisia	4.1	10.8	14.9	6.4	3.4	9.9	1.1	0.5	1.6	5.4	17.2

Turkey	17.7	36.2	53.9	6.4	11.6	18.0	0.9	1.7	2.6	21.3	57.9
Total	**207.1**	**356.7**	**563.8**	**93.5**	**90.2**	**183.7**	**14.1**	**13.5**	**27.6**	**171.5**	**451.1**

The overall efficiency of the wastewater treatment system is only 42 per cent, which is fairly mediocre. Two countries have no wastewater treatment plants (Albania and Syrian Arab Republic) and several others eliminate a maximum of around 10 per cent of BOD_5 (Croatia, Lebanon, Morocco, Slovenia, Turkey and Egypt). It is clear that an effort is required to install treatment plants where they do not exist and to supplement primary treatment systems by secondary and more refined techniques.

Half of untreated pollution in terms of BOD_5 originates from direct discharges, under one-third from the discharges of treatment plants and the remainder from storm water during periods of rain. These proportions are extremely variable between countries, corresponding to differences in the sanitation systems, differences in the total population, but also partly the quality of the information used to establish assessments.

The country with the biggest loads from treatment plants is Greece, which can be explained by the total population of the country combined with the emphasis placed in treatment plants on primary treatment techniques. Turkey is in a similar situation, but with a lower population on the shores of the Mediterranean. These are followed by three high-population countries in which the system of treatment plants is more effective, but where the performance could be improved (Spain, Italy and France).

In terms of untreated waste, Italy is by far the country with the highest volume discharged (almost 40% of the total). Examination of the data provided shows that very many cities do not have treatment plants and that their systems discharge waste water directly into the sea. This situation weighs heavily in the assessment. Spain comes in second place, as many treatment plants have been planned, with their size being given in the survey, so that the situation should improve once they are constructed. Egypt is in third place, with an evident problem of an insufficient number of treatment plants and a major problem posed by the city of Alexandria. It should be noted that France is the country which discharges the least untreated waste water only because the replies supplied do not mention this type of discharge, but only the size of the treatment plants. However, in contrast with Spain, the treatment plants are all constructed, with one exception, which is a very positive point. It is nevertheless almost evident that certain direct discharges persist in reality, even if only through the erroneous connection of domestic waste waters to storm water systems.

As shown by Figure 4.21, a mere 18 cities (see Annex) contribute half of urban waste containing BOD in the Mediterranean, and five account for one quarter of this waste. These are Alexandria, Naples, Izmir, Barcelona and Beyrouth. Fortunately, significant sewage and sanitation programmes are under way in several of the cities, although it is clearly urgent to extend these efforts to others.

Figure 4.24 Wastes discharged by Mediterranean coastal cities

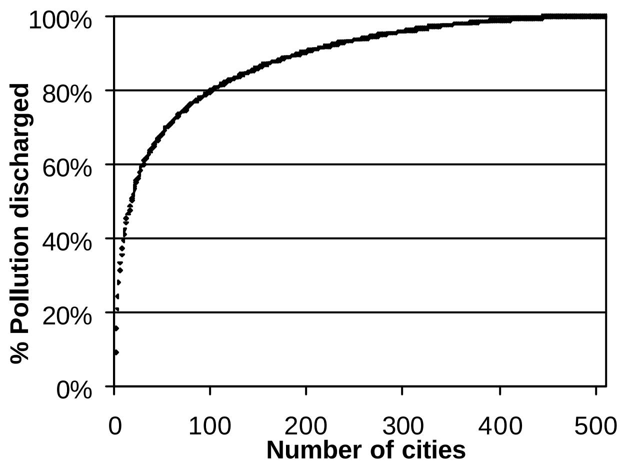

Table 4.56 **The 20 urban centres discharging the most BOD**

Country	Urban centre	BOD_5 disch. (kt/yr)
Greece	Athens	65.2
Egypt	Alexandria	43.6
Italy	East Naples	35.9
Turkey	Izmir	26.3
Spain	San Adrian del Besos (<-Barcelona)	25.7
Lebanon	Beirut	21.2
Spain	Barcelona	15.5
Greece	Thessalonica	14.9
Israel	Tel-Aviv	14.8
Italy	Palermo	13.0
France	Marseilles	12.0
Spain	Malaga	11.5
Algeria	Algiers	9.6
Algeria	Oran	9.5
Italy	West Naples	8.5
Turkey	Mersin	8.5
Tunisia	Tunis Centre	8.3
Italy	Bari-Barletta	7.7
Italy	Piombino	7.5
Italy	Catania	6.8

The global loads discharged are indicated in Table 4.57. It is interesting to compare them to the loads released into the Mediterranean by rivers and from the atmosphere (see section

4.1). In the case of nitrogen, the figures are 1011 kt by rivers and 1067 kt through the atmosphere. The 184 kt discharged by coastal urban centres therefore only accounts for around one-tenth of these two major sources of pollution and are of little significance at the level of the Mediterranean as a whole. Urban coastal sources are, however, highly significant at the local level in the case of towns which are not under the direct influence of a significant watercourse. These loads contribute very significantly to the trophic imbalances of coastal waters. In each local situation, a comparison of these loads should also be made with the loads released from other processes, such as up-wellings, which can bring very high quantities of nutriments from the depths.

Table 4.57 **Loads of BOD_5, N, P and coliforms released by coastal cities in the Mediterranean**

(wastewater treatment plants and outfalls of untreated waste waters (not including discharges during periods of rain)

	BOD_5 (kt/yr)			N (kt/yr)			P (kt/yr)			Coli/10^{15} (per yr.)	
	Plants	Direct	Total	Plants	Direct	Total	Plants	Direct	Total	Plants	Direct
Albania	0.0	3.3	3.3	0.0	1.0	1.0	0.0	0.2	0.2	0.0	5.2
Algeria	9.9	17.5	27.4	7.6	5.6	13.2	1.1	0.8	2.0	11.8	28.0
Cyprus	0.2	1.0	1.2	0.2	0.3	0.5	0.0	0.0	0.1	0.2	1.6
Croatia	3.0	4.4	7.4	1.1	1.4	2.5	0.1	0.2	0.4	3.6	7.0
Egypt	8.3	37.1	45.4	4.0	11.9	15.8	0.6	1.8	2.3	10.1	59.3
Spain	30.5	38.5	68.9	13.0	7.7	20.6	2.0	1.2	3.1	22.9	38.5
France	20.9	0.3	21.2	8.2	0.1	8.2	1.0	0.0	1.0	5.7	0.3
Greece	58.6	16.4	75.1	17.1	3.3	20.4	2.4	0.5	2.9	44.4	16.4
Israel	9.9	0.0	9.9	8.8	0.0	8.8	1.4	0.0	1.4	8.1	0.0
Italy	32.3	144.2	176.6	16.1	28.8	44.9	2.6	4.3	6.9	25.1	144.2
Lebanon	7.2	24.2	31.4	2.6	7.7	10.3	0.3	1.2	1.5	8.6	38.7
Libya	3.4	0.5	3.9	1.7	0.2	1.9	0.5	0.0	0.5	3.5	0.8
Malta	0.1	1.2	1.3	0.1	0.4	0.5	0.0	0.1	0.1	0.1	1.9
Morocco	0.1	8.4	8.5	0.0	2.7	2.7	0.0	0.4	0.4	0.1	13.4
Monaco	0.2	0.0	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Slovenia	0.4	0.4	0.8	0.1	0.1	0.3	0.0	0.0	0.0	0.5	0.7
Syria	0.0	12.5	12.5	0.0	4.0	4.0	0.0	0.6	0.6	0.0	20.0
Tunisia	4.1	10.8	14.9	6.4	3.4	9.9	1.1	0.5	1.6	5.4	17.2
Turkey	17.7	36.2	53.9	6.4	11.6	18.0	0.9	1.7	2.6	21.3	57.9
Total	207.1	356.7	563.8	93.5	90.2	183.7	14.1	13.5	27.6	171.5	451.1

Loads of metals are indicated in Table 4.58. The loads of lead and cadmium for coastal cities are low in relation to atmospheric contamination, being in the order of 1 per cent. However, direct discharges of zinc are significant. These data should also be compared with the estimated loads released by major rivers.

Table 4.58 **Loads of the various metals (t/yr) in discharges from treatment plants and of untreated waste waters from Mediterranean coastal cities**

	Zn	Cd	Cu	Pb	Cr	Hg
Urban loads except discharges when raining	619	3	186	77	46	1.5
Atmospheric loads	2523	743	-	7404	-	-

It should be added that where action is taken to combat pollution in urban waste waters, its impact in improving coastal pollution is as effective as expected, as shown by the table indicating the changes in the quality of bathing water in the city of Marseilles from 1981 to 2000 (Figure 4.25).

Figure 4.25 Changes in the quality of bathing water on the Marseilles coast since the beginning of the 1980s**.**

(Class A: good quality water. Class B: average quality water. Class C: water which may be polluted from time to time. Classe D: bad quality water).

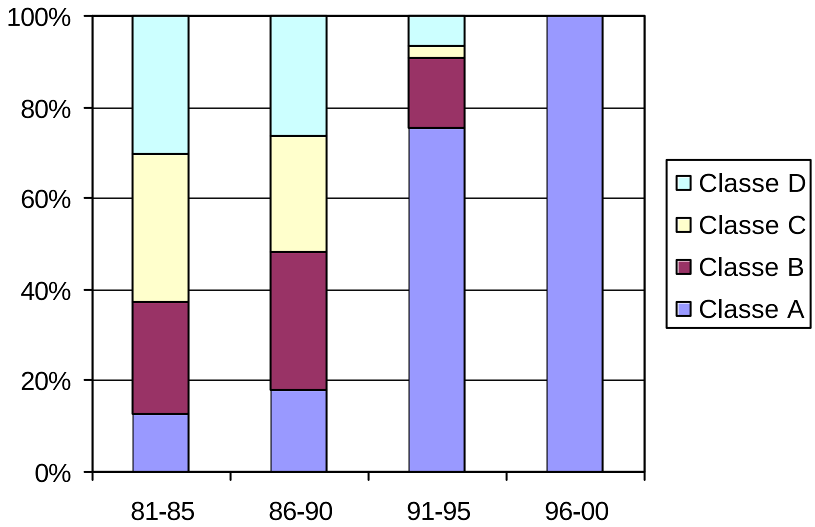

Table 4.59 gives figures for the loads of BOD, nitrogen, phosphorus and coliforms which would result from the total equipment of cities with primary treatment systems (or better where they exist), secondary or tertiary systems (treatment of nitrogen).

Table 4.59 **Loads discharged where all inhabitants are linked up to the system and all treatment plants are equipped for one type of treatment or more where they exist**

Country	Primary treatment				Physical/chemical treatment				Secondary treatment				Tertiary treatment (nitrogen)			
	BOD kt/yr	N kt/yr	P kt/yr	Coli/10^{15} (per yr)	BOD kt/yr	N kt/yr	P kt/yr	Coli/10^{15} (per yr)	BOD kt/yr	N kt/yr	P kt/yr	Coli/10^{15} (per yr)	BOD kt/yr	N kt/yr	P kt/yr	Coli/10^{15} (per yr)
Albania	2.7	1.0	0.1	3.3	1.7	0.9	0.1	0.1	0.4	0.7	0.1	0.5	0.3	0.2	0.1	0.3
Algeria	20.9	12.2	1.8	24.9	17.1	11.8	1.6	13.1	12.4	11.0	1.7	14.9	11.6	5.2	1.1	11.7
Cyprus	0.4	0.3	0.1	0.5	0.4	0.3	0.1	0.3	0.3	0.3	0.1	0.3	0.3	0.1	0.0	0.2
Croatia	9.9	3.5	0.5	11.8	6.2	3.2	0.3	0.2	1.5	2.4	0.4	2.0	1.2	0.6	0.2	1.0
Egypt	36.0	14.6	2.0	43.3	23.0	13.2	1.4	2.5	6.5	10.5	1.7	8.7	5.5	2.6	0.9	4.4
Spain	51.2	19.0	2.8	38.6	36.0	18.0	2.4	8.8	16.4	15.9	2.6	13.4	13.8	4.1	1.4	6.9
France	21.1	8.2	1.0	5.9	19.5	8.1	1.0	2.6	6.8	6.8	1.1	5.6	5.6	1.7	0.6	2.8
Greece	62.5	19.3	2.8	47.4	41.7	17.9	2.2	6.4	15.3	15.1	2.5	12.7	12.8	3.8	1.3	6.4
Israel	9.9	8.8	1.4	8.1	9.4	8.8	1.4	7.1	8.7	8.7	1.4	7.3	7.3	2.2	0.8	3.6
Italy	121.5	41.9	6.3	92.2	87.0	39.6	5.2	24.2	43.2	35.0	5.7	34.6	37.8	10.7	3.3	21.1
Lebanon	26.6	9.6	1.3	31.9	16.6	8.5	0.8	0.5	4.0	6.4	1.0	5.3	3.3	1.6	0.6	2.7
Libya	10.0	4.8	1.1	10.5	9.5	4.7	1.0	8.8	8.8	4.6	1.1	9.0	8.6	3.7	1.0	8.5
Malta	1.1	0.4	0.1	1.3	0.7	0.4	0.1	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.0	0.2
Morocco	8.8	3.2	0.5	10.3	8.8	3.2	0.5	10.3	8.8	3.2	0.5	10.3	8.8	3.2	0.5	10.3
Monaco	0.2	0.2	0.0	0.1	0.2	0.2	0.0	0.1	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.1
Slovenia	0.8	0.3	0.0	0.9	0.5	0.2	0.0	0.0	0.1	0.2	0.0	0.2	0.1	0.0	0.0	0.1
Syria	14.1	5.1	0.7	16.9	8.8	4.5	0.4	0.3	2.1	3.4	0.5	2.8	1.8	0.8	0.3	1.4
Tunisia	6.4	9.1	1.5	8.4	6.1	9.1	1.5	7.5	5.8	9.0	1.5	7.6	4.9	2.3	0.8	3.9
Turkey	53.4	19.9	2.7	64.1	33.6	17.8	1.7	1.8	8.5	13.6	2.2	11.3	7.1	3.4	1.2	5.7
Total	457.4	181.4	26.6	420.4	326.6	170.4	21.6	94.8	149.9	147.1	24.2	147.1	131.0	46.5	14.2	91.2

o Industrial activity

In the EEA report on the state and pressure of the marine and coastal Mediterranean environment (EEA, 2000), a description of the industrial activities in the Mediterranean region is presented. A general overview of the industrial activity in the region is given in section 3.6.

▪ *Sources of industrial pollution*

The specific sources of industrial pollution that are assessed in this report, are the following:

- industrial wastewater discharges,
- industrial solid waste disposal on the coastal zone,
- discharge via rivers, and
- atmospheric deposition.

As the last two have been the subject of separate chapters, only the direct industrial discharges will be considered here.

• *Land-based sources: industrial waste water*

At the time of adoption of the Barcelona Convention in 1976, it was estimated that more than 80% of the pollution load of the Mediterranean Sea originated from sources on land. These were mainly in the form of still largely-uncontrolled discharges of municipal and industrial wastes reaching the sea both directly from coastal sources and indirectly through rivers (UNEP, 1996b). The first survey of pollutants from land-based sources in the Mediterranean (MED X) was added to the initial list of MED POL Phase I pilot projects with the aim of providing documentary evidence of the state of land-based pollution of the Mediterranean Sea. This was added as one of the technical inputs into the preparatory stages of the protocol.

Relevant data on industrial pollution are summarised in Table 4.8 In general, on the basis of data received, it could be concluded that approximately 48% of the total amount of industrial process water is discharged untreated, while the remaining 52% is treated before discharge. Approximately 13% of the process water is discharged into municipal sewers, about 15% of this amount being treated. Approximately 14%, two thirds of which remains untreated, is discharged into rivers; 14%, again two thirds of which is untreated, on the shoreline, 1% is discharged on land or into septic tanks, and approximately 1.4% is discharged in an unspecified manner. The remainder, approximately 57% of the total amount of process water, of which 33% is untreated, is discharged into the sea directly or via outfall.

The amount of cooling wastewater is about four times greater than the amount of process water. This is quite a large magnitude normally disregarded in the water cycle analyses. The bulk (95%) of this is discharged untreated on the seashore, about 2% into rivers, and 0.5% directly into the sea. Less than 1% of the total cooling wastewater produced is discharged on land. Domestic wastewater from industry amounts to only 28% of the volume of process wastewater. Approximately 92% of domestic wastewater is discharged untreated, either on the shoreline (54%), into municipal sewer systems (36%) or on land (3%).

Table 4.60 **Types of waste water from industry and way of discharge (UNEP, 1996b)**

	Type of waste water								
	Process waste water			Cooling water			Domestic water		
	Untreated m^3/y	Treated m^3/y	%	Untreated m^3/y	Treated m^3/y	%	Untreated m^3/y	Treated m^3/y	%
Municipal system	15,947,125	2,906,734	12.6	3,002,094	-	0.5	10,133,345	595,260	25.9
River	13,582,751	6,458,838	13.4	6,996,300	2,930,400	1.8	1,286,932	554,375	4.4
On land	298,004	1,219,200	1.0	3,777,480	-	0.7	1,211,433	36,140	3.0
On shore	13,728,600	6,280,500	13.4	512,815,380	1,999,500	94.8	22,074,000	49,500	53.4
By outfall		19,536,000	13.0	3,600	0		0	0	
Sea	27,515,550	38,809,865	44.2	2,708,100	0	0.5	716,632	2,119,155	6.8
Lake				0	0		0	0	
Dam				0	0		19,200	0	
Sept. tank	884,086	586,980	1.0	0	0		693,672	1,515	1.7
Other	39,199	2,004,320	1.4	0	0		652,600	29,200	1.6
Total	71,995,315	77,802,437		529,302,954	4,929,900		38,041,159	3,385,145	

- *Industrial solid waste disposal*

It has been highlighted that for some countries dumping of industrial solid waste in coastal zones appears to be a significant source of pollution of the marine environment (UNEP, 2002). Some of the cases reported are presented below which do not include the EU countries:

Albania

Several kilometres north of the town of Durres, there was a chemical factory that produced chromium salts and other products, The solid wastes were deposited within the factory premises so today there is a contaminated area of approximately 5 ha covered by some 20,000 tonnes of waste containing 4-5 per cent of hexavalent chromium salts. In some places the depth of the layer reaches up to 2m. Rains wash away the chromium salts and transport them into the nearby sewer, and thus the chrome reaches the sea.

Algeria

The majority of industrial activity is situated on the coast. The four largest port and industrial zones, where there is practically no treatment of industrial waste, are all on the coast. These are, on the one hand, the industrial zones of Skikda and Annaba in the east, Algiers-Oued Smar and Rouiba-Reghaia in the centre, Oran-Arzew in the west, and on the other the industrial complexes of Ghazaouet, Mostaganem, Béjaia and Jijel.

Most of these zones discharge their principal wastes, full of toxic substances, into the sea or nearby wadis, causing heavy pollution along the Algerian coast. Urban and industrial activities generate large amounts of chemical and organic pollutants, which are discharged directly into the marine environment, usually without any treatment.

Like urban and industrial wastewater, solid wastes receive practically no prior treatment and no precautions are taken before they are discharged, as can be seen from the proliferation of illegal dumps that are only too often to be found in or beside wadis (rainfed watercourse), cliffs or other natural depressions. This means twofold pollution of the marine environment by solid wastes: directly, through illegal dumping on cliffs and beaches, and indirectly, through dumping in wadis, where the waste is subsequently carried down to the sea whenever the water level rises.

Croatia

The oil refinery of Rijeka is the largest in Croatia, with capacity of 6 million tonnes of oil derivates, and is the only one situated on the coast. Although it has appropriate treatment equipment for industrial and rainfall waters, the refinery pollutes the sea and soil with accidental spills of oil and its derivates. Between 14,000 and 20,000 tonnes of hydrocarbons also containing sulphides and mercaptans, are deposited in the soil. In 1993, soil recovery archives were launched. An additional threat is approximately 8,000 tonnes/year of solid waste remaining in the production and wastewater treatment plants.

Egypt

Abu Qir Bay receives a huge amount of industrial wastewater from three main complexes. There is one, namely Kafr El-Dawar complex (Textile factories) which dumps its wastes in El-Amia drain.

Lebanon

Solid waste dumps are considered one of the major sources of pollution along the coastal zone. The Ministry of Environment initiated a project on Integrated Hazardous Waste Management in mid 2001 and is expected to end up by mid 2002. This project budget is of

189,000 USD made available by METAP threw the Italian trust fund of the WB. On-shore uncontrolled dumping site of solid wastes are considered as discharges with high level of pollution (leached).

Morocco

Mining and industrial activities produce a great amount of solid waste which are discharged into the surrounding areas and are likely to pollute the groundwater through infiltration or lixiviation. The risk of pollution of coastal environment has not been determined yet.

So, as we can see from the cases above, dumping of industrial wastes in the coastal zones can pollute the marine environment in the following ways:

- Direct dumping on cliffs and beaches
- Dumping on wadis (rainfed watercourse), and carried down to the sea.
- Disposal in unprotected soils: leaching and pollution of groundwater

▪ *Loads of contaminants*

- *Trace metals*

The quantities mobilised by human activities are often small compared to those mobilised in the normal biogeochemical cycle in the course of weathering of rocks, transport and discharge (into the sea) by rivers and release in the course of volcanic and tectonic activity (mercury being an example) (UNEP, 1996a). Although, anthropogenic activities have increased the flux of heavy metals by 300% in the last 50 years (Meadows et al., 1991).

The **main sources** (primary and secondary) of the principal trace metals are: rocks (mainly as sulphide ores); mining; ore processing; smelting (of copper, lead, nickel and zinc); agricultural, domestic and industrial wastes; combustion of fossil fuels.

The **main trace metals**, in the context of the Mediterranean Sea, are: cadmium, mercury, lead, tin, copper and zinc, the latter two being considered as biologically necessary to organisms. Arsenic, which is a metalloid (i.e., can form "metallic" compounds such as arsenic sulphide and "non-metallic" ones such as sodium arsenate) has some environmental impact and is also considered in this sub-section.

Mercury

Sources

Mercury comes from rocks (mainly as sulphide ores), degassing (of elemental mercury) from the Earth's crust and oceans, volcanoes, chlor-alkali plants, petrochemical industry and sewage outfalls.

Levels

The levels of total mercury (Hg-T) in the Mediterranean marine environment seem to be decreasing in many areas, mainly owing to the fact that analytical procedures have improved and more attention has been paid to the problem of sample contamination. Earlier results indicated high values, with concentrations in sea water in the so-called "open" sea areas reaching 140ng/L, and in coastal areas, 520ng/L. However, more recent data indicate that open-sea concentrations are only a few nanograms per litre, and those in coastal areas affected by pollution sources do not exceed 50ng/L. That is, in general, mercury levels in sea water are no higher, on average, than those elsewhere (UNEP, 1996a).

Loads

In general, human emissions are substantially less than natural ones; ratios of 1:4 up to 1:30 have been derived, admittedly from very rough raw data (UNEP, 1996a).

On the basis of published data and modelling results, in UNEP (1998) the following data on mercury loads are presented:

- the pollution of the Mediterranean Sea by mercury and its compounds is brought about mainly via the atmosphere and riverine runoff;
- the total input from anthropogenic sources through the atmosphere is 10-40 tonnes per year. The contribution of riverine runoff varies within the range of 50-200 tonnes per year (mainly in particulate form);
- apart of riverine runoff of mercury (about 10-40 tonnes per year) and the bulk of atmospheric deposition come to the Mediterranean Sea as soluble mercury compounds which can be assimilated by the marine biota and thus would affect the marine life.

Impact

Special attention should be paid to coastal zones where higher concentrations of mercury are observed due to riverine runoff, intensive sedimention and atmospheric deposition. In addition these zones are characterised by enhanced biological productivity. The Western Mediterranean, the Tyrrhenian and Adriatic Seas are believed to be the most vulnerable regions (UNEP, 1998).

Cadmium

Sources

Cadmium comes from: copper refining (as a by-product); lead processing; electroplating; solders; batteries; production of alloys, pigments and PCBs; sewage sludges.

Levels

The levels in sea water cover a wide range of values: open sea 0.004 - 0.06 µg/L (recent and probably more reliable data); coastal sea <0.002 - 0.90µg/L, with a tendency for high values to be related to sources (estuaries, coastal mining) (UNEP, 1996a).

Arsenic

Sources

Arsenic is a by-product or waste of non-ferrous metal processing (copper, zinc, lead, gold and cobalt), of fossil-fuel burning and the processing of phosphate rock and bauxite (for aluminium).

Levels

The levels of total dissolved arsenic in sea water, in the western Mediterranean below the photic zone (since arsenic is metabolised by phytoplankton), are 1.3 - 1.4µg/L. In estuaries and rivers the values are much more variable: 1.5 - 3.75µg/L in the Rhone delta (UNEP, 1996a).

Although arsenic itself is insoluble, many of its compounds are soluble in water, leading to average seawater concentrations of 2.0-3.0 ug/L. (UNEP, 1996d).

Loads

There is no accurate information available as to the amounts of arsenic reaching the Mediterranean Sea through domestic and industrial effluents (UNEP, 1996d)

Impact

Marine organisms especially invertebrates, are able to concentrate arsenic from seawater to high levels. Most of the arsenic is in the organic form in marine organisms, which is much less toxic than the trivalent inorganic compounds (UNEP, 1996d).

Copper/Zinc

Sources

Copper comes from: mining; alloys; metal plating; electricals; catalysts; jewellery; algicides; wood preservatives.

Zinc comes from: smelting; alloys; steel-making; metal-plating and galvanising; paints and dyes; batteries; organic chemical production; oil refining; fertilisers; paper pulp; viscose rayon production. A ratio of 2.5:1 for industrial:domestic discharge has been calculated.

Levels

Copper: the levels in sea water cover a wide range of values: open sea 0.04 - 0.70µg/L (recent and probably more reliable data); coastal sea <0.01 - 50µg/L, with a tendency for high values to be related to sources (Nile discharge, coastal mining) (UNEP, 1996a).

Zinc: the levels in sea water cover a wide range of values: open sea 0.24 - 0.56µg/L; coastal sea 0.20 - 210.0µg/L. A wide range of 0.016 - 48µg/L for a variety of Mediterranean waters have been reported (UNEP, 1996a).

Loads

The amounts of copper discharged into the Mediterranean Sea through domestic and industrial effluents have been estimated 2.3 and 6.0 tonnes x 103 per annum respectively (UNEP, 1996d).

Zinc and copper loads are specifically assessed based on information provided by Scoullos and Constantianos (1996). In this study it is highlighted that zinc and copper loads entering the Mediterranean are significant and are considerably higher than those reported in the past, as a result from the inclusion of marine (via Gibraltar and Dardanelles) and atmospheric inputs, which were not taken into account in previous assessments. Results are presented in Table 4.61.

Table 4.61 **Zinc and copper loads entering the Mediterranean Sea (in tonnes x 10^3 per year)**

Inputs	**Zinc**	**Copper**
Inputs through the straits of Gibraltar Inputs through the straits of Dardanelles (Çanakkale Bo_az_)	23.5(b) 0.08-1.3(b)	9.2(b) 0.5-11 (b)
Load by direct effluent discharges: Domestic Industrial	 1.9(a) 5(a)	 2.3(c) 6(c)
Loads carried by rivers: Anthropogenic Background	 18(14-22)(a) 0.6-1.6(b) 4(a)	 0.2-0.6(b)
Atmospheric inputs (mixed)	42.5(b)	5.3(5-10)(b)

(a) UNEP/ECE/UNIDO/FAO/UNESCO/WHO/IAEA (1984)
(b) Dorten et al. (1991)
(c) Scoullos, unpublished data

It is clear that although both the marine and atmospheric inputs into the Eastern Mediterranean were assessed indirectly, they are of the same order of magnitude. This has been confirmed in the N.W. part of the Mediterranean. The atmospheric inputs are also considerably higher than the riverine and direct discharges, and thus could have a strong effect on concentrations in offshore waters and even in deep sea sediments.

Lead

Sources

Lead comes from: mining; smelting; steel-making; production of alloys; batteries; pigments; combustion of leaded (by tetraethyl lead) petrol. A ratio of 7:1 for industrial:domestic discharge has been calculated (UNEP, 1996a).

Levels

The levels in sea water cover a wide range of values: open sea 0.018 - 0.14µg/L (recent and probably more reliable data); coastal sea 0.016 - 20.5µg/L, with a tendency for high values to be related to sources (lead tetraethyl production and estuaries) (UNEP, 1996a).

Loads

The amounts of lead discharged into the Mediterranean Sea through domestic and industrial effluents have been estimated at 200 and 1400 tonnes per year respectively. These figures apply to discharges from the coastal zone, and do not include river inputs (UNEP, 1996a).

Other metals

Large amounts of **chromium** are used by industry, and sources to the environment include fossil fuel combustion, metal plating, ore refining, the leather industry, etc. In the Mediterranean, the Liguro-Provencal region receives the highest Cr load from land-based sources, mostly due to river run off (UNEP, 1996d).

There is no accurate information available regarding the amounts of chromium discharged into the Mediterranean Sea through industrial and domestic effluents. Earlier estimates were 250 and 950 tonnes per annum from domestic and industrial discharges respectively, originating in the coastal zone, with a further 1,200 tonnes per annum reaching the Mediterranean Sea through rivers (UNEP, 1996d).

Responses

Because of the very restricted use of pollution prevention and abatement technologies in the area, there is a clearly significant potential for a drastic reduction of the loads described in this section. Filters to reduce industrial emissions to the atmosphere and primary sedimentation of effluents could reduce discharge loads by 70%, and secondary effluent treatment (eg. by activated sludge) could reduce it by 10-20 fold. Better management of the currently available technologies for the treatment of industrial effluents, sludges, and tailings, and emissions to the atmosphere, could reduce the inputs to one tenth of their present levels.

Although the installation of such efficient effluent treatment processes will reduce the coastal discharges, and thereby reduce local pollution problems, a need for a more general reduction of inputs would require stringent controls to be placed on discharges to inland waters and to the atmosphere.

If such improved remedial measures are extended to inputs from the Atlantic coasts and around the Black Sea, marine inputs to the Mediterranean could also be reduced significantly.

Organic pollutants

Organohalogens

According to UNEP (1996a), the main organohalogen contaminants in the Mediterranean marine and coastal environment are PCB, DDT and its metabolites (DDE, DDD), hexachlorohexane (HCB), hexachlorobenzene (HCB), heptachlor, and pesticides aldrin, dieldrin and endrin. Scarce information on loads of these compounds to the Mediterranean Sea has been found.

Sources

Industrial sources of organohalogen compounds in the Mediterranean region are indicated in UNEP (1996d). The major user of organohalogen compounds is the pesticide manufacturing industry, whose discharges contain varying amounts of organohalogen compounds. The other user is the pulp and paper industry which uses these compounds as fungicides, and biocides. The other major sources of organohalogen wastes are petroleum refineries, research laboratories, iron and steel work, foundries, and the electrical industry in which PCB's are used in capacitors and transformers.

Levels

There is a wide range of levels in sea water, depending on the type of water sample (e.g., surface microlayer, surface water, sea-water-dissolved phase, subsurface water) and sampling site; only PCBs have been satisfactorily analysed in Mediterranean open-sea water samples.

Loads

Organohalogen compounds reach the marine environment through atmospheric deposition, agricultural run-off, rivers and discharge of industrial and municipal wastes. According to UNEP (1996a), over 80% of the total input into the sea is via the atmosphere, and less than 20% via rivers.

Polychlorinated biphenyls (PCB)

Three main kinds of PCB industrial sources can be defined:

- Manufacturing of items containing intentionally introduced PCB

An important fact is that items such transformers, capacitors, fluorescent light ballast, and many other products created before PCBs were banned have a long useful life, so many of them remain in service. At present, leaks and spills from transformers in use are important sources of PCB.

- Combustion and incineration of materials containing PCB

It is also very important to identify how PCB-containing items are destroyed/managed. In case that incineration is allowed, it will be critic to identify in which conditions incineration takes place, and which APCD (air pollution control devices) are used. If incineration of PCB-containing items is not performed in optimal conditions, it could be a major PCB source.

- Inadverted generation of PCB

Apart from industrial production, PCBs also originate as subproducts from a wide variety of chemical processes, (e.g., chlorine solvent production, pigments, adhesives, etc.), combustion processes and vehicle exhausts emissions. It has been estimated (US EPA) that up to 200 chemical processes may inadvertently generate PCBs. Numerous products such as paints, printing inks, agricultural chemicals, plastic materials, and detergent bars could also contain inadvertently generated PCBs.

It is clear that there are a lot of potential sources, but just a few of them have been characterised. So this is a field were data gaps are common, and therefore during the next years studies should be carried out in order to fill in these gaps. It has also to be said that it has been estimated that the quantity of PCBs released to the environment from these processes is negligible compared to the release from items that contain intentionally introduced PCBs.

PCBs are ubiquitous in the atmosphere and are transferred to the sea by scavenging by rain and by dry deposition. In the sea, they are particle-reactive compounds, partitioning between lipid and natural organic phases.

Levels/Loads

Most of the first data published 25 years ago for seawater lied below the analytical sensitivity of the method used (0.1 ng/L for PCBs), so the significance of the data sets is limited. In general, the concentrations of PCBs for all the investigated areas in the Mediterranean Sea were similar except in the Ligurian Sea where concentrations were higher. Consequently, a larger effort has been done in the Western basin (Tolosa et al., 1997). The highest concentrations are reported in urban and industrial wastewaters (e.g. from Marseille and Barcelona) as well as in river discharges (e.g. from the Rhône). Accordingly, decreasing concentration gradients have been found in transects offshore from these sources (Marchand et al., 1988; Burns and Villeneuve, 1987; Bayona et al., 1991).

Even though PCBs exhibit high particle/dissolved concentration ratios, the low levels of suspended particles in Mediterranean waters (0.4-1 mg/L) make the dissolved phase of the open sea the dominant reservoir of PCBs. In vertical profiles measured in the Gulf of Lions in 1982-83, PCBs recovered from the particulate fractions of surface samples ranged from 32-65%, whereas in deep waters with lower suspended particle loads, the fraction was from 11-19% (Burns and Villeneuve, 1987). PCB concentrations in the suspended particulate matter from coastal and open Western Mediterranean waters were in 1990 (5-35 pg/L) (Tolosa, 1993) of the same order of magnitude as those reported in other regions, e.g. North Sea (1988; 5-155 pg/L) (Schulz et al., 1991), Pacific, Indian and Antarctic oceans (1980-81; 6-94 pg/L) (Tanabe and Tatsukawa, 1983), and North Atlantic (1986-87; 3-42 pg/L).

Finally, a large water sampling was carried out in 1993-94 in the Western Mediterranean, including the straits of Sicily and Gibraltar (Dachs et al., 1997). Concentrations of dissolved PCBs were almost one order of magnitude higher than in the corresponding particulate phase. Suspended particulate matter at the Ebro mouth exhibited higher concentrations than at the Rhone River mouth. A spatial gradient was also observed from the continental shelf (3.5-26.6 pg/L) towards the open sea (1.7-6.6 pg/L). A relatively important enrichment (8.4 pg/L) was found in open sea stations located in higher productivity frontal zones.

Hexachlorobenzene (HCB)

HCB is predominantly an industrial product, although its sources (as a marine contaminant) are still not precisely known (UNEP, 1996a). It is mainly used as a fumigant and a fungicide in grain storage. HCB was also used in some countries in the production of fireworks and to manufacture synthetic rubber. Nowadays these uses are banned in most countries. HCB is also formed as a by-product, impurity or residue in some industrial processes. For example it is generated as by-product during the manufacturing of chlorinated solvents, it is found as impurity in some pesticides, and it is formed during the incineration of municipal and hazardous wastes. HCB emissions also take place during coating application and curing processes in metal surfaces, during the production of silicone-based products, during the manufacturing of hydrochloric acid, etc. (UNEP, 2002).

Levels/Loads

Western Mediterranean coastal waters exhibited concentrations of dissolved HCB in the range of 0.9-4.3 pg/L, with higher values offshore the Rhone River (10 pg/L) (Grimalt et al., 1988; Burns and Villeneuve, 1987). The concentrations in the dissolved and particulate phases found at the bays of the Ebro delta, were in the range of 1.0-4.1 and 12-31 pg/L, respectively (Grimalt et al., 1988).

DDT

DDT is a well known, potent insecticide used on a global scale especially to control the spread of malaria by mosquitoes. DDT is metabolised to DDE which is very persistent in the environment and is thought to be a metabolic dead-end with a considerable toxicity (UNEP, 1996a)

In some Mediterranean countries (north and south side) some specific uses are still in practice. Also DDT is produced to be used to produce Dicofol; sometimes it is also used directly in some flowers and plants cultures (UNEP, 2002).

Levels/Loads

Concentrations of dissolved DDTs in water samples collected in 1993 in the Western Mediterranean (0.8-4.3 pg/L) were one order of magnitude higher than in the corresponding particulate phase (0.16-0.98 pg/L). Suspended particulate matter at the Ebro and Rhone River mouths exhibited a surface enrichment indicating a certain riverine input to sea. However, about 80% of the input consisted in DDE, indicating a large prevalence of weathered residues (Dachs et al., 1997). Concentrations were slightly higher in the continental shelf waters than in the open sea surface. A vertical gradient was also observed in the Straits of Sicily and Gibraltar, which has implications in the exchanges of pollutants with the adjacent seas.

Concentrations of dissolved DDT metabolites 2,4'-DDT, 4,4'-DDD and 4,4'-DDE were detected in significant amounts in estuarine water samples of Axios, Loudias and Aliakmon rivers as well as of Thermaikos Gulf during 1992 and 1993 (5-31 ng/L) (Albanis et al., 1994; Albanis et al., 1995a). Similar concentrations (1-29 ng/L) were also detected in estuaries of Louros and Arachthos rivers as well as in marine wetlands of Amvrakikos Gulf in N.W. Greece during the period from March 1992 to February 1993 (Albanis et al., 1995a; Albanis et al., 1995b).

Hexachlorohexanes

HCHs are a mixture of isomers of which one (gamma-HCH, lindane) is an insecticide. The atmosphere is the main pathway (99% of total input) in the global distribution of HCHs, but they are highly soluble in water so they may be washed out of the atmosphere by rain and accumulate in aquatic biota (UNEP, 1996a).

Levels

Lindane levels off shore in the Eastern Mediterranean basin ranged from 0.06 to 0.12 ng/L, whereas values one order of magnitude lower were found in the Western basin. Higher concentrations were observed near terrestrial run-off and river inputs.

Concentrations of dissolved a-HCH, ß-HCH and lindane were detected in significant amounts in estuarine water samples of Axios, Loudias and Aliakmon rivers as well as of Thermaikos Gulf during 1992 and 1993 (1-30 ng/L) (Albanis et al., 1994). Similar concentrations (2-11 ng/L) were also detected in estuaries of Louros and Arachthos rivers as well as in marine wetlands of Amvrakikos Gulf in N.W. Greece during the same period (Albanis et al., 1995a and 1995b).

Dieldrin, Aldrin and Endrin

The main uses of aldrin are to control insects on cotton, corn and citrus crops, as a wood preserve and for termite control. In EU countries, its uses are very restricted (for some of them written authorisation is required) and some of them are banned (i.e. plant protection use is banned since 1995).

Dieldrin is easily derived from aldrin. Dieldrin is used to control soil plagues and for the treatment of seeds. Several countries of the region have adopted measures to ban this compound including Israel, Portugal, Turkey and the European Union.

Endrin is not included in the PIC Convention, so there is few data available. The main uses of endrin are as a pesticide on cotton, rice, sugar cane and corn, but at present its use is banned or restricted in most of countries. In the Mediterranean region, Algeria, Cyprus, Israel and Greece have banned all uses, while France, Italy, Portugal and Spain allow very limited applications.

Levels/Loads

Several studies have been carried out in the mouth some rivers (see section 4.2.7) but no data is available for seawater.

Organophosphorus compounds

Sources

There are roughly 250 organophosphorus compounds manufactured all over the world, and approximately 140 of these are pesticides, the remainder being mainly industrial chemicals used as flame retardants, plasticisers and industrial hydraulic fluids and solvents (UNEP, 1996d). According to their uses they can be divided into the following categories:

- Industrial use (flame retardants, plasticisers, solvents, antifoaming agents, industrial hydraulic fluids, lubricants, dispersants, detergents);
- Pesticides (insecticides, acaricides, nematicides, anthelmintic agents, fungicides, herbicides).

Information on both the sources and inputs of organophosphorus compounds into the Mediterranean is scarce. Most of the information available reports contamination levels in surface waters in Western Europe, especially in Italy. Additional information is available related to the surface waters in France, Spain, and Greece (UNEP, 1996d).

Levels

According to data reported by UNEP (1996d), in France, 2 and 4 µg/L concentrations had been reported for ethyl-parathion and malathion in the Saone River in 1968. In the Albufera Lagoon in Spain, a fenitrothion concentration of 0.1-2.0 µg/L have been reporeted for the period 1983-1985; these values were reported to decrease each time to non-detectable levels (below 0.05 µg/L) within two weeks. In Italy, 0.02-0.03 µg/L and 0.04-0.13 µg/L tributyl phosphate have been reported in the rivers Po and Turin, respectively.

In Greece, organophosphorus pesticides (diazinon, azinphos-methyl and parathion-methyl) were detected in the Ioannina Lake and in the Kalamas River. For the period 1984-1985, diazinon concentrations varied from 0 to about 35 ng/L in both sites. However, the concentrations of the other two organophosphorus compounds, azinphos-methyl and parathion-methyl varied from 0 to about 13 ng/L in the Kalamas River, whereas the concentration ranges for these compounds are 0 to about 13 ng/L in the Ioannina Lake.

Organotin compounds

Sources

The uses of organotin compounds can be divided into two main categories: nonbiocidal and biocidal. The main nonbiocidal use is for polyvinyl chloride (PVC) stabilization. Diorganotin compounds are used for preventing PVC degradation induced by UV light, and prolonged exposure of heating. Another important nonbiocidal use of organotin compounds is as catalysts in the production of polyurethane foams, and in the room-temperature vulcanization of silicones, since they are chemically reactive. Other minor nonbiocidal uses are for heat stabilization of materials other than PVC (such as rubber paints, cellulose acetate, polyethylene); and for waterproofing of paper and textiles (UNEP, 1996d).

Loads

There is no information in the literature on the amounts of organotin compounds discharged into the Mediterranean. However, it seems that the main source relates to the biocidal use of triorganotin compounds in antifouling compounds (UNEP, 1996d).

The load due to non-biocidal use of organotin compounds does not seem to have a great pollution potential for the Mediterranean. As the major use of organotin compounds (essentially diorganotins) is as a stabiliser in PVC, the pollution potential of this use must be evaluated

Petroleum hydrocarbons

Sources and loads

The land-based discharges of petroleum hydrocarbons are both industrial and urban. The number of major refineries located in the Mediterranean region is more than 40 with a combined capacity, in 2000, of about 438 million tonnes (Int. Petr. News, 2000). On the other hand, the weighted average oil content of European coastal refinery effluents, is approximately 1.9 g per tonne of crude oil processed (CONCAWE, 1998). Therefore, considering the total quantity of oil processed in Mediterranean countries, a total input of about 900 tonnes of oil, and an input of PAHs ranging from 1 kg up to 180 kg, depending on the kind of oil processed, can be estimated. These oil discharges seem to be constant since the last ten years (EEA, 2002).

There are no figures or estimates available regarding the amount of petroleum hydrocarbons carried directly through land run-off into the Mediterranean or indirectly via rivers (UNEP, 2002). As the pollution load and pollution pattern vary widely in rivers, it seems impossible to transfer to the Mediterranean the results of detailed analysis from rivers outside the region without substantial amendments. However, as several of the countries surrounding the Mediterranean are highly industrialised, it seems very likely that, considerable amounts of oil enter the sea through run-off from land.

Other sources and inputs of petroleum hydrocarbons are the transportation at sea, the mainland sources (municipal/ industrial oil wastes), atmospheric fall out and natural (seeping out of oil deposits), which are described in the corresponding sections.

According to UNEP (1996d) it is reported that the input of petroleum hydrocarbons from land-based industrial discharges into the Mediterranean had been conservatively estimated at 20,000 tonnes per year in 1975. In UNEP (2002) some estimations for the 80's indicates that the overall input of oil from different industrial sources in the Mediterranean can be 110,000 tonnes. However, the total input in the selected hot spots exceeds 120,000 tonnes.

Levels

The levels of dissolved/dispersed oil in sea water range from 0µg/L to 5µg/L, with a few values exceeding 10µg/L. Tar, which floats in the sea until it is deposited on the sea shore, ranges (in sea water) from 0.6g/m^2 to 130g/m^2 and (on beaches) from 0.2 to 4388g/m (linear metre of whole beach along water edge). There is some suggestion of a reduction in these tar levels in recent years, notably in the eastern Mediterranean (UNEP, 1996a).

Lubricating oils

The definition of used lubricating oils in terms of Annex I to the Protocol for the protection of the Mediterranean Sea against pollution from land-based sources, to serve as a basis for national measures, is given as "any mineral-based lubricating oils which, through use, storage or handling, have become unfit for the purpose for which they were originally intended, in particular used oils from combustion engines and transmission systems, as well as mineral oils for machinery, turbines and hydraulic systems". It should be recognised that "used lubricating oils" are those made at least in part from petroleum (including chemical additives) but do not include lubricants that are wholly synthetic or chlorinated lubricating or insulating oils, e.g. those containing PCB's or PCT's. In addition, used motor vehicle lubricants should be included within the scope of the definition of used lubricating oils. However, discharges of oil from oil production, refining and storage installations; and other substances such as pesticide residues, gasoline, solvents, PCB's or hazardous wastes, or include oils with more than specified proportions of other substances should not be included (UNEP, 1996d).

Sources

The industries giving rise to used lubricating oils are the primary metals, fabricated metal products, machinery, electrical equipment, transportation equipment, chemical products, and rubber and plastic products. Automobiles, trucks, buses and heavy machine equipment all use oil in their engines, gears, transmissions and hydraulic systems. Therefore, used lubricating oils are also generated from dealerships, service stations and garages.

Another source of used lubricating oils is terminals and airports at which the lubricants of both railroads and airplanes are collected. Both refrigeration units and shock absorbers also use lubricating oils and generate used oils. These oils are usually made from naphtenic base stocks.

Loads

The amount of used lubricating oil reaching to the Mediterranean through coastal non-refinery effluent discharges was estimated to be 1630 tonnes per year, by calculating the number of employees in appropriate industries and utilising the standard estimate for used oil generation per capita on the basis of the Industrial Standards International Classification (ISIC) for each category of employee (UNEP, 1996d).

Polycyclic aromatic hydrocarbons (PAHs)

Sources

The main sources of PAHs in the environment are natural and intentional combustion of organic matter (e.g. forest fires and fuel combustion) and petroleum manipulation (extraction, transport and refining). The contributions, therefore, range from diffused chronic inputs (e.g. atmospheric deposition and terrestrial run-off) to large point releases (i.e. tanker accidents or accidents at coastal installations). Present information concerning the sources and inputs of PAHs in the region is rather limited, but the Mediterranean Sea has been considered to be relatively more polluted by oil than any other sea from which data are available (UNEP, 1980).

Levels

A large number of determinations of PAHs in sea water were performed in the 80's within the MEDPOL Program, following the ICES procedures (UNEP/IOC, 1988). In general, DDPH in water samples collected offshore have concentrations below 10 µg/L, but very high concentrations have been found in coastal waters and in particular in harbours and close to large cities. Concentrations ranging from 30 to 200 µg/L were reported for the Gulf of Fos (France). In Israel near harbours and oil refineries values of 10 to 20 µg/L were reported. In unpolluted areas and in the open sea waters of the Croation coast (Adriatic Sea) values range from 1µg/L to below. In polluted areas, concentrations of up to 50 µg/L have been determined. Concentrations ranging from 1.4 to 6.4 µg/L were reported for the Ionian Sea (Sakellariadou et al., 1994).

In the Eastern Mediterranean along the Greek coast, concentrations varied from 0.1 to 2.6 µg/L. In the Aegean Sea, concentrations range from 0.15 to 1.4 µg/L, with some "hot spots" far from major land-based sources having concentrations levels of up to 10 µg/L. Recent data 1997, for PAHs from water samples from the North Aegean sea give concentrations of 0.01 to 0.03 µg/L. Along the Turkish coast, concentrations vary over a wide range (0.02 to 40 µg/L), with high concentrations from offshore samples caused most probably from direct discharges from the ships. Near Cyprus concentrations from 0.8 to 15 µg/L were reported for the years 1983-84. Obviously, discharges from ships can greatly influence the concentrations in offshore waters (UNEP/IMO/??C, 1987). In general it appears that recent data show lower concentrations, but are not sufficient for statistical treatment.

Recently, data on individual PAHs in the water column of the Western Mediterranean has also been reported (Dachs et al., 1997). These encompass 21 surface water and 6 vertical profiles for suspended particulate matter (SPM) and 7 sampling sites for dissolved hydrocarbons (DP). PAHs associated to SPM were evenly distributed in subsurface waters, and their concentrations ranged from 200 to 750 ng/L, maximising at the Rhone and Ebro river plumes (570-970 ng/L) and at a frontal zone located midway between the Iberian Peninsula and the Balearic Islands. The vertical profiles exhibited a decreasing concentration trend with a relative increase of the more polycondensed compounds derived from pyrolytic sources. The PAH content in the DP samples of the open sea were of 0.4-0.9 ng/L, with values around 2 ng/L in coastal areas.

Loads

Lipiatou et al. (1997) estimated that the total PAH riverine inputs amount to about 5.3 to 33 tonnes per year from the Rhone River and 1.3 tonnes from the Ebro River. The difference in these riverine fluxes is due to differences in the annual water discharges and upstream land use.

As regards atmospheric inputs, Ho et al. (1983) estimated the annual input of hydrocarbons (HC) into the Western Mediterranean: If we consider that the western Mediterranean Sea has a surface area of 8.5 X 10^5 km^2, then the estimated flux of aromatics will be 59 to 629 tonnes per year. These figures are much higher than those estimated more recently by Lipiatou et al. (1997) where total PAH inputs from the atmosphere were estimated to be from 35 to 70 tonnes per year with a mean value of 47.5 tonnes (wet/dry mean ratio of ~2-3).

<u>Anionic detergents</u>

Sources

The most important sources of detergents in the Mediterranean Sea are the land-based sources which introduce them into the marine environment (UNEP, 1996c): a) directly, from outfalls discharging into the sea or through coastal dispersion, b) indirectly through rivers, canals or other watercourses, including underground watercourses, or through run off.

Another source of detergents is related to the use of chemical dispersants (mixtures of solvents and surface-active agents which reduce oil/water interfacial tension and hence stabilise small oil droplets dispersed in the water column) and other agents for control of oil spills.

Levels

A pilot monitoring survey carried out in 1992 provided some information on levels of anionic detergents. Levels in sea water range from 0.01 to 4.2g/L; in effluents, from 0.11 to 34.07g/L; and in rivers, from 0.06 to 26.86g/L. This study, however, had to be restricted to a few coastal areas and the results cannot be interpreted as providing any indication of the situation prevailing in the Mediterranean as a whole (UNEP, 1996c).

- *<u>Geographic sites of impact</u>*

In this section geographic sites of impact are identified and assessed from the review of available information, particularly, the UNEP report *Identification of priority hot spots and sensitive areas in the Mediterranean* (UNEP, 1999) and Revision of pollution hot spots in the Mediterranean (UNEP/MAP, 2002).

- *Hot spots*

Information on Hot Spots in the Mediterranean Sea is provided in the UNEP report *Identification of priority hot spots and sensitive areas in the Mediterranean* (UNEP, 1999).

Through the compilation of data from the reports of 20 countries, 101 priority Hot Spots are identified. The geographical distribution is shown in Figure 4.23. In the UNEP/MAP (2002) report, the evolution some of these hot spots are reviewed. The main results are synthesised below.

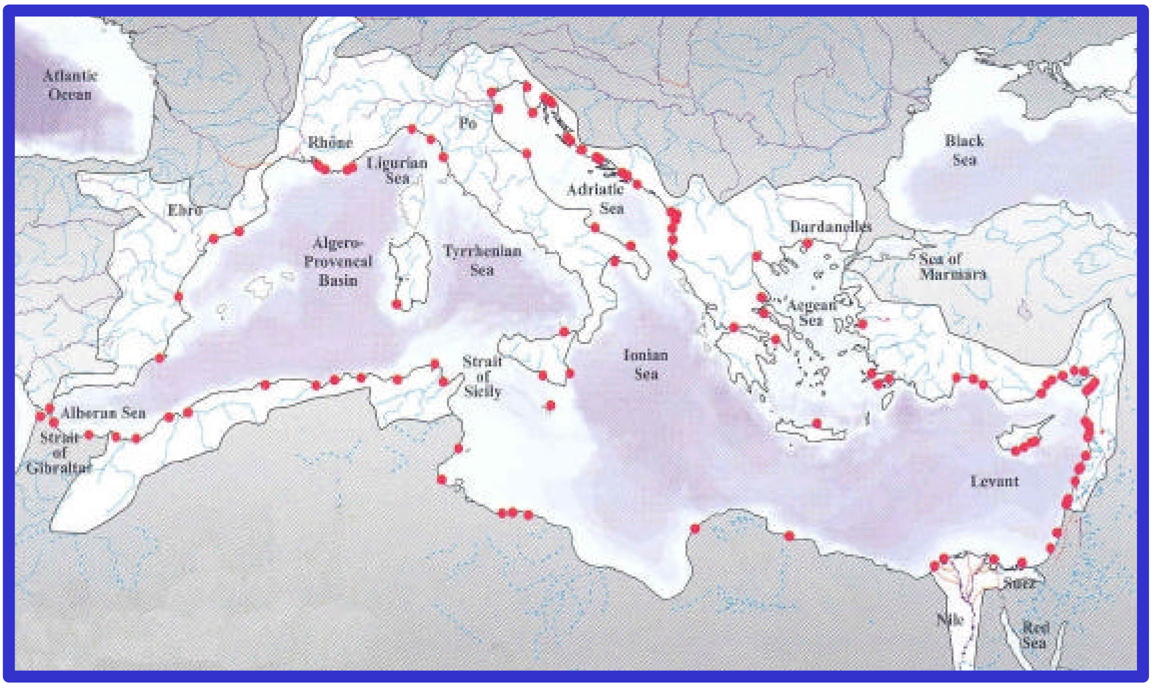

Figure 4.26 Location of the coastal hot spots identified in the Mediterranean Sea

Results of the first hot spots report (UNEP, 1999)

101 priority hot spots have been identified as impacting public health, drinking water quality, recreation and other beneficial uses, aquatic life (including biodiversity), as well as economy and welfare (including marine resources of economic value). Some idea of the distribution of their weighted total impacts can be gleaned from Table 4.6.

- Only one hot spot (Manzala Lake in Egypt) scored a total weighted impact greater than 25. A little less than one fourth were in the (25-20) bracket, while about one fourth are in the (15-10) bracket. Almost one half of the hot spots are in the (20-15) bracket.
- Almost all hot spots are considered, in the national reports, as having transboundary impacts on the six issues considered in the analysis.
- The main sources of pollution in the hot spots can be identified as domestic (22, 21.8%), industrial (21, 20.8%) and mixed (58, 57.4%).

Table 4.62 **Distribution of the weighted total impact of hot spots (UNEP, 1999)**

	Number of Hot Spots	**% of Total**
Hot Spots scoring > 25	1	0.99%
Hot Spots scoring 25-20	24	23.76%
Hot Spots scoring 20-15	45	44.55%
Hot Spots scoring 15-10	26	25.75%
Hot Spots scoring < 10	4	3.96%
Hot Spots with no score	1	0.99%

Total	101	100%

It is worth noting that a limited number of pollution hot spots is responsible for the bulk of pollution loads:

- **BOD loads**: of the total reported BOD load data (804,248 t/yr) three hot spots contribute more than 40,000 t/yr each. These are: El-Mex Bay (Egypt) (219,498 t/yr), Abu-Qir Bay (Egypt) (91,701 t/yr) and the Inner Saronic Bay (Greece) (59,386 t/yr). They account for no less than (370,585 t/yr) or 46 % of the total.
- **COD loads:** The same three hot spots are responsible for COD loads of more than 100,000 t/yr. Abu Qir Bay (Egypt) is responsible for one third of the total COD load (575,490 t/yr), whereas El-Mex Bay (Egypt) and the Inner Saronic Bay (Greece) contribute with 175,654 and 118,735 t/yr, respectively. Together they account for 50% of the total COD loads (1,729,852 t/yr)
- **TPBs**: within the limitations of the considerable gaps in the data collected on TPBs, compared to other parameters, eight hot spots, are prominent as main sources of TPBs. Table 4.6 summarises their contributions to the different TPBs for which data were compiled in the national reports, and the percentages of their combined shares of the total discharges of TPBs.

Table 4.63 **Main sources of TPBs (UNEP, 1999)**

TPB (kg/yr)	Hg	Cd	Pb	Cr	Cu	Zn	Ni	Others (t/yr)
Abu Qir Bay (Egypt)		31+	193+	362+	2,669+	3,394+	859	1906 (oil)
Haifa Bay (Israel)		2,600			3,250	58,500		425 (oil)
Tartous (Syria)		54	2,703	1,784	5,406	5,163	2,649	
Lattakia (Syria)		85.4	4,271	2,135	4,271	7,686	2,562	
El-Mex Bay (Egypt)	1278	1,562		530	25,430	46,524		1,319 (oil)
Gush Dan (Israel)	60	430	1,670	11,400	19,000	54,000	2,500	
Sfax South (Tunisia)					3,456	17,000		
Larymna Bay (Greece)						313,170		
Totals	**1338**	**4762.4+**	**8837+**	**16211+**	**63,482+**	**505,737+**	**8570**	**3,650**
% of total TPB discharges	**99%**	**74%**	**48.2%**	**70.1%**	**96.3%**	**82.15**	**75.1%**	**71%**

As can be seen from the table, these eight hot spots are responsible for:

- more than 90% of the recorded discharges of mercury and copper.
- more than 80% of zinc.
- more than 70% of chromium, nickel, cadmium and oil.
- and just under 50% of lead.

- **The concentration of population in and around the pollution hot spots** identified reveals some significant aspects Table 4.6.

Table 4.64 **Concentration of population around the pollution hot spots (UNEP, 1999)**

Population	> 1,000,000	1,000,000 - 500,000	500,000 - 250,000

No. of cities	11	11	10
Total population for the group	23,594,433	8,333,859	3,448,369
% of total	**58,7%**	**20,7 %**	**8,6%**

Although the number of urban concentrations around hot spots of populations of one million and more is only eleven, they account for a little less than 60% of the total population in and around hot spots.

Greater Alexandria with a population of over 4 million, and responsible for around 40% of Egypt's total industrial production, is prominent as a major source of pollution. The Inner Saronic Gulf in Greece, with a population of over 3 million is also a significant source of BOD and COD.

There are eleven cities with populations between one million and half a million. They house more than 8 million people and thus account for one fifth of total population around hot spots. None of these cities is particularly prominent as a significant source of pollution.

Ten cities have populations between 500,000 and 250,000. Their total population is about five million less than that of the previous group. Of these 10 cities, Tartous, in Syria and Sfax South in Tunisia also appear on the list of major sources of TPBs (Table 4.6).

Figure 4.23 shows the geographical distribution of the Table 4.6 shows the total number of pollution hot spots for each source of pollution (domestic, industrial, mixed) as well as the share of each group of the total BOD and COD loads of all hot spots. The fifty-eight hot spots having mixed sources of pollution account for 88,9% of total BOD load and 88% of COD load. Six of them appear in Table 4.6 as main sources of TPBs.

Table 4.65 **Distribution of BOD and COD loads for different sources of pollution** *(UNEP, 1999).*

Source of pollution		Domestic	Industrial	Mixed	Totals
No. of Hot Spots		22	21	58	101
% of total number		21,8%	20,8%	57,4%	100%
BOD load	**t/yr**	67,083	22,096	715,065	804,243
	% of total	8,3%	2,8%	88,9%	100%
COD load	**t/yr**	79,107	128,104	1,522,641	1,729,852
	% of total	4,6%	7,4%	88%	100%

Results of the second hot spots report (UNEP/MAP, 2002)

a) Evolution of impact

- There are some countries that generally improves the weighted impact of their hot spots, like Croatia, Egypt, Lebanon, Morocco, or Syria; some other countries remain the same, like Libya or Algeria; and some other decrease their quality, like Slovenia, Turkey, and specially Albania and Tunisia.

b) Specific comments

- ALBANIA. In Vlora and Durres, the source of pollution are now reported as industrial, as wastewater treatment plants are expected for this cities. Industrial wastewater remains being discharged directly to the urban sewerage.
- ALGERIA. Results indicates still significant impact form hot spots, as urban, industrial and solid wastes receive no prior treatment before they are discharged. There is a

lack of information on the concentration of hydrocarbons, heavy metals and organochlorines in domestic sewages; and also on particular industries.

- BOSNIA-HERZEGOVINA. Four new land-based hot spots (domestic and industrial) are reported, with high transboundary pollution potential to Neretva River and some inner lakes, and significant risk to human health, ecosystems, biodiversity, sustainability and economy. Neum is the only real coastal Hot Spot, with transboundary effect as well.
- CROATIA. Comparing the primary hot spots indicators form the previous report with the reviewed data (UNEP/MAP, 2002), there have been established a certain improvements in Bakar, Zadas and Sibenik, and significant improvements in Kastela Bay and Split. The main reason of these enhancements is closing of some industrial plants, pre-treatment of some industrial wastewaters and municipal wastewaters of Split. Some transboundary effects from pollution of hot spots are not excluded.
- EGYPT. As a consequence of construction of wastewater treatment plants, improvements in hot spots are reported, despite some data on different quality parameters is lacking.
- LEBANON. Urgent requirements for immediate infrastructural and organisational intervention to prevent negative impacts have already been identified, and the government has initiated action.
- LYBIA. Impact of hot spots remains equally scored, and currently capacity building of labour is required to achieve further improvements.
- MOROCCO. Sea water quality has decreased due to urban waste waters, and as a consequence, investments in wastewater treatment plants have been defined. Industrial sources of pollution are also affecting the coast, as well as maritime transport.
- SLOVENIA. An integral project of industrial and urban wastewater treatment plants has been proposed.
- TUNISIA. Some requirements on wastewater treatment have been identified, in order to decrease the load of phosphates and nitrate discharges. Industrial sources of pollution are not assessed.
- TURKEY. Lack of information on quality parameters, and industrial sources of pollution are reported (major hot spots are domestic).

o ***Ports and maritime transport***

Ports and maritime transport are a major transboudary issue and, therefore, constitute a central unit of the TDA report. Ports provide the interface of maritime transport between their inner-land and the open sea, they belong to the marine world and their pollution risks are ship-related, whilst the solution of most of their environmental problems are linked with safer and cleaner shipping operations. Pollution from maritime transport activity occurs not only in open sea but also, and even more, near the coastline in ports, outside anchorage areas, access channels, estuaries and seaways.

Freight passing through ports has increased during the last decades and this trend is probably going to continue, as the enlargement of the world trade generates new transport flows. About 220,000 vessels of more than 100 tonnes crosses the Mediterranean each year, which is estimated as the 30% of the total merchant shipping and 20% of oil shipping in the world (MAP/REMPEC, 1996).

- *Mediterranean ports and maritime routes*

The most important Mediterranean ports (Table 4.64) are located along the maritime routes, which are passing through the Dardanelles, the Strait of Gibraltar and the Suez Canal (Figure 4.24).

Table 4.66 **Important Mediterranean ports from NW to NE and from SE to SW**

Barcelona	Trieste	Izmir	Tunis
Marseille	Split	Bayrout	Algiers
Genova	Patras	Haifa	
Napoli	Pireus	Alexandria	
Palermo	Thessaloniki	Tripoli	

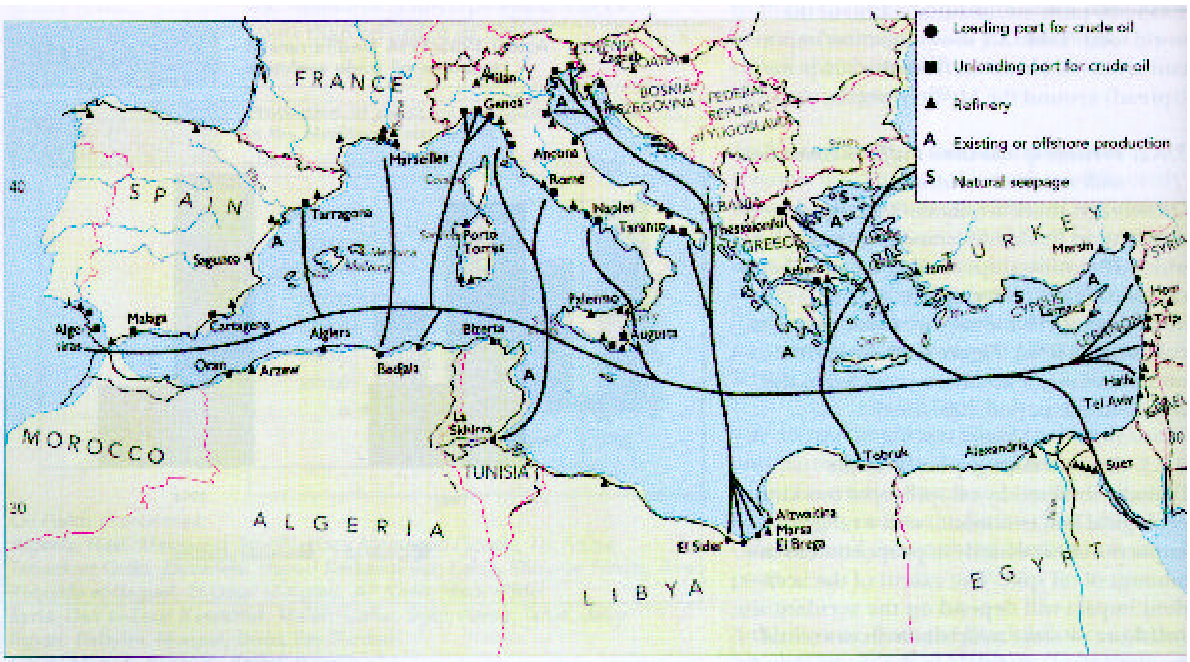

Figure 4.27 Main maritime routes of oil transport in the Mediterranean Sea
(Source REMPEC)

The major axis (90% of the total oil traffic) is from east to west (from Suez to Gibraltar), following closely the south coasts of Crete, passing through the Sicily-Malta and Sicily-Tunisia seaways and longing the coasts of Algeria and Morocco. The east-west axis is intersected by some south-north axis, connecting the Algerian and the Libyan loading terminals (about 100 MT) to the northern Mediterranean oil ports. The number of tankers passing annually through the Strait of Gibraltar is estimated to represent about one-fifth of the world total.

Apart of the traditional transboundary maritime routes described in the previous paragraph there is a very complex and fine network of routs used by pleasure crafts connecting marinas and nautical tourism destinations, at the national as well as at the international level.

Pleasure crafts are small, thus by definition pollution loads related to their activity (mainly garbage and wastes) are small. On the other hand, thousands of them are cruising every summer the Mediterranean and their number increase rapidly. Pleasure crafts are able to reach every single bay, in the most uninhabited and unpolluted areas of the Mediterranean. Any pollution control is inefficient due to the dispersion of the target.

- *Transboundary character of the ship-related pollution in the Mediterranean ports*

Most of the 2000 large ships, which are cruising daily in the Mediterranean, are loaded in one country and unloaded in another. Nautical tourism is also a transboundary activity. Thus, the pollution related to a transboundary activity in the ports has, by definition, a transboundary character.

In some Mediterranean countries like Italy, Greece and Turkey there is also an important domestic maritime traffic. However, even in these cases the pollution issues deriving from ships in the ports may have a transboundary character (e.g. pollution from domestic distribution of oil products, processed in local refineries from imported crude oil). Almost every national ship-related pollution issue in a port may have an international component (e.g. pollution from ship-repairing activities of ships operating in a country under the flag of another country).

Consequently, the rules for navigation safety, pollution prevention and abatement have to be elaborated in an international level. The ratification by the relevant flag-state of all the Conventions discussed and adopted by International Maritime Organization (IMO), is the prerequisite for the successful combat against ship-related pollution in the Mediterranean ports. A successful combat against ship-related pollution in ports and marinas has benefit effects on the protection of the Mediterranean marine environment and improvement of life quality at local, national and international levels.

Thus, pollution management in ports and marinas has a key role in the development of an environmental sustainable maritime transport and nautical tourism in the Mediterranean and the improvement of marine transboundary water quality.

- <u>*Major Mediterranean sea-borne trades*</u>

  - *Preliminary remark about the current dearth of statistical data.*

A detailed cargoes analysis and forecast of the Mediterranean international sea-borne trade flows was prepared in the framework of the "BLUE PLAN" in 1990 /1991 and presented in an ECOMAR report entitled *Maritime Transport in the Mediterranean sea and its consequences on the Environment* .

This sea-borne trade flows analysis was based upon the loaded and unloaded transboundary cargoes volume figures, derived for each country from national port traffics statistics for 1985, tabulated by the UNO Statistical Office yearbook. The data concerning Mediterranean countries was computed according an origin / destination matrix form adopted for an earlier unpublished "pilot study" of this Office, and specially processed for this ECOMAR report by the Dutch Maritime Economics Research Centre (MERC).

Unfortunately, it was not possible to undertake at a later date a comprehensive up-dating of this analysis. The base information exists but presently it is placed in the data banks of private companies and can only be processed and disseminated against the payment of relatively expensive fees. In order to monitor the evolution of maritime transport generated pollution risks in the Mediterranean Sea it would be advisable that a Regional Statistical Observatory of Sea-borne trade flows could be created within the framework of the Mediterranean Action Plan.

The 1985 Mediterranean Sea-borne trade analysis was carried-out for each of the following main cargo categories:

Liquid bulk cargo group	- Crude oil - Petroleum refined products - Liquefied gasses (LPG and LNG) - Liquid chemicals
Dry bulk cargo group	- Iron ore - Coal - Grains - Minor and other dry bulk cargoes
General cargo group	-Refrigerated and frozen goods -Containairisable cargoes - Other general cargoes

For each of the above cargo categories, the following four sets of Mediterranean trade flows Origin / Destination matrices were built-up by MERC according ECOMAR specification:

- *Intra-Mediterranean ports traffics* (cargoes loaded in a Mediterranean port and unloaded in an other)
- O*ut-Mediterranean ports traffics* (cargoes loaded in a Mediterranean port and unloaded in an other geographic area)
- *Towards-Mediterranean ports traffics* (cargoes loaded in an other geographic area and unloaded in a Mediterranean port)
- *Thorough-Mediterranean Sea transit traffics* (cargoes loaded and loaded in other geographic areas the respective locations of which imply the use of a route passing through the Mediterranean sea or suggest the probability of such use, taking into account other possible routes selection factors, such as Suez Canal draft limitation for loaded crude oil tankers).

- *Intra-Mediterranean Cargo flows*

During 1985, 172 million tonnes of international sea-borne cargoes were shipped between Mediterranean countries. Out of this total, *crude oil and refined petroleum products* amounted to 123 million tonnes (71.5 %) when liquefied gasses and bulk chemical liquids together represented 10 million tonnes (5.8%). Consequently, tanker trades represented more than three quarter of these intra-Mediterranean international shipments.

Among other cargo categories, it is interesting to point out the relative importance of *other dry bulk* with 27 million tonnes (15.7 %). In the intra-Mediterranean trade, the shipments of the numerous "minor commodities" amalgamated in this category exceeds by far the combined volume of the three "major commodities" : *Iron ore*, *Coal* and *Grains*. Having in mind the protection of the environment, it shall be emphasised that, among the "minor" commodities, rank several hazardous chemicals, carried in bulk form, but distributed among numerous partial shipments loaded on non-specialised handy-size and mini bulkcarriers or even on smaller multi-purpose cargo vessels.

This tramping section of the merchant fleet comprises a large percentage of ageing vessels operated by small shipowning firms. Thus, it requires a special attention of flag and port states vessel safety and pollution prevention authorities as far as the protection of the marine and coastal environment is concerned.

General cargo categories only totalled 9.4 million tonnes (5.4 %). This figure underlines the weakness of the manufactured goods import / export intra-Mediterranean North-South trade and the fact that nearly all such goods, exchanged between Spain, France and Italy, are carried by road or rail transports.

To obtain a more comprehensive review of these intra-Mediterranean shipments, the international sea-borne trade figures should be complemented by the volumes shipped between ports of the same country, under the so-called "national cabotage" regime. The 1997 total cabotage trade volume for Spain, France, Italy and Greece reached 134 million tonnes of which about 68 million (50.7 %) are for liquid bulk cargoes. Apart from the EU Mediterranean countries, only Turkey presents an important domestic sea-borne trade activity in the Mediterranean basin. However, Turkish national cabotage figures have not been found. It should also be underlined that the figures for France and Spain are concerning all national shipments and doesn't discriminate between the ones loaded and / or unloaded in Mediterranean ports and the ones loaded and unloaded in ports located on other coasts of these countries.

Finally, passenger/car ferries services to the Mediterranean islands generate an important part of short-sea vessels regional movements. In 1997, about 86 millions passengers were carried in the Spanish, French, Italian and Grecian national cabotage trades. Greek services have carried 47.3 % of this total, whist the Italian share was 43.1 %.

Cross-Mediterranean International passenger/car ferries services exists also in the Region, mainly in its Western part between Morocco, Algeria and Tunisia, on one side, and Spain, France and Italy, on the other. There is also large international passengers movements between Italy and Greece and less important ones between Italy and Corsica. To fully cover the field of passengers transport within the Mediterranean Sea, cruise ships should also be mentioned at the other end of the comfort scale. No specific statistical data are available for this activity.

- *Cargo flows linking the Mediterranean Sea with the rest of the World.*

Cargoes loaded in Mediterranean ports

Here again, "liquid bulk cargoes" play the major part: out of a total of 177 million tonnes in 1985, they reached nearly 100 million or 56.5 %. This total volume was distributed between 90 million tonnes for crude oil and oil products and about 10 million for liquefied gasses and chemical liquids. The relative weigh of the " minor bulk cargo" category - 47 million tonnes- reached 26.6 %. Out of a total of 25.5 million tonnes for General cargo, the "containerisable" segment was accounting for more than 16 millions tonnes.

Cargoes unloaded in Mediterranean ports

The total volume of these shipments from other parts of the World, at about 305 million tonnes, exceeds by far the one of the sea-borne "exports" of the Mediterranean area. Such unbalance can be related to the relatively low level of economic development presented by several countries of the South and the East part of the Region and to its overall relative paucity in mineral and agricultural resources.

As regards the liquid bulk group (45.7 % of the unloaded cargoes) only liquid chemicals present a positive trade balance. It may seem surprising that for crude oil, which is the more plentiful natural resource of the region, the unloaded quantities - more than 98 million tonnes in 1985- were exceeding the loaded ones by 57. 6 %. In fact western Europe, which is one of the more important oil consuming area of the World, is importing a large part of its crude requirements by its Mediterranean ports to be processed in local refineries or transported inland by pipe-lines.

In the group of dry bulk cargoes (46.4 % of the total), major commodities- Iron ore, Coal and Grains- totalled 90 million tonnes against 51 million tonnes for the "other dry bulk" shipments. This underlines the dependency of the Mediterranean region from the rest of the World for the three major solid bulk cargo categories of the global sea-borne trade.

As far as general cargo is concerned, the unloaded containairizable volume, nearing 7 million tonnes, only reached 43.3 % of the loaded one. Conversely, the volume of unloaded other general cargo - breakbulk and variously packaged shipments- at more than 11 million tonnes, was twice as big than the corresponding figure for the loaded one.

These unbalances, tending to compensate each other, can be explained by the reduced level of the local demand for imported manufactured consumer goods and domestic appliances as well as by the traditional structure of inland distribution in many countries of the south-east part of the Mediterranean region.

However, since 1985, the global rate of containerisation has continued to growth and the Mediterranean Region certainly was not an exception. Therefore the above mentioned unbalances have been probably corrected, at least partially, in the meantime.

- *Distribution of the Mediterranean countries sea-borne trade by main groups of cargo categories*

Table 4.65, extracted from the 1991 ECOMAR report, presents an overview of the Mediterranean countries sea-borne trade flows in 1985, distributed by main groups of cargo Categories- liquid bulk, dry bulk and general cargoes. Loaded and unloaded volumes are analysed by three origin and destination areas. The considered areas are:

- *The North-west Mediterranean countries* (Spain, France, Italy,Serbia and Montenegro/ Albania and Greece). Apart Albania (for which no valid trade statistical data were available), the economies of the countries of this group are of the highly developed or semi-developed types, four of them being EEC member states. For Spain and France only shipments to and from Mediterranean ports were taken into consideration.
- *The South and East Mediterranean countries* (Turkey, Cyprus, Syria / Lebanon, Israel, Egypt, Libya, Malta, Tunisia, Algeria and Morocco). Apart Turkey and Israel, where the industrial development is important in some sectors and can be considered as advancing in the process of economical take-off, the other countries of this area are rated as developing ones. Now, Palestine should be added to the list but the current events are jeopardising the development of the new Gaza port.

From this overall analysis of the 1985 Mediterranean generated maritime transport flows the main findings can be summarised as follows:

Out of a total volume of 375 million tonnes of liquid bulk cargoes, 204 (54.4 %) originated from the countries of the South and East area when 242 million tonnes (64.5 %) were destined to the North-west area. The comparison of these figures shows the importance of the rest of the World in the Mediterranean liquid bulk cargo flows: it is the origin of 37.9 % and the destination of 26.7 % of their volumes.

In the dry bulk cargoes group, the part played by the rest of the World as origin of the Mediterranean traffic flows is clearly predominating: About 142 millions tonnes out of a total of 223, i.e. more than 60 %.

The general cargoes group represents a total exceeding 55 millions tonnes. Essentially, this group comprises manufactured goods, therefore it is logical that nearly half of this total is loaded in the ports of the industrialised North-West area. An other important share -37 %- originates from the rest of the World whilst only 12.8 % is provided by the developing countries of the South and East area. Conversely the same countries receive 28.8 % of general cargoes unloaded in Mediterranean Maritime Transport, a little more than the North-west area (26.8 %) but far less than the rest of the World (45.6 %).

The total Mediterranean generated cargo flows reached about 654 million tonnes in 1985 of which 99 (15,1%) were loaded in the North-west area and 242 (37 %) in the South and East area. The remaining volume 304 million tonnes (46.6 %) originated from the rest of the World, a fact underlining the relative weakness of the intra-Mediterranean trade.

Table 4.67 **Geographical distribution of the main 1985 cargo flows in the Mediterranean Sea (figures in million tonnes)**

Main Cargo Categories	LOADED CARGOES Port Origin areas	Port Destination areas	Volume	UNLOADED CARGOES Port Destination areas	Port Origin areas	Volume
Liquid bulk cargoes : 375 million tonnes	N-W Mediterranean	N-W Mediterranean	7.88	N-W Mediterranean	N-W Mediterranean	7.88
		S-E Mediterranean	3.85		S-E Mediterranean	112.67
		Rest of the World	16.74		Rest of the World	121.22
		All destinations	28.47		All origins	241.77
	S-E Mediterranean	N-W Mediterranean	112.67	S-E Mediterranean	N-W Mediterranean	3.85
		S-E Mediterranean	8.39		S-E Mediterranean	8.39
		Rest of the World	83.24		Rest of the World	21.05
		All destinations	204.30		All origins	33.29
	Rest of the World	N-W Mediterranean	121.22	Rest of the World	N-W Mediterranean	16. 74
		S-E Mediterranean	21.05		S-E Mediterranean	83.24
		All Med. destinations	142.27		All Med. origins	99.98
Dry Bulk Cargoes : 223 million tonnes	N-W Mediterranean	N-W Mediterranean	4.83	N-W Mediterranean	N-W Mediterranean	4.93
		S-E Mediterranean	13.58		S-E Mediterranean	7.70
		Rest of the World	28.47		Rest of the World	97.62
		All destinations	46.88		All origins	110.25
	S-E Mediterranean	N-W Mediterranean	7.70	S-E Mediterranean	N-W Mediterranean	13.58
		S-E Mediterranean	3.78		S-E Mediterranean	3.78
		Rest of the World	18.97		Rest of the World	43.87
		All destinations	30.45		All origins	61.83
	Rest of the World	N-W Mediterranean	69.00	Rest of the World	N-W Mediterranean	28.47
		S-E Mediterranean	31.00		S-E Mediterranean	18.97

		All Med. destinations	100. 00		All Med. origins	47.44

Table 4.67 (cont.) - *Geographical distribution of the main 1985 cargo flows in the Mediterranean Sea (figures in million tonnes)*

	LOADED CARGOES			UNLOADED CARGOES		
	Port Origin areas	Port Destination areas	Volume	Port Destintion areas	Port Origin areas	Volume
	N-O Mediterranean	N-O Mediterranean	1.66	N.O Mediterranean	N-O Mediterranean	1.66
		S.E Mediterranean	5.67		S-E Mediterranean	1.52
		Rest of the World	20.41		Rest of the World	10.97
		All destinations	27.74		All origins	14.15
General cargoes: 56 million tonnes	S-E Mediterranean	N-O Mediterranean	1.52	S-E Mediterranean	N-O Mediterranean	5.67
		S.E Mediterranean	0.55		S.E Mediterranean	0.55
		Rest of the World	5.12		Rest of the World	9.92
		All destinations	7.19		All origins	16.14
	Rest of the World	N-O Mediterranean	10.97	Rest of the World	N-O Mediterranean	20.41
		S-E Mediterranean	9.92		S-E Mediterranean	5.12
		All Med. destinations	20.89		All Med. destinations	25.53

Source: ECOMAR 1991 BLUE PLAN report on *Mediterranean Maritime Transport and its impact on the Marine Environment*

- *Cargo flows transiting by the Mediterranean Sea*

To obtain a comprehensive coverage of the Maritime transport activity in the Mediterranean Sea, the analysis of the 1985 regional sea-borne trade flows, has to be complemented by an assessment of the transit traffics. These are constituted by cargo flows loaded on ships passing through the Mediterranean Sea but without any commercial call in one of its ports. From the global origins/destinations matrices prepared by MERC for the various cargo categories taken into consideration, the ECOMAR report has determined two types of transit traffic flows.

The first type comprised, on both ways, the cargo flows existing between Black and Marmara seas ports, on one side, and ports located elsewhere out of the Mediterranean Sea, on the other. For these flows , the crossing of the Mediterranean Sea is unavoidable. The second type was formed by cargo flows for which the transit by the Suez Canal and Mediterranean Sea, or vice-versa, was likely for geographical reasons, but not compulsory. Therefore estimates were needed for each of these relations.

These estimated flows amount to 215 million tonnes of which 54.5 million tonnes (25.3 %) are liquid bulk cargoes. It is noteworthy that crude oil and petroleum refined products volumes are practically equal with about 21 million tonnes for each category. Chemical liquids, mostly loaded east of Suez, with nearly 12 million tonnes form a relatively important part (5.5 %) of these transit traffics. Among the major dry bulk cargoes transit flows totalling 127 million tonnes, Grains, with more than 32 million tonnes, mainly imports of the former USSR and other Black Sea riverine countries, as well as Coal, with about 30 million tonnes, are the predominant commodities.

Within the 33.5 million tonnes of transit flows in the general cargo group, the respective volumes of "containairisable" ones and "others cargoes" nearly appear equal at about 15 million tonnes, each. Due to the progress of the containerisation process, in the meantime, within the liner trades linking North-western Europe and Us East Coast, on one side of Gibraltar, with the Middle East, Southern Asia, Australasia and Far East, on the other side of Suez, the present distribution should differs from the 1985 one and the share of containerised among containairisable cargoes is probably nearing 90 %.

- *Estimate of the evolution of the volumes of the Mediterranean cargo traffic flows in the 1985-2000 period.*

The 1991 ECOMAR report for the BLUE PLAN was comprising a long term forecast of the possible evolution of the Mediterranean Maritime Transport from the base year 1985 to the target year 2000. The framework of the BLUE PLAN, provided a cluster of co-ordinated prospective studies aiming at assessing the possible demographic, economic, industrial, agricultural and environmental evolution of the countries participating to the Mediterranean Action Plan.

These prospective studies were conducted according various social and economical scenarios that were common to all of them. Also common were their two target years 2000 and 2025. In drafting the BLUE PLAN *Maritime Transport* report, having taken place after the completion of most of the other prospective studies, it was decided to use, when available, their data and assumptions to prepare a forecast of loaded and unloaded future cargo volumes in the Mediterranean ports. This exercise was done for each of the cargo categories analysed at the base year 1985.

For the sake of simplification, only the two most contrasted scenarios were retained in order to prepare a high and a low hypothesis. Also, it was decided to present the forecast at single target year, and the nearest one -2000- was chosen. Having in mind the very high number of explanatory variables to be taken into consideration for a regional Maritime Transport forecast, it was considered that the respective evolution of so many independent factors during a very long period cannot be seriously predicted.

Due to the current impossibility to up-date to a most recent year the ECOMAR 1985 origin / destination Mediterranean Maritime Transport analyse for lack of suitable detailed and recent published statistics, it is of interest to check by any available indirect means the 2000 forecast volumes for the three main groups of cargo categories: Liquid Bulk, Dry Bulk and General. The forecasted figures can be compared with others based on different but more recent maritime statistical sources. For such a comparison, the well-known global sea-borne trade statistics, published by the Norwegian firm Fearnley in its "Yearly Review", have been used to determine, for each of these three cargo groups, the growth of the World sea-borne trade for the period 1985/2000. The resulting coefficient was applied to the 1985 Mediterranean sea-borne trade figures to get a corresponding 2000 estimate. The validity of such estimate depends of the actual degree of compliance of the regional evolution with the global one for each of these three groups.

Table 4.66 presents the result of the comparison, respectively for Liquid bulk, Dry bulk and General cargoes, between Mediterranean Maritime Transport figures, computed in the Low and High hypothesis of the ECOMAR year 2000 forecast, and corresponding estimates based on Fearnley Statistics. The estimates for the 2000 transit cargo flows through the Mediterranean sea also figures on Table 4.66; they are computed according the same cargo growth coefficients derived from Fearnley Statistics.

As regards dry bulk cargoes, the Fearnley-based estimate at 332 million tonnes is situated within ECOMAR forecast range of 286/342 million tonnes but nearer the high hypothesis. For general cargoes, the Fearnley-based estimate at about 90 million tonnes is placed near the average of the low and high forecast respectively 78 and 97 million tonnes.

For the liquid bulk cargo group, the 2000 low and high forecasted volumes are respectively 385 and 423 million tonnes within a very narrow range when the corresponding estimate, derived from Fearnley global statistics, reaches a very much higher volume of nearly 660 million tonnes. This estimate is based, for the whole liquid bulk group, on the growth coefficient recorded for the combined volumes of crude oil and refined products as the Fearnley global sea-borne trade statistical analysis is not sorting out the Liquefied Gasses and Liquid chemicals cargo categories.

Therefore, the above comparison exercise would suggest that the Fearnley-derived figures can be taken as possible guesstimate for the 1996 Mediterranean sea-borne trade volumes of the Dry bulk and General cargoes groups.

By far, the exercise is less favourably conclusive for the Liquid bulk cargoes group as the Fearnley-derived figure exceeds by 56 % the one provided by the high hypothesis of ECOMAR forecast. This large discrepancy can be explained either by the fact that the Liquid bulk Mediterranean Cargo flows (mainly composed of crude oil and refined petroleum products) have experienced a much slower growth since 1985 than the one registered at the World level or by a too pessimistic forecast of the evolution of the oil consumption in the Mediterranean countries, in the framework of the BLUE PLAN prospective studies for the Energy sector.

Table 4.68 **Comparison of forecasts and estimates for the main cargoes categories of the 1985 /2000 Mediterranean sea-borne trade evolution**

(Figures in million tonnes)

	ECOMAR FORECAST (Mediterranean ports) 1985	target year 2000 Low	High	2000 FEARNLEY BASED ESTIMATE (based on1985/ 2000 World SBT growth) Mediterranean ports	Mediterranean transit
Liquid bulk cargoes	374. 99	385.25	423.16	659.98	102. 68
Dry bulk Cargoes	223.11	289	341.78	332 .43	197. 64
General Cargoes	55.79	77.54	97.24	89. 82	52. 04
Total	653. 89	751.79	862.18	1,082. 23	352. 39

Sources : ECOMAR I991 BLUE PLAN report on Mediterranean Maritime Transport
"Yearly Review " published by FEARNLEY .in February 2001

- *The Mediterranean oil sea-borne trade in 1994 and 2000*

Of course, the answer to this alternative can only be found in taking into account some recent published data and information concerning the regional distribution of the global oil sea-borne trade in the recent years. A report on the “Tanker Market”, published in 1996 by the well-known London firm DREWRY Shipping Consultants, includes relatively detailed World-wide Origin / Destination matrices for crude oil and refined products in 1994. Table 4.67 combines these two matrices in order to sort out the Mediterranean flows, the volume of cargoes loaded and unloaded in the inter-Mediterranean ones, being taken only once into consideration in summing up the figures.

The result of the Drewry analysis tends to confirm the validity of the low hypothesis of ECOMAR forecast at least until 1994 as: the volume of the Mediterranean ports crude oil sea-borne trade, as computed by Drewry for this year, stands at 284.4 million tonnes. Thus, it was only 8 % higher than the corresponding figure for 1985. Surprisingly enough, the volume of products -70.5 million tonnes- was lower by 14 % than the one recorded in 1985. The combined volume of the two categories reaches 355 million tonnes and can be compared with an interpolation to the year 1994 of the ECOMAR low and high hypothesis forecasted to the target-year 2,000. The resulting range stay at 350 / 370 million tonnes. Thus the DREWY reported actual volume is only slightly exceeding the lower figure, when the forecasted volumes also includes liquefied gasses and chemicals.

The DREWRY matrices permit to identify transit crude and oil products flows crossing the Mediterranean Sea, either from the Suez Canal to Gibraltar or Dardanelles (originating from the Middle East) or from Dardanelles to Gibraltar or Suez (originating from the Black Sea riverine countries). During the year 1994, their total volume was 21.8 million tonnes (13 million for crude oIl and 8.8 million for products). This figure is about half the ECOMAR 1985 figure, the volume of which reached 42.3 million tonnes.

Therefore, the comparison of the 1985 and 1994 regional traffic and transit flows for crude and products shows that the total Mediterranean oil sea borne trade has remain more or less stagnant during this 9 years period: its volume was nearing 388 million tonnes in 1985, it was only about 377 million tonnes in 1994. Indeed, from the statistician viewpoint the validity of this comparison may be questioned as it is based on sources which are different for each of the two considered years, but for an Energy economist, this stagnation of the Mediterranean international oil trade is not surprising.

It confirms that the fast growth of the World oil shipping traffics recorded during the late eighties and early nineties (53 % from 1985 to 1994 according the Fearnley yearly statistical Review of World Bulk Trades) was mainly due to the rapid development of the economies of the new industrialised nations in the South and East parts of Asia. Conversely, in Western Europe, GNP growth was sluggish and the energy conservation efforts triggered by the two successive oil shocks have reduced the regional dependency from imported oil.

Also, during the period, an increasing recourse to the North Sea oil source for Europe and to the Mexican, Caribbean and Alaska ones for USA have resulted, for both regions, in a reduction of crude oil imports from the Middle East.

Finally the closure of the Iraq-Turkey pipelines during and after the Gulf War, has drastically reduced the volume of oil loaded in the East Mediterranean terminals whilst the growing share of VLCC in the World tanker fleet has enhanced the use of the Cape route for the carriage of Middle East crude to North America and North-West Europe.

Unfortunately, the DREWRY "The Tanker Market" study as not been up-dated since its publication in 1996. For 1998 we have to use again Fearnley World Bulk Trades review that contains a simplified origin / destination matrix of the Crude oil total seaborne trade during this year. In combining the Mediterranean imports with the Near East and North Africa exports and avoiding double counting we obtain a volume of 289 millions tonnes which is not much exceeding the 284 millions found by Drewry for 1994. Fearnley review provide also a matrix for Oil shipments by Tankers and Combined carriers of 50,000 tdw and over. In combining the figures as above we get a Mediterranean oil sea-borne trade volume of 352 millions tonnes for 1998. This higher value is explained by the fact that this volume includes also petroleum products.

Despite the fact that a non negligible share of the Mediterranean product trade is performed by tankers, the capacity of whom is less than 50,000 tdw, this figure confirms that the phase of sluggish development of Mediterranean oil sea-borne trade has been extended to the late nineties. In order to summarise the evolution of the Mediterranean oil sea-borne trade since 1985, Table 4.69 presents the most relevant figures mentioned in the above tentative analysis of the available sources of information.

It can be added that, according the figures published in BP AMOCO statistical Review of World Energy for oil import of Western and Central Europe, their 2000 total reached a little more than 453 millions tonnes when the same total in 1998 was about 470 millions. This reduction of 3.5 % was a little more than compensated by an increase in products imports from 75 to 96 millions tonnes.

Table 4.69 **Actual forecasted and estimated 1985 / 1994/ 1998 Mediterranean oil sea-borne trade evolution (Figures in million tonnes)**

	1985	ECOMAR FORECAST FOR 1994 *		1994 DREWRY OIL TRADE MATRICES		1998 ESTIMATE
		Low	High	Inter Med.	Med. transit	Inter Med.
Crude oil	263.37	-	-	284.40	13	289
Refined Products	82.17	-	-	70.50	8.80	63
Oil total	345.54	349.68	370.54	354.90	21.80	352

* interpolated from target year 2000 forecast.
Sources: ECOMAR 1991 BLUE PLAN report on Mediterranean Maritime Transport and "The Tanker Market" a 1996 study of DREWRY SHIPPING CONSULTANT FEARNLEY (1998 "WORLD BULK TRADE REVIEW")

The stagnation of West Europe oil imports during these last years was certainly reflected in the Mediterranean oil sea-borne trade. In fact for this one the stagnation has lasted all along the nineties: the volume of oil cargoes movements at Marseilles, one of the most important Mediterranean port for this cargo category was practically the same during the year 2000 than the one registered in 1991.

As regards the evolution of oil spill risks in the Mediterranean Sea and ports, this long lasting stagnation of regional crude and products flows can be considered as a favourable development. However, this situation is not likely to last for ever: The embargo on Iraqi oil exports has been partially lifted and the North Sea reserves are diminishing. The progressive drying-up of this major EU "domestic" energy resource along the first decades of the XXI century will have to be compensated by increasing imports from the rest of the World, particularly from the Caspian states of the former USSR.

Already, the rapid growth of number of oil tankers loaded in the Black Sea ports and passing the Bosphorus and Dardanelle straits is considered by Turkey as a major and increasing risk for the safety of people living in the Greater Istambul area as well as for the marine environment of these straits, their approaches and of the Marmara Sea. Despite the fact that the Turkish straits are not geographically considered as included in the Mediterranean sea, the south Dardanelle approaches are within its Aegean part and anyhow the PAM member states has to take into consideration such a tremendous environmental and safety problem existing at one of their doorstep and to be faced by one of them.

- *Pollution risk analysis of ship types and cargo categories*

  - *Relationship between ship types and pollution causes*

A preliminary distinction is to be made between operational and accidental pollution causes. Operational pollution causes shall be reduced as far as possible, accidental one are to be prevented by all means. Apart cargo and passengers carrying vessels, other merchant ships such as off-shore and port service craft may be the source of operational or accidental pollution.

Dredgers constitute a very special case of operational pollution as the material dredged in the port basins and access channels are generally heavily polluted. These materials are often dumped at sea and the selection of dumping sites to mitigate damages to the marine environment is a very complicated matter. By chance, most of the Mediterranean Sea ports are located in areas where, silting being minimal, depth maintenance dredging has not to be performed according a continuous program.

Fishing and pleasure craft are also source of operational pollution and the latter are particularly numerous along the Northern shores of the Mediterranean Sea. A possible, but practically not documented, pollution source derives from Warships operations in the Mediterranean sea. In fact, the NATO navies units are well equipped and their crews well trained to avoid operational pollution not primarily to protect the Environment but rather for a tactical discretion purpose.

  - *Ship-generated operational pollution*

Most operational pollution causes are common to all types of merchant ships. Some are related to propulsion plant: oily water and wastes collected in machinery space bilge tanks, nitrogen acid and other pollutants in machinery exhaust fumes, others to the crew and passengers: garbage and sewage, others to the ship's maintenance and operation: cleaning of tanks and piping before repairs, anti-fouling organotin paints, unwanted aquatic organism and pathogens fund in ships' ballast water and sediment discharges.

However, some well publicised pollution causes are specific to the operation of a certain ship type / cargo category combination. The most infamous is the operational discharge of oil and / or oily wastes at sea as the consequence of the washing of cargo-tanks of an oil tanker after unloading a shipment of crude or petroleum products and before loading the next one or undertaking a maintenance or repair operation. Same kind of problem exists for tank cleaning in chemical and LPG tankers which has to be carried-out each time a change happens as regards the category of cargo to be carried in a given tank or group of tanks.

  - *Ship-generated accidental pollution.*

Severe accidental pollution is usually related to oil tanker major casualties These cargo oil spills, often involving large quantities of hydrocarbons, attract the attention of the public through their wide coverage by the media, showing terrific pictures of blackened beaches and of dead or dying oily birds, otters or seals.

It should be reminded here that oil accidental pollution may also be generated by similar casualties involving any other type of ship whose bunker tanks and /or luboil ones happen to be fractured and release their contents in the sea. Bunkers are at present mainly composed of heavy fuel which is classified as a "persistent" and consequently dangerous pollutant. In fact heavy fuel used to feed most of the high power so-called "diesel" marine engine is not different from the heavy fuel carried in the cargo tanks of the ill-fated Erika and Prestige.

- *Ship-related contaminant loads in the Mediterranean ports*

Ship-related pollution in ports is directly or indirectly linked with pollution deriving from maritime transport. Most of the operational or accidental ship-related pollution categories can happen in port or at the open sea. Nevertheless, the preventing and curative measures are different in the semi-close and shallow area of a port, from ones intended for open and deep-sea intervention.

- *Major environmental issues related to ports and maritime transport*
  - *Petroleum hydrocarbons*

Oil spills deriving from operational pollution

Oily waters. At the Mediterranean as well as at the world level the major source of petroleum hydrocarbon pollution in the marine environment results mainly from discharge of oily water and residues resulting from the washing and deballasting at sea of the cargo tanks. Similar problems exist for chemical tankers, carrying hazardous substances (see paragraph 2.1.5). The operational discharge of oil comprises also effluents of oily bilge water and residues from the machinery space of all ships.

According IMO MARPOL Convention, the main lines of which will be presented in the paragraph 2.3, the Mediterranean Sea has been designated as a “Special Area” and harmful discharge of hydrocarbons is not permitted. Nevertheless, the problem of operational oil pollution is persisting.

The estimated volume of oily wastes from tanker operations (especially deballasting) reaches 450,000 tonnes. Discharge of “oily bilge waters, sludge and used luboils from ships” are supposed to represent a further 60,000 tonnes (UNEP/MAP, 1997b).

Oil discharges from coastal and offshore activities. A comparison between the 1985 and 1994 regional traffic and transit flows for crude oil and refined products shows that the total Mediterranean sea-borne oil trade has remained more or less stagnant. In 1994 the amount of crude oil was only 8% higher than 1985. In contrast, the volume of refined products was 14% lower than recorded in 1985 (ECOMAR, 1991).

There are already more than 40 oil-related sites (pipeline terminals, refineries, offshore platforms, etc.) distributed along the Mediterranean coastal zone. From and to them an estimated 0.55 and 0.15 billion tonnes respectively of crude oil and petroleum products are annually loaded, unloaded and transported by oil tankers (Clark, 1994; EIA, 1996-97).

Despite increased oil production, oil discharges from offshore installations and coastal refineries are decreasing as a result of an increased application of cleaning technologies and improved waste water treatment before discharge as shown in Figure 4.28.

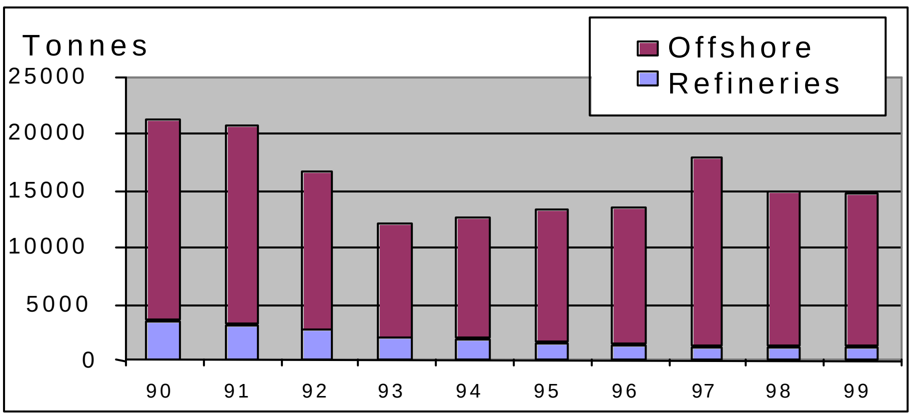

Figure 4.28 Total discharges of oil from refineries and offshore installations in EU
Discharges from refineries (1991-1992, and 1994-1999) are based on emission coefficients developed by DHI (Sources: OSPAR 2001, EUROSTAT 2001 and CONCAVE 1999)

Due to limited regular aerial surveillance in the region compared to other “Special Areas” such as the Baltic Sea and the North West European waters, and the resulting lack of regional statistics on pollution arising from routine ship operations, estimating operational oil pollution in the Mediterranean has been incomplete. A recent study by the EU (EC, 2001), using reconnaissance carried out over the entire Mediterranean region through the analysis of ERS-1 and SAR images presents the following data:

- During the year 1999, a total of 1638 spills were detected. Enhanced spill concentrations appearing along major maritime routes, such as those crossing the Ionian Sea (towards the Adriatic Sea, towards the Messina Straits and towards the Sicily Straits) and those in the Ligurian Sea, the Gulf of Lions and the East coast of Corsica.
- During the year 1999, the total area of the 1638 detected spills was estimates to be 17,141 Km^2.
- During the year 1999, an estimated 13,858 tonnes of spilled oil was estimated from the satellite images. This amount, considered by many researcher to be a conservative estimate, is already four times greater than the average amount of oil spilled in the region due to shipping accidents (REMPEC, 1998).
- A considerable number of the detected oil spills (38.5%) during the year 1999, were considered to represent without doubt spilling in action.

Oil spills deriving from accidental pollution

Out of a World total of 8395 registered events during the 1981-1990 period, involving oil pollution, 1246 have taken place in a geographical area covering the Mediterranean and Black Seas as well as the Suez Canal. The corresponding percentage of the World total - 14.8%- is only exceeded by North-Western European area -21%- and the very wide Far-East and Australasia area: 18.4 % (ITOPF, 1997).

From the same major casualties statistical analysis it appears that, among the "Fire/explosion" events recorded all over the world during the period, 21.7% have taken place in the Mediterranean/Black seas area. The corresponding percentage for "Foundered vessel" events was 16.9%, when the one for "Collisions" was 16.3%. Thus, the frequency of the above casualty categories that are the more likely to provoke cargo and bunker spills was higher for the considered area than the World average. The specially high percentage of "Fire and explosions" in the Mediterranean Basin should probably be related to the importance of oil and chemical tanker trades in this area, as the ships of these types are particularly exposed to this category of casualty. Such a global and regional Marine casualty analyse has not been repeated for a more recent period; however, when the yearly number of major casualties at the world level happily has been on the decrease, there is no indication that their geographical distribution nor their typology has been much modified during the last decade.

The most accident-prone areas are: the Strait of Gibraltar and Messina, the Sicilian Channel, as well as several ports and their approaches, particularly Genoa, Livorno, Civitavecchia, Venice/Trieste, Piraeus, Limassol/Larnaka, Beirut and Alexandria. The geographical distribution of these pollution hot-spots is related to the density of shipping traffic on the various Mediterranean routes. Out of 311 accidents listed by REMPEC for the 1977-2000 period, 156 (50,16 %) resulted in oil spillage. The most common types of accidents during this period were collisions (37.7%) and fire/explosions (51%). For the more recent 1998/2000 period the main casualty categories have been grounding (30.3 %), fire/explosion (25.6 %), sinking and collision/contact (both with 13.7 %).

It is worth recalling that collision appears to be the type of accident most likely to produce an oil spill, according to the records for the Mediterranean Sea kept by REMPEC. Among the accidents registered in 1994 and 1995, the 47% occurred in ports or in their vicinity. The fact that a disproportionately high percentage of accidents is registered in a very small percentage of the area occupied by ports and their approaches is related to very high traffic density caused by a large number of daily shipping movements in such areas. A contributing factor might also be the absence or the poor quality of the local vessel traffic systems in some of the Mediterranean ports. MAP/REMPEC (1996)

During the 1981/1995 fifteen years period, the total quantity of oil entered in the Mediterranean Sea as the result of shipping accidents reads 54,622 tonnes, a yearly average of about 3,641 tonnes. The most severe oil-spills in which more than 10,000 tonnes of hydrocarbons were spilt were the “Cavo Cambanos” the “Haven” and the “Sea Spirit” accidents. During the same period there were four incidents in which between 1,000 and 5,000 tonnes of oil were spilt in the Mediterranean Sea.

Indeed, when comparing the spilled quantities with the volume of about 350 millions tonnes of crude oil and products transported in the Mediterranean Sea in transboundary trade during 1998 (to which should be added about 60 millions tonnes of oil in domestic Maritime Transport) one cannot fail to conclude that, up to now, the actual contribution of ship-generated oil accidental pollution in the Mediterranean Basin has been kept much below the risk estimates.

Nevertheless, it should be stressed that a major oil spill can occur tomorrow in any part of the Mediterranean Sea and particularly along the major sea routes and in, or around, the more important oil loading and unloading terminals. Unfortunately, it is probable that several ageing tankers, the hull structure of whom is not stronger than Erika or Prestige, still presently operate in the Mediterranean waters, particularly on short-sea domestic or international "dirty" products trades in the eastern part of the basin where port-state control is weaker than in the western part. Therefore, the probability of a major oil pollution accident remains high in the region and preventive actions as well as preparedness efforts should be sustained and even increased.

- *Heavy metals*

Contamination from heavy metals is related to the operational pollution and especially to ship repairing and anti-fouling paints disposals in the sea. Another source of heavy metal contamination in the marine environment is the dumping of dredging materials.

Contamination from anti-fouling paints

A joint UNEP/MAP/MED POL and FAO report entitled "Assessment of organotin compounds as Marine pollutants in the Mediterranean" was published in 1989 in the framework of the Protocol for the Protection of the Mediterranean Sea against pollution from Land-Based Sources and activities adopted in 1980 by the riverine States parties to the Barcelona Convention.

The part played by organotin compounds as marine pollutants derives mainly from their biocidal uses in agriculture and anti-fouling paints. These paints are used inland mainly in cooling water pipes for electric power plants and other industrial facilities. Leaching from such cooling systems using water of rivers flowing to the Mediterranean Sea, reaches finally this one. According to the report, the potential contaminant load to the marine environment from this source may not be negligible but the range of estimates is very wide: from 1.7 to 48 kg/d of tributyltin (TBT) compounds.

In any case, their main source in the marine environment is related to their use as antifouling paint in pleasure boats. As regards the use of anti-fouling paints on the submerged parts of a ship's hull, the same report mentioned the value of 15 kg/d as the TBT compounds input to the sea of 100 large vessels with 1,500 m^2 of painted surface each. If the corresponding value of 0.15 kg/d is adopted as a average standard per vessel and applied to the estimated number of merchant ships we obtain a total daily discharge for the Mediterranean Sea of 210 kg/d.

These quantities appear negligible when compared with the overall volume of Mediterranean water. However, when considering that they are discharged each day, in a very restricted volume of harbour subsurface water, it can be of concern.

Some examples of organotin levels in the Mediterranean ports are given in the Table 4.68. The levels are high, but even higher values have been reported for other ports in the world (e.g. 147,700 ng/g in sediment from Ontario Canada, Scott et al., 1991; and 40,000 ng/g in sediments from Australia, Batley and Scammell, 1991).

Table 4.70 **Organotin levels in Mediterranean ports**

Ports and Marinas	TBT levels in water (ng/L)	TBT levels in sediments (ng/g dry wt)
Greece		225 - 10,000 (Tselentis et al., 1999)
Spain		124 – 18,722 (Diez et al., 2002)
Italy	2 -833 (Bacci and Gaggi, 1989)	0 – 1700 (Caricchia et al., 1992)
Malta	5 –300 (Axiak et al., 2000)	0 - 1500 (Axiak et al., 2000)
France Cote d’Azur Corsica	40 – 237 (Michel and Averty, 1999) 0 – 456 (Tolosa et al., 1996) 30 – 200 (Michel et al., 2001)	

In some cases there are reports that contamination is also found in coastal waters and even in nature reserves in areas adjacent to shipping activities. The levels of organotins are also high in bivalve tissues from locations near marina and shiprepair facilities (e.g. Barcelona, La Spezia). Other studies, however, indicate that TBT levels fall dramatically in sediments collected on the open sea side of the breakwater. High degradation rates are often attained in Mediterranean waters where oceanographic parameters such as sediment type, organic carbon content, turbidity, suspended matter, temperature and sunlight favour this process. These findings provide evidence as to the ineffectiveness of current regulations, which still allow the use of TBT in antifouling paints.

- *Contamination from the disposal of dredging materials*

In all ports a certain amount of dredging is required from time to time, when mud is accumulated in the basins. Also the creation of new quays and docks, require large and lasting dredging operations.

Marine sediments from harbor basins are usually contaminated with potentially-toxic trace elements (mainly heavy metals as Cd, Cr, Cu, Ni Pb, Zn and Hg). In addition to the heavy metals the sediments are characterised by high concentrations of organic carbon and the presence of polychlorynated biphenils (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

The concentrations of heavy metals in the Mediterranean port sediments depend on the importance of each port in the maritime transport. Some indicative concentrations of pollutants in dredged sediments from the Mediterranean ports could be the following:

Cadmium (Cd) 5-10 mg/kg, Chromium (Cr) 30-150 mg/kg, Copper (Cu) 25-100 mg/kg, Nickel (Ni) 75-150 mg/kg, Lead (Pb) 50-100 mg/kg. Zinc (Zn) 25-100 mg/kg, Mercury (Hg) 0-40 mg/kg. The organic carbon concentration values vary from 2 to 10%. The concentrations of PCBs and PAHs are very variable depending on the industrial activities near (or in) the port area and the presence of oil terminals.

Numerous studies have shown that the dry weight metal concentrations in sediments are not predictive of the bioavailability and sediment toxicity to benthic organisms. However, metal concentrations in interstitial (pore) water appear to be correlated to many observed biological effects. In the Mediterranean, which is characterised by high oxygen concentrations in the water column as well as in the sediment pore waters at the open sea, when the anoxic sediments of the harbor area are exposed to an oxic environment will eventually result in the release of the toxic divalent metal ions to the surrounding marine environment.

Several criteria for the determination of the toxic effects of sediments contaminated with potentially-toxic heavy metals have been proposed (Ankley et al., 1996). It is generally accepted that the calculated sum of the respective SEMs (simultaneously extracted metal) for each metal is approximately 1/10th of the available AVS (acid-volatile sulfide). According Di Toro *et al.,* (1992) when the AVS levels exceed the sum of total potentially-toxic metals in the sediments, metals are not the cause of the observed toxicity (with the possible exception of mercury). In this case toxicity is strongly associated with PAHs and PCBs (Ho et al., 1994). Nevertheless, the oxidation of AVS raises the levels of the SEMs increasing the toxic effects of the heavy metals (Hansen et al., 1996).

An alternative strategy for the disposal of dredged materials from ports is the “confined disposal”. Confined disposal involves the placement of dredged material within a dike near-shore, island or a land-based containment area (e.g. the enclosed landfill area that will form the base of new docks. The US National Academy of Sciences points out that a “Confined Disposal Facility” is the most commonly used placement for contaminated harbor sediments (NAS, 1997). The CDF approach is applicable to a wide variety of sediment types and project conditions.

- *Garbage and wastes*

The problem of garbage and wastes remains as a major one in the Mediterranean. The ship generated garbage could be classified as:

- Domestic solid waste, distributed between wet garbage (mainly food wasted) and dry garbage (mainly paper, plastic, textile, bottles etc)
- Maintenance waste (soot, paint scraping, wiping and sweeping)
- Cargo-associated waste (pallets, strapping materials, spoiled cargoes)

Domestic wastes are related to the number of people on board. The average person/day estimates are 1.9 kg for wet garbage and 1 kg for dry garbage.

Pollution from domestic wastes is related to the operational activity of every type of ship, but the major problem comes from passenger carriers. The study of an example on the Italian and Greek domestic routes (UNEP/MAP, 1997b) gives an estimation of 74,000,000 passengers traveling were during the year 1995 or a daily average of about 200,000 persons. On the basin scale this estimation gives about 385,000 persons which should produce 267,000 tonnes of wet garbage and 141,000 tonnes of dry garbage per year. Thus, the Mediterranean receives daily the equivalent of a large city garbage.

The domestic wastes disposed in the sea are usually floating for several hours affecting the transboundary waters. The problem of domestic wastes is not located in the ports, but the reduction of their volume passes through the port management. On the other hand, the problems of maintenance wastes and cargo-associated wastes are located in ports.

Maintenance wastes are related to the number of ships. They are estimated to a total of 11 kg per ship/day (about 4 tonnes per unit yearly) or a total load of about 5,620 tonnes yearly, at the basin scale.

Cargo-associeted westes are related to the volume of carried dry cargoes and are estimated to 1 tonne per 123 tonnes on non containerised general cargo, 1 tonne per 10,000 tonnes of bulk cargo and 1 tonne per 25,000 tonnes of containerised cargo. According to the 1996 interpolation of the average forecast of these cargo categories in the ECOMAR Mediterranean sea-born trade prospective study, the yearly quantities of cargo-associated waste at Mediterranean ports should reach about 200,000 tonnes (UNEP/MAP, 1997b).

Taking into account the volumes of garbage and wastes received daily in the Mediterranean port facilities and the number of ships operating in the region, it appears clearly that dumping in sea of garbage and wastes remains the favorite option of the ship Masters in the Mediterranean, despite its inclusion as a "Special Area" where disposal at sea of all types of garbage, but food waste, is prohibited (ANNEX V of MARPOL). There are many reasons for such a behavior:

- Garbage and waste receiving facilities are absent in many Mediterranean ports
- The access to the receiving facilities is usually time consuming
- The Mediterranean Port States are not able verify the respect of the regulations

Thus, the Port State authorities have to continue their effort in order that the IMO regulations will be fully applied. The ship owners have to be convinced for the application of the regulations. The ship Masters and crew have to be trained for the environmental safe handling of garbage and wastes.

- *Organic pollution and microbial contamination*

The main source of ship-related organic pollution in the marine environment is sewage (liquid wastes). Nevertheless, sediments dredged from the ports are usually charged with important loads of organic matter and they could be an important source of organic pollution when they are dumped in the sea.

Sewage

Pollution from liquid wastes is related to the operational activity of every type of ship, but the major problem comes manly from passenger carriers. Assuming that the average number of persons traveling in the whole Mediterranean reaches 400,000 per day, and using urban standards for this population, the estimated daily volume of sewage disposed in the sea is about 40,000 m^3. A part of this volume should be treated on board according to the MARPOL regulations.

Sewage disposal in harbor basins and marinas is the source of severe organic pollution and microbial contamination. Nevertheless, sewage disposal in the open Mediterranean could not be considered as a major problem of transboundary pollution due to the rapid dilution of the liquid wastes and the oligotrophic character of the Mediterranean.

Is worth to note that most of the cities on the south Mediterranean coasts dispose their waste waters in the sea without any treatment. Even on the north Mediterranean coasts cities like Athens and Marseilles disposed untreated wastes until the last decades of the 20th century, in daily volumes of one order of magnitude higher than the above estimated ship-related volume.

An severe transboudary problem of organic pollution and microbial contamination is related with pleasure crafts not respecting the MARPOL regulations. In this case, usually during summer, small bays and beaches used for bathing are receiving loads of organic pollutants, as well as microbial contamination. Although the loads per craft are relatively small, the presence of people bathing in the vicinity gives a high potential risk of aesthetic pollution and human health.

Organic pollution from dredging material.

Dredging materials, apart the potential chemical pollution from heavy metals, they could be the source of organic pollution, as their content of organic carbon is about 2-10%. Nevertheless, as particles are settling down slowly, there is natural oxidation of the organic material.

- *Gas emissions*

Studies have concentrated on gas emissions from ship movements within specific areas and estimates have been published for the Mediterranean Sea and Black Sea in a recent EU study (EC, 1999). Relevant data is shown in Table 4.71.

Table 4.71 **Total estimated emissions (tonnees/annum) from ships within port in the Mediterranean and Black Sea area in 1990**

Emissions	**NOx**	**CO**	**Hydrocarbons**	**SO_2**
Main engines	1,620,336	129,055	29,549	1,171,784
Auxiliary engines	104,338	17,987	5,783	73,893
Total	1,724,674	147,042	35,332	1,245,677
Medium speed engines	781	2	1	221
Slow speed engines	779	113	12	505
Total	1,560	115	13	726

Fewer published studies have concentrated on the atmospheric emissions due to ship movements within a port area, which although much smaller in magnitude compared to the above, nevertheless have a serious effect on the adjacent to the port, urban area.

Estimation of atmospheric emission loads generated in Mediterranean ports was undertaken within the framework of this report, using data available from Lloyd's Maritime Information Services concerning port calls and ship movement data estimated in the previously mentioned EU study. The engine load in all vessels was assumed to be operating at 50% MR for all the time whilst moving and manoeuvring within the port area. The findings are summarised in Table 4.71, which are in accordance to values available from studies on individual ports of the Mediterranean (Englezou et al., 1995).

Auxiliary engine emissions are not included. Studies involving passenger shipping (Ro-Ro and cruisers) indicate a contribution exceeding 25% of main engine emission loads.

In response to these increased levels of pollutants, the International Maritime Organization IMO has already published a new Annex (VI) to the MARPOL 73/78 convention. Serious efforts in the areas of engine performance, ship design, and transport efficiency, have resulted in a 20% reduction in atmospheric emissions from the maritime industry, for the 1980 –1990 period.

- *Other pollutants*

Operational chemical cargoes-related pollution

Contrarily to oil wastes, the quantities involved in the tank washing process of chemical liquids are small and practically impossible to detect in the seawater. However, the washing of tanks is a very frequent operation as the cargoes of chemical tankers are much diversified. As regards dry bulk chemicals, the stripping of the bulk-carrier holds is generally carried out in ports and part of the wastes may be dumped in the surrounding water.

Curiously enough, MARPOL do not consider the Mediterranean Sea as a "Special Area" for chemical tankers. Thus, in the Mediterranean waters these ships follow the general regulations for monitoring and controlling chemical discharge at sea.

The published Port statistics are not detailed enough to sort out noxious substances from the various chemicals liquids and soils shipped in bulk from and to the Mediterranean Ports.

Pollution from radionucleids

The problem of ship-related radioactivity affects mainly the military ports and no data are available for these areas. Nevertheless, during the visits of nuclear vessels in civil ports a detectable increase of radionuceid concentration in the seawater might be observed. These visits where frequent in the Mediterranean ports during the first 2-3 decades after the war, but during the last decade they became rare.

- *Introduction of alien species*

The introduction of alien species in the region is directly or indirectly related with the human activity and maritime transport is one of the most common ways of alien species introduction. Mediterranean ports have a key role for the introduction of alien species in the region. Indeed, many cases of spectacular “invasion” of alien species have been observed in the vicinity of the ports and the major ecological and economic impact is affecting the port areas.

The introduction of alien species in the ports is related with ballast waters or the surface of submerged hulls (usually combined with ship repair waste disposal). The first way of introduction concerns mainly unicellular organisms or reproductive cells of multicellular organisms (benthic or planktonic). The second way concerns also adult benthic multicellular organisms, attached on the submerged hulls. Both ways are very effective for the introduction of alien species and equally difficult to fight against. Some of the most spectacular examples of ship-related introduction of alien species in ports are:

- The benthic geen alga *Codium fragile*, introduced from the Atlantic during the second half of the 20th century and actually dominant element of the marine vegetation in many Mediterranean ports (west and east basin).
- The marine Angiosperm *Halophila stipulacea*, introduced from the Red Sea after the opening of Suez canal and actually common element of the marine vegetation in the ports of eastern Mediterranean.
- The dinoflagellates *Alexandrium* spp. (and other related genera) introduced from the Indo-Pacific ocean after the opening of Suez canal and actually common element of the plankton flora in the ports of the Mediterranean.

In the case of the first two examples the main effect is ecological: the native flora is in competition with the invasive species and the result is usually a loss in biodiversity. In the case of the third example additionally to the ecological impact there is important economic impact: the introduced species are able to produce “red tides” and release substances, which are toxic for fish and shells. In this case fish and mussel farming in the area is damaged.

In same cases an alien species are introduced in the Mediterranean by a non ship-related activity (acuaculture, aquaria etc), but the dissemination of the species is ship-related and located in the port vicinity. The example of the ship-related dissemination of the green alga *Caulerpa taxifolia* is the most striking because of its ecological and socio-economic impacts on the French Riviera.

o *Exploitation of sea bed and subsoil*

Exploitation of the seabed and its subsoils is limited to two key activities, mineral extraction and oil and gas production.

To date, offshore mineral extraction has primarily concentrated on aggregate (sand and gravel) for the construction industry and metals (primarily tin) from sediments known as placer deposits. Neither of these are found in significant quantities in the Mediterranean although there are large sand deposits in the Gulf of Lions and chromium rich placer deposits to the east of Cyprus. In addition, there are known deposits of calcareous products off southwest Italy, the south of France and south of Sicily and concentrated metalliferous deposits off southwest Italy. In general, marine mineral extraction is very limited in the Mediterranean.

In contrast, the oil and gas industry in the Mediterranean is much more extensive. Over 350 wells have been drilled and offshore production is taking place in Italy, Egypt, Greece, Libya, Tunisia and Spain (Table 4.70). In addition, concessions for offshore exploration have been identified off Turkey, Malta, Israel, Lebanon, Algeria and the formerSerbia and Montenegro (Oilfield Publications Ltd, 1997). Profitable oil and gas reserves were discovered in Western Mediterranean (Pujol Gebelli, 2001), between the Balearic to Corsica and Sardinia Island, and between French and Italian to Algerian coasts. These reserves are likely to be located in 1 to 15 oil fields and in 60 to 140 gas deposits, with expected productivity reaching 50 to 2,500 millions of oil barrels and 600,000 to 3,600,000 millions of cubic feet of gas. Other significant offshore gas discovery was made by Israel, with an initially estimation of 3-5 trillion of cubic feet in proven reserves. To date (Roussel, 2002) the number of wells and number of producing fields are small in comparison with the more highly developed areas in the Middle East, North Sea or Gulf of Mexico and the overall production modest.

Reserve estimates for the Mediterranean Basin are currently set at over 50 billion barrels of oil and 8 trillion cubic metres of gas (Babies and Hilmar, 2002), to be compared with previous estimates of 400 million tonnes of oils and 100 billion cubic meters of gas (Isoard, 1997). In year 2000, Mediterranean countries produced a little over 4 million barrels of crude oil and condensate per day and 135 billion cubic meters of natural gas per year (Energy Information Administration, 2002) and consumed just over 8 million barrel of oil per day and 198 billion cubic meters of dry natural gas per year (Energy Information Administration, 2002). In result, the production of oil and gas in the 1995-2000 period increased much more than previously expected, approximately twice compared with the 1990-1995 period. Nonetheless, the deficit in the energy balance of the region remained almost unaltered because of the concurrent increased demand.

Table 4.72 **Offshore fields, wells and production**
(Oil and Gas Journal, December 96)

Country	**No. of offshore fields**	**No. of producing wells**	**Average oil production (barrels/day)**
Libya	1	46	57,192
Tunisia	4	33	41,923
Italy	6	58	15,547
Spain	2	36	12,702
Greece	1	12	9,000
Egypt*	41	13	640,393

* Includes Red Sea production facilities

- *Sources, magnitude and scale effects*

The exploitation of seabed and subsoil activities result in environmental impacts. The magnitude and extent of any impacts are generally dependent on the activity together with the physical regime (i.e. wind, currents, water depth, mixing etc.) and the environmental sensitivity of the area.The main sources of environmental impacts that were identified are:

- Noise emission by seismic surveys, drilling operations, supplies ships, tanker and helicopter traffic. These emissions cause disturbance to cetaceans and marine mammals, thus altering feeding, communication and, in general, the community life. Noise may also affect fishes and seabirds.

  The scale of effects is dependent on the sensitivity of organisms to the sound source and varies from metres to kilometres. Generally, the magnitude of impacts is small, affecting individuals rather than populations, unless activities impact areas where species congregate to breed or feed or interfere with migration routes. The most sensitive animals are marine mammals which may show behavioural responses up to 10 km or more from the source.

- Discharge of drill cuttings, drilling mud and produced water, which contain dangerous organic chemicals (especially PAHs), heavy metals and a number of other additives such as scavenging agents, corrosion inhibitors, defoamers, bactericides and biocides. The toxic compounds may affect significantly all the sea life through direct and indirect effects, some of them being capable of bioaccumulate.

  Water based muds (WBM) are used in most wells drilled in the Mediterranean. Typically, the toxicity of the whole mud is very low, with an LC50 of >50,000 mg/kg (Leuterman et al., 1989). Field studies indicate that biological effects, following the discharge of water based mud cuttings, rarely show an impact beyond that of the immediate vicinity of the rig, in which smothering by the cuttings pile appears to be the most important factor (Bakke et al., 1986; Neff, 1987). Although the benthic communities present will be affected by the discharged cuttings, the area will be relatively small. On the other hand, the major waste product of a drilling operation is the generation of rock cuttings. These are inert solids, and their composition reflects the well geology.

- Oil and gas spills by offshore platforms during the extraction and the processing phases, including both accidental or operational spillages, and transport (pre- or post-processing). Estimates of the total inputs of petrogenic hydrocarbons to the marine environment show that the major inputs are the result of discharges from land (i.e. mainly through rivers), spills and discharges from ships, and smaller but significant input from natural sources (such as seeps or sediment erosion) (see sections 4.2 and 4.7).

  Massive spilled oil may affect especially the coastal environments, causing heavy damages to flora and fauna in ecological, social and economical valuable habitats, resulting in long-term consequences that require long time for acquiring partial recovery. There have been no large oil spills reported from exploration and production in the Mediterranean (REMPEC, 1996).

- Atmospheric emissions including greenhouse gases (carbon dioxide and methane), volatile organic carbon (VOCs), and nitrogen and sulphur oxides. Rough estimates of total emissions from exploration and production operations suggest that the contribution of atmospheric emissions in the Mediterranean is very small compared to total regional emissions.

- Decommissioning. The environmental impacts of disposal of the non-hazardous material of structures will primarily revolve around the physical effects of moving or leaving a structure in a certain place. These will be small localised effects.

Transboundary impacts may be expected especially from noise emission, discharges of toxic and persistent chemicals, accidental tankers oil spills and atmospheric emissions.

- *Regional issues and transboundary impacts*

The potential environmental impacts from oil and gas exploration and production can be grouped into four types with similar geographic zones of impact (Table 4.71). The following sections discuss the importance of these impacts in a regional context and the possibility for cumulative effects resulting in regional problems.

Table 4.73 - **Type and scale of impacts from exploration and production activities**

Type	**Key inputs**	**Source**	**Scale of impact**
Acoustic Effects	noise	seismic surveys	up to 10 km
Operational Inputs	metals, hydrocarbons, other chemicals	drilling muds drill cuttings drilling chemicals	<0.5 km
Atmospheric Emissions	CO2, NOx, SOx, CO	power generation flaring	regional/global
Oil Spills	oil	fuel, reservoir	regional (up to 1000 km for large spill)

- *Acoustic effects*

Acoustic emissions are produced by seismic survey in the exploration phase, for a short-term period, but long-term significant noise may be also emitted during the operational phase, by drilling operation, operative machinery, by ships and aircraft – helicopter traffic, and finally by movement of oil and gas through the pipelines.

Lethal effects of acoustic emissions as part of seismic surveys are highly localised. There is the potential to impact the behaviour of marine mammals at distances up to 10 km from the source. This can result in transboundary or regional impacts on these scales. Seismic operations can affect breeding of some animals (e.g. fish, turtles, marine mammals) but primarily for populations that form site specific breeding aggregations and only if operations are sufficiently close to disrupt the aggregations. If this were to occur, there may be short-term impacts on these populations.

Similarly, populations of marine mammals could be affected if migration routes or breeding areas were close to seismic operations.

Severe impacts from seismic surveys are unlikely if suitable preventative measures are taken. Seismic surveys are undertaken over a very short period of time and there is no evidence of long term or cumulative implications.

Greater attention should however be posed to the noise emission during the oil filed developing. The impacts on fish and seabirds are not well documented. Impacts on marine mammals are the same caused by seismic operations, but extended to a long-term period, providing altered behaviour, disturbance of displacements and stress. These impacts require an in depth investigation, especially on induced stress, which may cause a disease increasing in combination with marine chemical pollution, reduction of communication ability, altered breathing/dive behaviour, prolonged exposure to loud sounds.

- *Operational inputs*

The impacts from operational inputs are most evident in the immediate vicinity of an operation (up to 500 m) although some data suggest minor impacts from 2 to 10 km away. In either case, these are generally local impacts with no regional or transboundary implications.

There is the possibility of cumulative effects as discharges include metals and hydrocarbons. A large number of studies have shown that the metals are not readily bioavailable so the potential for accumulation in the food chain is limited (Neff, 1987; Leuterman et al., 1989).

Concentrations of hydrocarbons in the Mediterranean Sea have been increasing in recent years (*EC, 1995*). Higher concentrations have been found in sediments than in water and the highest concentrations near river mouths, ports and industrial areas. A study of background hydrocarbon concentrations in sediments using historical data over a 13 year period in the North Sea was unable to show any indication of hydrocarbon accumulation as a result of E&P operations, although there were problems with comparing data as a result of analytical techniques, in spite of the greater input of hydrocarbons due to higher levels of oil industry activities and the discharge of oil based drilling muds (UKOOA, 1994).

Generally, the potential for regional problems as a result of accumulation of these discharges appears to be small. However, the likely increase of oil and gas production in Mediterranean Sea suggests to pose more attention to this aspect of E&P activity, and to evaluate in particular the bioaccumulation and biomagnification through the food web of carcinogenic PAHs. There are also some evidences of the bioaccumulation of heavy metals in benthic infauna. The application of new technologies such as drill cuttings and produced water re-injection is expected to limit the amount of discharges, and the resulting impacts.

- *Atmospheric emissions*

The impacts from atmospheric emissions may vary greatly depending on both size and complexity of the E&P activities. For some operations (e.g. seismic surveys, exploration drilling) emissions are comparable to those of a ship at sea. However, whenever E&P activities include extended processing, impacts associated with the gaseous emissions become significant. On a regional scale, emissions from E&P operations contribute so far only to a minor proportion of the Mediterranean region’s total emissions. So, although operations may contribute to the global pool of pollutants, the overall impacts are probably small.

- *Oil spills*

Impacts from accidental spills can range from hundreds of metres as a result of a fuel spill to 1,000 km or more from a large spill. Although the probability of a large spill from E&P activities is low, spills are an important issue when considering impacts on anything greater than a local scale.

A significant issue associated with oil spills concerns long-term impacts, following the release of the oil buried in beaches sand (where the anoxic conditions slow the biodegradation process) and causing re-oiling of the environment. Hydrocarbons incorporated into sediments may persist at least for a period of 20 years. Moreover, this condition may facilitate the re-oiling events, caused by the oil leaching from sediments (Clark, 1992), as shown after the Amoco Cadiz spill.

The spilt oil affects the whole flora and fauna, causing direct and indirect effects. Long-term impacts may occur for marine mammals populations (i.e. during the breeding season, reducing the reproduction capability of the population), as well as fish and shellfish species, causing sublethal effects and reduced biodiversity. Ecological damages may occur, with reduce of local species, favoring a high growth of opportunistic species; long-term effects may be observed after 5 years.

- *Cumulative impacts*

A detailed list of environmental impacts resulting from off-shore E&P activities was reported by Byron (1993) and are presented in Table 4.72. For each E&P activity (i.e. exploration, development, extraction, transport), the sources of impacts were identified and then impacts were qualitatively estimated according to a) scope and permanency of the impact and b) areal extent of the impact. From the inspection of Table 4.71, it follows that major impacts are associated with the extraction (through accidental or operational oil spillage, and clean-up and remediation) and transport (through spillage/leackage). The most significant areal impacts result again from extraction (through accidental or operational oil spillage, and recovery activities or natural effects) and transport (through spillage/leackage). In result, extraction and transport are major sources of cumulative impacts.

Table 4.74 **- Environmental Impacts and Area of Impact of Offshore Oil and Gas Operations**

Type of Development and Consequences	Relative Impact[a]	Area of Impact[b]
Exploration		
Small-scale impact on sediments and sedimentation	M	VL
Small-scale disruption of benthic and pelagic organisms	M	VL
Alteration of nearshore drainage	M	L
Seismic disruption	M	L
Local release of drilling fluids/muds	M	L
Oil spillage (accidental or operational)	M	L
Onshore staging area impacts	M	L
Development		
Bottom and sub-bottom sediment disturbances	S	L
Local release of drilling fluids/muds	S	L
Oil spillage (accidental or operational)	S	P
Gaseous emissions	M	P
Increased disruption of benthic and pelagic organisms	S	L
Modified current and sedimentation patterns	M	L
Visual and aesthetic effects	S	L
Extraction		
Extensive offshore or onshore disruption for storage and handling	S	L
Oil spillage (accidental or operational)	H	P-R
Micro-seismic events	S	P
Groundwater/oceanic water pollution from recovery activities or natural effects	H	P-R
Processing		
Surface disruption and modification	S	L
Gaseous emissions (COx, SOx, NOx, particulates)	H	R
Effluent emission	H	P
Residual wastes	S	L-P
Spillage (accidental or operational)	S	L-P
Surface and groundwater contamination	S	P
Visual and aesthetic effects	S	L
Transport (pre- or post-processing)		
Surface disruption and modification (pipeline)	S	P-R
Spillage/leakage	H	P-R

[a] Qualilative estimate of the scope and permanency of the impact.
M = Minor
S = Significant
H = High
[b] Qualitative estimate of the areal extent of the impact. VL = Very local, that is, confined largely to site of occurrence.
L = Local, that is confined largely to immediate area of site of occurrence.
P = Provincial, confined to broad surrounding area bounded by primary dispersal controls.
R = Regional, broad distribution resulting from primary and secondary dispersal.

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• Assessment of the impacts of transboundary elements

o *Living marine resources*

▪ *Increase in nutrients and eutrophication*

Eutrophication is the process by which waters enriched with nutrients, primarily nitrogen and phosphorus, under favourable physico-chemical conditions stimulate aquatic primary production (EEA, 1999). Nutrient enrichment may also change the order of succession and seasonal length of different phytoplancton groups by altering nutrient ratios, where unbalance of nitrogen and phosphorus is perhaps as much a problem as the overquantity of nutrients. Although still unclear, a relationship has been shown between the succession and balance of phytoplancton species and the periodic occurrence of massive blooms of the jellyfish *Pelagia noctiluca* in coastal waters throughout the northwestern, central and northeastern Mediterranean. Putting aside such specific study, reports on zooplancton response to eutrophication in coastal waters are few.

Microphytobenthos (bottom diatoms) are particularly affected by nutrient enrichment. Primary production of phytobenthos in the Adriatic Sea increased dramatically, especially in the Po delta area where massive blooms of diatoms have turned in the production of mucilage and recurrent anoxia of the bottom waters which caused profound modifications in the benthic ecosystem. As for macroalgae, and like in many other seas, there is a general shift from long-lived macrophytes (*Cystoseira* spp., *Dictyota* spp., *Halymenia* spp., etc.) to short-lived nuisance algal species in the most exposed areas like deltas or bays.

The problem of eutrophication in the Mediterranean appears to be limited largely to specific coastal and adjacent offshore areas. The situation at basin level is clearly illustrated in the satellite image in Figure 5.1 where chlorophyll variations in surface waters reveal that the highest concentrations are found close to river deltas and estuaries or near large urban agglomerations. Almost all coastal countries appear to be affected by eutrophication, although at different levels and scales depending on the extent of the continental shelf and the movement of water masses.

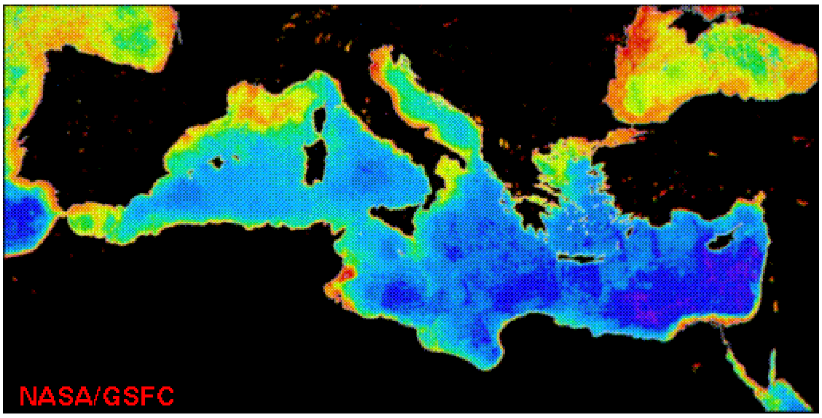

Figure 5.1 - Satellite image illustrating average chlorophyll variations in surface waters of the Mediterranean Sea, winter 1979-85
Source : NASA/GSFC

The most important cases of eutrophication are found along the northern and western coasts of the Adriatic Sea which, due to the Adriatic's circulation characteristics and shallowness, are mainly affected by river loads and by sediment/water exchange processes. But eutrophication events (algal bloom) and related side effects (hypoxia/anoxia of the waters near the seabed, toxins, bottom fauna kills, mucilage, water discoloration, reduced transparency, etc.) are taking place in other areas as well like the coastal waters of Cyprus where pronounced proliferation of ephemeral macroalgae (*Ulva* spp., *Enteromorpha* spp., *Cladophora* spp.) are regularly reported.

Although the northern shores are logically the most affected (the most industrialised), the phenomenon in the south should not be underestimated in spite of a limited number of recorded events which may well be linked to less active monitoring networks. While pressure is increasing with rapid population expansion, it is likely that these eutrophication problems will multiply in the future.

When evaluating eutrophication effects, it should be remembered that, though irregular, there is a tendency of an unexpected increase in fishery landings, especially those of small pelagic fish, with the eutrophication of the basin. The FAO Bulletin of Fishery Statistics shows, that for a few decades (1970-80), the productivity has increased especially on the continental shelf in the Northern Mediterranean, very clearly related with the human impact. What might appear as a positive effect now, in the long run and in association with other environmental factors, could have direct effects on the decrease of biodiversity.

It is known, on the other hand, that the South-East of the Mediterranean remains a very oligotrophic area and that this character has been worsened by the construction of the Aswan dam which would have caused :

- a reduction of 75% of total catch in the area,
- a progressive coastal erosion,
- the salinisation of the deltaic grounds.

Although the nutrient contents in the Western Mediterranean has increased by 0.5% each year from 1965 to 1995, reliable figures are still rare because of the inherent difficulties of measuring anthropogenic eutrophication under conditions of high natural variability. Given current limits of knowledge, it is impossible to predict the appearance of eutrophication effects and how harmful they may be.

The spatial and temporal scales of processes related to the environmental impacts of mariculture are shown in Table 5.1 (Karakassis, 2001).

Table 5.1 **- Spatial and temporal scales of processes affected by or related to mariculture**

Impact	Spatial scale	time scale
Diel nutrient increase in (P + N) concentrations	10 –1 00 of m	hours
Thickness of farm sediment	cm	weeks – months
Distance of anoxic area around cages	5 – 50m	months
Recolohization of anoxic sediments by macrofauna	m	years
Residence time of antibiotics in wild species	km	days
Propagation of microbial strains resistant to antibiotics or introduced parasites	10 – 100 km	2 – 10 years
Replacement of biota by introduced species	depending on motility and larval propagation	depending on life cycle
Modification of gene pool of wild stocks	10 – 100 km	several generations (> 10 years)

- *Eutrophication : The case of the Northern Adriatic Sea*

Starting in the 70's, eutrophication phenomena such as algal blooms and the production of mucilage has given rise to great concern , particularly in the northern Adriatic, because of their new considerable frequency, intensity and geographical extension.

The physico-geographical characteristics of the Adriatic, in addition of specific climatic conditions and the prevailing surface water circulation, make this basin (already a theatre of natural eutrophication phenomena) an especially vulnerable area in view of the extensive land and river inputs of pollutants deriving from human activities. However, the situation differs considerably from the southern part to the northern par of the Adriatic. According to the 1966 assessment by UNEP/MAP, based on the work of many researchers during the last twenty years, the trophic conditions of the Adriatic sea can be summed up as follows:

- Coastal areas in the north-western Adriatic and at some sites on the coasts of Croatia and Montenegro that have high nutrient levels and are affected by recurrent microalgal blooms are classified as eutrophic;
- The open sea waters of the north-western basin are mesotrophic-oligotrophic; and
- The majority of the central-southern basin is oligotrophic.

The serious deterioration that has occurred in the northern area of the Adriatic for over twenty years is attributable to the nutrient input in amounts that exceed the basin's natural assimilation capacity. The Po, carrying some 100,000 tonnes/year of inorganic nitrogen and some 6,000 tonnes/year of inorganic phosphorus, contributes most of the total nutrient load of the northern Adriatic basin. The next largest of the rives flowing into the northern Adriatic, the Adige, contributes about 14,000 tonnes/year of total nitrogen and 1.200 tonnes/year of total phosphorus, although its mean nutrient concentrations are lower than those of the Po. The total nitrogen and total phosphorus discharged into the northen Adriatic from Italy alone amounts to some 270,000 and 24,000 tonnes/year, respectively. To these must be added the inputs from Istria, estimated at 12,600 and 600 tonnes/years of total nitrogen and total phosphorus, respectively.

The other areas of the northern Adriatic, between the Po delta and Trieste, generally have lower levels than the adjacent area. The hydrodynamics of this basin are such that Po waters tend to be carried mainly southwards by the currents. Further, the area north of the Po delta receives a lower input of eutrophying substances, and residence times of water from local tributaries are shorter because of the absence of clear low-salinity fronts.

Eutrophication phenomena, with a distribution and persistence much greater than in any other part of the Mediterranean., have occurred and continue to occur in the coastal waters of Emilia-Romagna to the south of Po delta. The first cases reported date back to 1969. These were followed by a relatively long period in which the phenomenon was not observed until it returned in 1975, when an immense bloom of flagellates caused widespread anoxia in the bottom waters, accompanied by bottom fauna kills and the beaching of large quantities of bottom fish (7,000 tonnes in the Municipality of Cesenatico alone). Subsequently, events succeeded one after another in the summer of almost all the following years. The blooms in this area are normally caused by diatoms and dinoflagellates. The former, although they may cause blooms at any time of the year, tend to dominate during winter and spring, whereas flagellate blooms occur especially in the summer and autumn.

The recurrent anoxia in the bottom waters caused profound modifications in the benthic ecosystem; there were considerable reductions in the original populations of the least mobile bottom organisms (molluscs, crustaceans, and polychaetes) most sensitive to oxygen deficiency. Repetition of these dystrophies has led to the disappearance of about filteen species of mollusc and three species of crustacean.

Further, the recurrent phenomena of eutrophication and the general deterioration of water quality in the north-western Adriatic have had serious negative repercussions on the economy of the region, especially tourism and fisheries. With regard to fishing, and mollusc farming in particular, considerable damage has been done by the dinoflagellate of the genus Dinophysis, which produces (D.S.P.) toxins. The occurrence of these flagellates, which have become more plentiful during the last decade, has led to temporary and prolonged bans on the harvesting and sale of mussels (*Mytilus galloprovincialis*) farmed in the coastal and lagoon areas of Emilia-Romagna. Further *Alexandrium tamarensis*, a dinoflagellate capable of producing (P.S.P.) toxins, has been observed in the waters of the northern Adriatic, although no pathologies in the resident populations attributable to PSP intoxication have ever been encountered.

Considering that the eutrophication phenomena are no longer occasional events, but are induced by structural deficiencies on land, there is a need to eliminate such deficiences, which are mostly linked to tourism, agriculture, animal husbandry and municipal sewerage. During the 80's, important laws, decrees and norms were approved at the European Community and the national levels mostly addressing the reduction of phosphorus in the detergents produced, bringing the limit down to 1 percent. As a result, it has been possible to quantify a decrease of 10,000 tonnes/year in the input of phosphorus to the sea. In contrast no important reduction of nitrogen in the sea has been monitored in spite of a 1991 Community norm in that direction. This is mostly due to the difficulty of applying the norm (e.g. lack of economic incentives) and the lack of controls.

There is ample scientific evidence of the increased spread and intensity of eutrophication in several areas of the Mediterranean endangering the natural equilibria of the basin. The status of the Adriatic is in fact only a mirror of a situation more and more worrying for the entire Mediterranean. Methods already exist for the abatement of the intensity and extension of the eutrophication phenomena through appropriate analysis and management of the activity sectors concerned and the implementation of legal, technical and other measures. The fight against the causes of eutrophication should be a priority for all the Mediterranean coastal States.

- *Jellyfish blooms in the Mediterranean Sea*

The occurrence of massive blooms of the schyphomedusa *Pelagia noctiluca* in various areas of the Mediterranean is a case of the common and still not fully understood gelatinous zooplankton blooms. Large *Pelagia* blooms were first reported in the Adriatic in 1977; during their peak (1981-1983) they involved extensive areas of coastal waters throughout the northwestern, central and northeastern Mediterranean and had a significant impact mostly on tourism and fishing; they also created considerable concern for human health. The following are the findings of the MED POL Jellyfish Programme coordinated by UNEP/MAP and carried out from 1984 to 1986.

P. noctiluca (Semaeostomeae, Pelagiidae) was first described by Forskal in 1775 as *Medusa noctiluca*. Unlike meroplanktonic jellyfishes (Anthomedusae and Leptomedusae) which are usually restricted to shallow waters because of their dependence on a hard substrate on which their benthic life stages may settle, holoplanktonic jellyfishes, as *P. noctiluca*, may complete their life cycle in open waters because of the absence of a benthic stage.

The periodicity of occurrence of the bloom period appears to differ greatly between different parts of the Mediterranean. In the western Mediterranean, or at least in the Ligurian Sea, there appears to be a rough periodicity of 12 years. Bloom periods appear to be much less frequent in the Adriatic during the present century where they were reported during 1907-1914 and then not again until 1977. On the other hand, only a few aggregations of *Pelagia* were reported along the Lebanese and Turkish shores.

During the bloom period of the 80's, enormous numbers of *Pelagia* individuals (in some cases up to 100 individuals per cubic metre) were reported in coastal waters and on the shores of the Ligurian Sea, the central Mediterranean, the Adriatic and parts of the Aegean

Sea. Between the bloom periods, *Pelagia* appears to be absent from the Adriatic and rare in the western Mediterranean offshore waters.

Observations in the Mediterranean suggest that the bloom period may be divided into three phases: the initial phase, the peak phase and the phase of decline. The initial phase is recorded at different times in the different regions. During the blooms of the eighties, the first reports of *Pelagia* aggregations in coastal waters came from the northern Adriatic and only later in Maltese waters and in the Ligurian Sea. The occurrence of the peak phase and the declining phase appear instead to be more synchronised over the whole geographical region. Pronounced seasonal fluctuations in the populations of *Pelagia* have been shown to occur during the initial and the declining phases of the bloom period, with coastal aggregations being more evident during the March-June period. On the other hand, during the peak phase, Pelagia adults could be detected throughout the whole year. For example, during 1981-1983 (peak phase) the presence of Pelagia in the coastal waters off Villefranche did not change significantly although the seasonal fluctuations in seawater temperatures ranged from 13° to 26°.

Reports from the northern Adriatic indicate that some aggregations are formed by actively swimming individuals generally at subsurface levels. Reports from the same region, as well as from the central Mediterranean, indicate that other surface aggregations could also be passively maintained by surface currents.

The distribution of *Pelagia* in the Mediterranean during the bloom period appears to have been determined by the hydrological and possibly, the natural trophic characteristics of the particular area. For example, in the Ligurian sea, this was found to be correlated with natural eutrophic conditions, so that relatively large numbers were found to be concentrated on both sides of the Liguro-Provençal Front. The occurrence of *Pelagia* aggregations was never found to be directly correlated with localised land-based pollution. However, any enrichment in nutrients, whether by natural means or as a result of man's activities, may lead to localised increases productivity and this in turn may be expected to lead to increased numbers of Pelagia. It has been suggested that temperature may have a predominant influence on the stability and persistence of an aggregation. Aggregations in the Gulf of Trieste were normally formed when the seawater temperatures ranging from 20° to 25°, and were rarely seen at temperatures above 25° C.

The phenomenon of blooms of *P. noctiluca* in the Mediterranean may be taken to be a highly visible biological expression of the epipelagic community's response to long-term hydroclimatic changes in the physical environment. Although human activities, such as overfishing of the natural jellyfish predators and the discharge of land-based pollution, may help to sustain its blooms for longer periods of time, their occurrence is a natural phenomenon which has been recorded in the region long before man's impact on the marine environment could have reached significant proportions.

Various hypothesis to explain the triggering and controlling mechanisms of the Pelagia blooms have been suggested. For the northwestern Mediterranean, it was suggested that the occurrence of *Pelagia* bloom periods over the last hundred years may be correlated with pluri-annual climatic and hydrological cycles. The years prior to the bloom periods are in fact characterised by a deficit in rainfall and by anomalous high temperatures and atmospheric pressures, especially in May and June. Such climatic factors may possibly enhance the reproductive potential and , as a result, the increased investment in growth (hormesis) may constitute the biological response of this species to natural stressors as its popultations are introduced into new areas by anomalous water currents. Another hypothesis suggests that blooms in *Pelagia* or other planktonic species may result when their internal circannual clocks anticipate the regular and seasonal fluctuations in the environment so that they would be able to exploit the favourable season with greater success than their natural competitors, thus leading to a population explosion. It has still to be established whether any factors trigger the blooming phenomenon simultaneously in the various Mediterranean regions affected, or in some restricted primary centres from it later spreads by means of water movements.

- *Chemical contaminants: levels of exposure and associated effects*

The effects of contaminants on the marine ecosystem are very difficult to assess. Results of laboratory experiments give only limited information in relation to the field situation, on account of the complexity of the natural ecosystem and,in general, the co-occurrence of a multitude of contaminants in the field. Actual changes in the marine environment are often very difficult to discern owing to the high natural variability. In any case, coastal waters, receiving urban, industrial and riverine discharges are the most affected areas.

Heavy metals

A number of trace elements have been considered of priority in monitoring marine pollution, such as Hg, Cd, Pb, Cu and Zn. The potential hazard of mercury, like other heavy metals, stems from both its direct effects and its bioaccumulation, which often lead to an increase in concentration up the food chain and with the age of the organism. In the Mediterranean, observations of mercury levels in tuna or dolphin populations showed up higher mercury levels than in the Atlantic. These high mercury levels in the Mediterranean are known to be of natural origin. Although the ecotoxicological significance of these concentrations is not clear, following a MEDPOL study, they do not appear like threatening human health.

The concentrations of total cadmium in blue-fin tuna from the Mediterranean appear to be comparatively low and unlike mercury, do not show significant differences between the eastern and western Mediterranean. Also, cadmium concentrations do not appear to increase with the size and age of the species. As regard the cadmium concentrations in the surface sediments, high values may be found in polluted lagoons and other so called « hot spot » areas. As for mercury, the ecotoxicological significance of the observed concentrations is not clear.

Lead mean concentrations in marine organisms appear to be rather low in the Mediterranean except near highly industrialised coastal areas. A follow-up of water pollution carried out from 1983 to 1996 in the Western Mediterranean, shows a progressive reduction in lead concentration in open sea waters starting from 1994. This would be the consequence of the international limitation of lead additives in gasoline applied in 1976. This example allows to assess the response time of the system to an emergency measure.

The ionic component of total dissolved copper in sea water has been shown, through experimental studies, to have a deleterious effect on some phytoplankton and bacterial species at levels of 0.1-0.2 µg/L. However, in the wild, the metal is bound to natural ligand (soluble organic carbon) which decreases its toxicity. In the Mediterranean region, among the most important sources of copper are the fungicide used in vineyards and the copper-based paints as anti-fouling. Although rather high concentrations may be observed in « hot spot » areas, the mean value of concentration in marine organisms remains well below the maximum permissible limit (20 µg/g).

Zinc, nickel and arsenic concentrations are generally close to background levels, and there are no indications that the concentrations found exert toxic effects in themselves, i.e. not considering their contribution to the total contaminant mix.

In conclusion, it appears that the greatest risks to the Mediterranean ecosystems from the metals studied are somewhat similar to some other seas : they stem from the effect of copper, mainly on lower trophic levels ; from cadmium on top predators ; and from lead, on predators of shellfish.

Tributyl tin (TBT)

Derived predominantly from anti-fouling paints, tributyl tin produces distinctive responses in various organisms. It has a particular low threshold for effects on bivalves (particularly oysters) and gastropods. In the Mediterranean, concentrations in the surface waters may be very high in industrialised port areas, but there are only a few data available for concentrations in sediments and biota. Possible effects on phytoplankton and zooplankton (at levels > 1ng/L), oysters (shell anomalies at > 2 ng/L), effects on reproduction (at > 20 ng/L), and fish reproduction (1-10 µg/L) or behaviour (at 1-100 µg/L) can be anticipated.

A series of field investigations with marine invertebrates suggests that tributyl and triphenyltin compounds can induce imposex. The monitoring of a gastropod (*Bolinus brandaris*) along the Catalan coast (NW Mediterranean) showed that imposex was a widespread phenomenon (Solé et al., 1998). Imposex has also been described in the gastropod *Nucella lapillus* collected in the Galicia coast (Ruiz et al., 1998), in the whelks *Stramonita haemastoma* and *Hexaplex trunculus* in Israel (Rilov et al*.,* 2000) and Italy (Terlizzi et al*.,* 1998), and in Malta (Axiak et al*.,* 2000).

Persistent Organic Pollutants (POPs)

The two main categories of POPs measured in the MEDPOL programme are chlorinated pesticides and polychlorinated biphenyls (PCBs).

The most widely distributed group of chlorinated pesticides is the DDT family. Its main metabolites (DDE and DDD) are also widely observed in the marine environment and may in some cases have greater environmental impact. Although DDT production was banned in many countries of the northern hemisphere in the 70's for its deleterious effect on seabirds and marine mammals, it is still observed in significant concentrations in marine sediments and marine organisms.

As for PCBs, the highest concentrations are observed particularly in predators such as mammals and birds. The former demonstrate lipid concentrations far in excess of those found in terrestrial top predators. The lipid-rich blubber of marine mammals exacerbate their PCB accumulation potential, making them a sink for PCBs.

A wide variety of the compunds considered here (e.g. DDT, PCBs, etc.) have been associated with potential reproductive anomalies in fish, and there has been a growing awareness of the need to detect and assess the adverse effects. Recently, new evidence based on monitoring hormone and vitellogenin levels together with gonad histology indicate that the central Mediterranean male swordfish *(Xiphias gladius*) is undergoing sex inversion (14%) (Fossi et al., 2001). There is no evidence, however, of reproduction impairment. The effect on other large pelagic predators or on marine mammals is also unknown.

In marine mammals, PCBs levels determined in the blubber and liver of striped dolphins affected by the 1990 morbillivirus epizootic in the Mediterranean Sea, and in the blubber of striped dolphins from the same area in 1987-1989 and 1991, raised the question of the possible relation with the event. Although recent mobilisation of lipid reserves was found to have occurred in some of the diseased dolphins, this had little effect on their PCBs blubber levels and cannot explain the observed difference with the healthy individuals. Three hypotheses were put forward to explain the apparent link between high PCBs levels and mortality caused by the epizootic: (i) depressed immuno-competence caused by PCBs leading to an increase in individual susceptibility to the morbillivirus infection, (ii) mobilisation of fat reserves leading to increased PCBs levels in blood which, in turn, may produce a liver lesion capable of increasing the individual's susceptibility to the morbillivirus infection, and (iii) previous existence of an unspecific hepatic lesion producing impairment of the liver function which, in turn, could lead to an increase both in tissue PCBs levels and susceptibility to the morbillivirus infection.

Hydrocarbons

Because of many oil-related sites (pipeline terminals, refineries, offshore platforms, etc.) and heavy traffic of oil tankers, large amounts of hydrocarbons are introduced in the Mediterranean (see section 4.7). In assessing the effects of oil pollution, one should distinguish the impact of chronic pollution, which is the most common in the marine environment, from the episodic spills. In this case, the impact and the recovery of the ecosystems affected vary considerably. Both biotic and abiotic factors govern the extent of the biological consequences of each oil spill and it is the interaction and relative contribution of these factors which are important.

Danovaro et al. (1995) studied the meiofauna response to Agip Abruzzo oil spill in sub-tidal sediments of the Ligurian Sea, where about 30000 tonnes of crude oil were released in front of the Livorno harbour and caused a decline in meiofauna density relative to the pre-pollution conditions. Statistical analyses indicated that the structural characteristics of meiobenthos collected after two weeks were almost indistinguishable from pre-pollution, demonstrating the high resilience of these meiobenthos assemblages. High crude oil toxicity was also found by testing Erika oil samples with mussel larvae and algae, although the acute effects seem to decrease rapidly due to oil dilution and degradation.

The effects of chronic oil pollution are more difficult to be assessed as they usually co-exist with other forms of pollution. It is well documented that even 1µg/L of water-soluble oil component can harm sensitive organisms like larvae hatched from fish eggs. Exposure to low boiling hydrocarbons of 12 µg/L, halves the rate at which mussels can assimilate food. Low salinities and high temperatures enhance the effect. Bearing in mind the temperature in certain Mediterranean coastal areas, it is expected that chronic effects occur although at present there is little or practically no information on this subject. Long-term, sub-lethal effects were recently assessed by using the biomarker methodology. Results from Aegean Sea and Erika studies found that after a period of 6-12 months the biochemical markers returned to initial values, indicating no differences with original long-term contamination (Porte et al., 2000, Narbonne et al., 2001).

Oil is an important source of polycyclic aromatic hydrocarbons (PAHs). Concentrations in the Mediterranean Sea are enhanced by inputs from human activities, e.g. from discharges of oil, incomplete combustion process, and industrial effluents. Few data are available on the levels of PAHs in the marine environment. The first results from the new MEDPOL programme on the use of biomarkers, in this case the detoxifying enzyme EROD (ethoxyresorufin-o-deethylase) more specific to PAHs and PCBs, showed that benthic fishes like the red mullet may indicate a significant activity in the few « hot spots » with the highest concentrations in sediment.

Combined effects of contaminants

More generally speaking, the recent use of a few of these biomarkers in marine organisms (molluscs and fishes) opens the way to a better understanding of the combined action of different chemical contaminants. Even if these contaminants are present at concentrations too low to cause gross harmful effects, they can cause a suite of biochemical reactions in marine organisms generally called stress. Amongst the results of prolonged stress is the suppression of immune system, thus increasing sensitivity towards the impact of infectious agents and parasites. Natural factors, such as temperature extremes and fluctuations of salinity, or anthropogenic activities, can aggravate these reactions. The interest of biological effects technique is that it measures the integrate response of organisms to all possible factors. However, it should be noted that none of the techniques selected directly treat the questions of either the acute or the sub-lethal toxicity of the contaminant load present in sediment. There is a real need for sensitive *in situ* bioassays to measure sediment toxicity using organisms that normally live in sediments.

The biomarkers most commonly used have been the cytochrome P450 1A monooxygenase (CYP1A), the 7-ethoxyresorufin-O-deethylase (EROD) activity, the measurement of DNA damage, the benzo(a)pyrene oxydation (BPH), the inhibition of acetylcholinesterase and the determination of lysosomal membrane stability. CYP1A expression in the benthic species *Mullus barbatus* has been related to PAHs levels in sediments (Burgeot et al., 1996). Likewise, studies examining residue levels of bioaccumulated PCBs in muscle tissue have shown a direct correlation with CYP1A activity along the NW Mediterranean coast (Porte et al., 2002), the higher response being observed in specimens collected near urban and industrial areas. Other fish species, such as *Serranus crabilla* and *Dicentrarchus labrax,* have also been successfully used in biomonitoring programs, particularly along the Western Mediterranean coast.

Lysosomal alterations are accepted as a marker of general stress and it has been related to levels of PAHs and PCBs accumulated by mussels along the Spanish coast (Porte et al., 2001), the Adriatic Sea (Petrovic et al., 2001), and Venice Lagoon (Lowe and Fossato, 2000) among other areas. DNA damage in molluscs inhabiting contaminated areas has been reported in the Orbetello Lagoon (Frenzilli et al., 2001).

Diseases

Diseases in marine animals are a result of a combination of causes. Due to this complexity it is usually difficult to explain the process of disease initiation and development. Several hypotheses have attempted to link the outbreaks of the diseases observed to environmental degradation which results in a weakening of the immune system of the affected organisms, such as the mortality of dolphins in the early 90's or the severe sponge epidemic disease in the beginning of the 90's. Still in their infancy, biomarkers as presented above could help in that direction and in order to get answers as to whether these diseases are unpredictable episodic events or symptoms of ecosystem degradation.

Despite the difficulty to directly attribute population responses to pollutants, there are some indications that coastal fish assemblages respond to the impact caused by sewage discharge or mussel fisheries in SE Italy. But still more data is required at the population, community and ecosystem level to assess the health of the Mediterranean. The two approaches (individual and ecosystem health) are not exclusive, but the fact that the type of studies involved are very different usually means that they are not conducted in tandem. Actually, it is difficult to extrapolate from a cellular response caused by chronic exposure, and assess its effect on a whole organism or an ecosystem, as it is also difficult to extrapolate from an acute response resulting from a lethal concentration of a stressor to low-level effects occurring over long exposure periods.

- *Climate change exacerbating already existing problems*

Increase in temperature and salinity

In 1990, Béthoux et al. announced the increase in temperature and salinity measured since 1959 in the Algero-Provençal deep waters. This tendency has been confirmed so far and a recent radiative assessment, made by these same authors over the period 1940-1995 on the whole of the Mediterranean, shows that this is comparable with the one estimated in the northern hemisphere. Consequently, the increase in temperature observed in the Mediterranean would represent one of the first measured physical expression of climate change.

On the other hand, between 1987 and 1995, a dynamic change was observed in the Aegean Sea : salted and dense water spreading through the strait of Crete modifies the Ionian circulation. According to Bethoux et al. (1998), this modification in the water dynamics which could have direct consequences on the biological productivity is well related to the assessments of water and heat transfers. The freshwater deficit and the increase in salinity are connected, at the same time, with the decreasing precipitations (global change), with river impoudements, but also with the ingression of water from the Red Sea since the opening of the Suez Canal in 1869 and its enlargement in 1981. One could also recall the consequences of the Suez Canal works on the colonization of the Mediterranean by plant and animal species originating from the Red Sea, as they are usually called “lesseptian migrations”.

As a matter of fact, the sea water temperature changing has the main role on the lessepsian fish population development success. As shown by recent studies (Andaloro and Rinaldi, 2001), some species virtually disappear in the last years, as *Scyliorhinus stellaris, Squatina* spp. and *Argyrosomus regius*, while other species increased their biomass (*Sphoeroides pachygaster, Parablennius pilicornis, Scartella cristata* and *Diplopus cervinus*), and new species coming from the African continental shelf appeared like *Epinephelus aeneus, Lobotes surinamensis, Caranx rhonchus.* Under Fish Aggregating Devices and drifting materials some rare Carangidae are increasing their presence and several specimens of *Seriola fasciata* have been recorded in Southern Tyrrhenian Sea and Sicilia Strait. Istiophoride catch are increasing strongly too in all Tyrrhenian Sea and Tetradontidae presence recorded in Sicilian Strait only a few years ago is actually massive in trawl catches.

In such a context, competition as spatial and temporal overlap in the fish resources can be severe and alien species can take advantage of favourable condition in presence of fragile, feeble and overexploited autochthonous populations.

The global change and the consequent water temperature increase in the Mediterranean Sea is not reducing the biodiversity but on the contrary increase the number of fish species. The problem is then about new conditions of competition between species, probably exacerbated by over-fishing of certain species and high levels of pollution in certain areas.

Sea level rise

The physical impact of sea level rise on the Mediterranean lowland coasts can be predicted, even modelled quantitatively on the basis of the presently available data and information on morphology, hydrodynamics, sediment budgets, land subsidence and the effect of artificial structures. A mean sea level rise in the Mediterranean region comparable to global mean, of about 96 cm by 2100 is likely to happen taking into account the past trends and projected global increases given by IPCCs mid-range scenario. The worst affected regions appear to be the large river deltas and their wetlands, and lagoonal places like Thessaloniki and Venice which are currently subsiding.

Among the most likely consequences of sea level rise will be : increased direct wave impact on exposed coasts (e.g. the coastal barrier of the Venice lagoon, beach resorts of the Rhône delta) ; increased frequency and intensity of flooding of estuaries, canals and lagoons, with potentially serious consequences for agriculture, aquaculture, lagoon fisheries and wildlife (e.g. the delta of the Ebro and Ichkeul/Bizerte) ; and worsening of existing shore erosion problems (e.g. the deltas of the Nile and Rhône).

Seawater intrusion into wetlands and coastal aquifers will intensify with an elevation of mean sea level, changing drastically the balance between freshwater and salt water speciesand worsening the already quite widespread freshwater supply difficulties experienced in a number of locations along the shore of the Mediterranean.

o ***Biodiversity and ecosystem changes***

Biological diversity can be separated into three distinctive groups: (1) ecological diversity (diversity among ecosystems), (2) species diversity, and (3) genetic diversity (diversity within species). The most accepted and utilised definition of biodiversity is at the species level, which is just one of the components of biodiversity. This early attention to biodiversity at the species level is quite understandable because it is usually the systematics specialists that originally identified the loss of species as being at a crisis stage, and they are also the ones who have actively documented this loss of species. Such is the case in the Mediterranean although species inventories (taxonomy, distribution, abundance) are still very far from complete. This section will thus covered the species diversity and, when available (i.e. mainly for vegetated systems), their genetic diversity. The ecological diversity is to be considered at the scale of habitats/ecosystems and therefore will be presented in the "Habitat changes and physical disturbances" section.

As said before, the biological diversity of the Mediterranean basin is due to a series of historical factors, namely geomorphological and geological, climatic, etc. The influence of the ongoing global warming, as measured indicators (temperature and salinity) and observations (species distribution) seem to attest it, could change (or are already changing for some of them) many biologically important hydrodynamic processes in the Mediterranean. For example, changes in either the magnitude of upwelling or the timing of the upwelling season may have major effects on marine biodiversity since reproduction and larval recruitment are particularly sensitive to their occurrence and timing.

On top of it, man has greatly changed the nature and the distribution of this diversity during several millennia, through centuries of extensive or intensive grazing, agriculture, forestry and pastoral fires, and today by urbanisation, tourism, industrial development, pollution and the overuse of water resources. Biodiversity in the Mediterranean bears the mark of these multiple influences at every level of organisation.

- *Plankton communities*

While primary productivity often is considered N-limited in lagoons, estuaries and coastal areas, recent studies suggest that certain key ecosystem aspects are influenced also by other nutrients, particularly P and Si. It has then been proposed that human activities are causing similar shifts in nutrient fluxes in many of the world's large rivers and coastal waters, illustrated by a sharp increase of N and P abundances relatively to those of Si and causing nutrient inputs to approximate the "ideal" Redfield growth ratio of algae (Si:N:P = 16:16:1). It has been further argued that reductions in Si:N and Si:P ratios have not only increased algal production, but also caused the algal species composition to shift from a community dominated by Si-rich diatoms to a community that favors the growth of noxious flagellates. Such species shifts can also have wider consequences: several authors have proposed that changes in algal composition can propagate to higher trophic levels, triggering losses in species of zooplankton and/or fish. In the Mediterranean, Cruzado (1993) indicated that Si has never been reported to be a pollutant although its abundance may have a strong control of the kind of organisms that constitute the algal blooms. Therefore, the lack of sufficiently high concentrations of silicate in polluted waters will shift the blooming organisms to the less desirable flagellates.

Moreover, in disturbed Mediterranean areas communities (phytoplankton and zooplankton) tend to be highly dominated by several species compared to rather undisturbed areas where plankton communities are more diversified. The highest diversity is generally observed in offshore waters due to the presence of epi- and meso-pelagic species.

- *Fishes and catches*

Climatic change may act positively on biodiversity, favouring the co-existence of species potentially redundant functionally and thus allowing the formation of species-enriched assemblages. As in places outside the Mediterranean, such as the Gulf of Gascogne or the Channel, northward expansions of the geographical range of warm-water species have been observed in Mediterranean areas, e.g. the Corso-Ligurian Sea, following an increase in water temperature. There are increasing evidences that Mediterranean species richness patterns are presently facing changes related to increasing seawater temperature.

Among the Lessepsian migrants, fishes have always received great attention. Their expansion is continuous without any sign of decline, especially in the Eastern Mediterranean. As said before, although it must be assumed that the colonisers compete with some of the native species, there is no evidence of a drastic change in abundance of any of the Mediterranean commercial fishes that could be attributed to a new competitor. However, there are observations indicating changes in abundance of species among the migrants. Some of these non-indigenous species now form dense populations and are important in commercial catches.

- *Benthic animal communities*

Benthic communities in so called "undisturbed areas" in the eastern Mediterranean present high species diversity in coastal waters which declines with depth as seen before. They consist of polychaetes (50-65%), molluscs (15-25%), crustaceans (10-20%), echinoderms (5-8%) and miscellaneous taxa. In areas ranging from heavily disturbed (e.g. sewage outfall vicinity) to polluted (e.g. urbanised bay), echinoderms, crustaceans and miscellaneous taxa largely disappear, while a small number of polychaetes species account for 70-90% of the total abundance. The same applies to the western Mediterranean communities, where increasing disturbance also leads to reduction in species richness. Among the firs species to disappear under heavy stress conditions are benthic animals with large body size, whose bioturbating activities are of considerable importance for the benthic ecosystem. When organic enrichment and/or balance effects exceed the potential for remineralisation by benthic organisms, anoxic zones are created and the seabed is covered by bacterial mats. Although this type of ecosystem change is in general reversible, there could be severe and long-lasting consequences when the affected seabed is a critical habitat like the vegetated ecosystems described below.

- *Benthic vegetated ecosystem*

Among the most characteristic ecosystems of the Mediterranean the following deserves to be mentioned: for the mediolittoral zone, the *Lithophyllum lichenoides* rims, for the infralittoral zone the *Posidonia oceanica* meadows, and for the circalittoral zone the "Coralligenous" communities.

The most spectacular rims are those of the Grand Langoustier in Porquerolles (Var, France) and the Punta Palazzu (Scandola Reserve, Corsica). The biggest *Posidonia* meadows in the Mediterranean are those in the Gulf of Gabès (Tunisia), the harbours of Hyères and Giens (Var, France), the eastern plain of Corsica, the western coast of Sardinia (giving the town of Alghero its name) and Sicily (near Marsala). *Posidonia oceanica* meadows are considered as the most important ecosystem in the Mediterranean (Boudouresque and Meinesz, 1982). After the *Posidonia*, the Coralligenous communities constitute the second pole of biodiversity in the Mediterranean: the flora and especially the fauna there are indeed very rich, with many endemics. Coralligenous communities moreover constitute one of the most spectacular and most characteristic underwater sceneries of the Mediterranean. As such, they are one of the main diving grounds in the Mediterranean and have therefore great economic importance.

In the Mediterranean, the sea-grass ecosystems have been particularly studied by numerous teams at the different hierarchical levels: ecological, species and genetic diversity. Due to their contribution to global marine productivity and their role as "structural" species in the marine biodiversity of coastal environments, they have been given the priority for protection and represent one of the major biological indicator of the state of Mediterranean coastal waters and thus selected as such as a sustainable development indicator.

Six species have been recognised, each of them having different geographic distribution and exploiting habitats (i.e. open coastal waters, lagoons) differently exposed to human impact. On soft bottom, *Posidonia oceanica* forms a stable and long-living ecosystem but is nevertheless very sensitive to external disturbances, and thus can be considered as an endangered species, being replaced in case of meadow regression by other species such as *Cymodocea nodosa* (the case of *Caulerpa sp.* will be covered in the chapter on non-indigenous species). This is particularly true for some basins, such as the North Adriatic Sea, which, in addition, shows populations of *Zostera marina.* Many lagoon systems are rich in *Zostera marina* and *Zostera noltii.*

The bio-ecological properties of the phanerogames, characterised by a different capability to store energy during their life span and by a different resilience to disturbances (capacity of recovery following disturbance), give rise to various adaptations (e.g. nutrient assimilation) to environmental changes at different spatio-temporal scales. Investigations on *P. oceanica*, *Cymodocea nodosa* and *Zostera marina* conducted within the framework of the European programme PRISMA 2 ("Dynamics of seagrass ecosystem in the Northern Adriatic Sea"), showed differences in seasonal variability of structural parameters and in the biomass partitioning within the plant. In *P. oceanica* the seasonal forcing is buffered by the availability of internal resources stored in the below-ground, while in *C. nodosa* and *Z. marina* growth processes seem to be more directly influenced by seasonal variability in environmental factors.

In *P. oceanica,* the structure of natural populations results from the relative importance of sexual reproduction and clonal growth, that can also be related to local environment conditions. Genetic variability, moreover, is directly influenced by different-scale gene flow, that can result in genetic structure both within a population or a geographical area. Habitat fragmentation, as a consequence of natural and/or human induced impact on the coastline, can lead to the isolation of populations, inbreeding and reduction of effective population size. Populations of *P. oceanica* are therefore being sampled along the coasts of the entire Mediterranean basin and analysed with the help of DNA microsatellite markers. First results obtained along a latitudinal gradient in the Thyrrenian Sea suggested that overall genetic variability is low, with genetic divergence between northern and southern populations of the sampling area.

Annual (current and past) estimation of production yields of *P. oceanica* beds has been achieved at different geographic locations (Thyrrenian Sea, Ionian Sea and Adriatic Sea) by using chronological plant signals (lepidochronological method). In addition, taking into account the relationships between *Posidonia* leaf growth and water temperature, a numerical model of annual leaf growth has been devised. This model allows the evaluation of the *Posidonia* production on the basis of the water temperature variations. This indirect method has been applied to a number of *Posidonia* meadows around Ischia island and, comparing results with those of ten years ago, no temporal differences in growth pattern were found. Still, future research are needed for elucidating the relationships between climatic changes and variations in plant biological descriptors.

- *<u>Non-indigenous species</u>*

The introduction of new organisms, in the form of exotic species or highly cultivated strains of endemic species, nearly always poses a risk to the ecosystem involved. In the Mediterranean, these introductions can be classified into the three following categories :

- the natural invaders can be further divided into those that have entered through the Suez Canal (Lessepsian migrants), those coming through the Strait of Gibraltar and those coming from the Black Sea ;
- the species that have been passively transported can be divided into those that have been carried out accidentally by ships (fouling, sessile forms, clinging, vagile forms as well as planktonic forms transported through ballast waters) and those that have been intentionally and unintentionally introduced for aquaculture (baits, aquariums, commercial species, planktonic organisms from imported live shellfish) ;
- some other cases are known where exotic species have been successfully established in the Mediterranean basin for unknown reasons.

The geographic limits reached by the Lessepsian migrants both west and northwards, show a certain consistent stability although the climatic change and relative warming of waters could change patterns as it looks like they are already some signs of it. It is estimated that about 500 Indo-Pacific species have entered the Mediterranean since the construction of the Suez Canal to which more than 50 exotic species passing through the Gibraltar strait have to be added. Among the marine taxa, the four best known are Macrophyta, Mollusca, Crustacea (Decapoda and Stomatopoda) and fish. These numbers are probably underestimated and are currently under review by a group of specialists within the CIESM (International Commission for the Scientific Exploration of the Mediterranean).

Of the 61 well established macrophyta species in the Mediterranean, the most recent and probably the best-known one is the Chlorophycea *Caulerpa taxifolia,* distributed in tropical seas and recorded for the first time in the north-western Mediterranean in 1984.

Besides *C. taxifolia,* its con-generic *C. racemosa,* probably a Lessepsian species introduced in the 30's, is now expanding in the eastern Mediterranean and more recently in the north-western Mediterranean, often in combination (competition ?) with *C. taxifolia.*

Studies on the genetic structure and ecological role of these introduced macrophytes are of great interest for possible prediction of their future evolution :

- Populations of *Caulerpa racemosa* have been sampled in several localities of Tyrrhenian and Ionian Sea, with different depth distribution and substrate of colonization. Phenological analyses have allowed the identification of two morphotypes (shallow and deep) that appear to be correlated to different local environmental conditions, especially depth-related variables such as light and temperature. The preliminary analysis of the associated malacological fauna indicates that in low structured environments, such as the soft bottoms, *C. racemosa* covering increases spatial complexity and species richness, thus influencing both community composition and structure.
- On the opposite, the studies concerning *Caulerpa taxifolia*, settled much more recently in the Mediterranean, show that the strain which settled in the Mediterranean presents no polymorphism between populations. Although not completely satisfactory, one explanation could be that this species is considered to reproduce only asexually in the Mediterranean.

Mollusca is one of the leading taxa of Lessepsian migrants with more than a hundred species nowadays settled in the Mediterranean. One of the most striking example can be seen in the gastropod *Rhinoclavis kochi,* initially reported from Haifa Bay (1963) and now collected in large numbers not only along the Israeli coasts but also along the coasts of southern Turkey and Cyprus.

Within the Decapoda and Stomatopoda species, another example of strong settlement and diffusion is given by the portunid crab *Callinectes sapidus,* a western Atlantic species commercially fished along the coasts of North America, and which was first recorded in the Bay of Biscay (1901) and then probably introduced with ballast waters into the Mediterranean Sea. It has proved to be a very successful coloniser and became of local economic importance in the Mediterranean.

Although many of the introduced species have no visible effect on the indigenous communities, changes in the faunal composition of marine ecosystems have been described in:

- Haifa Bay, with the massive penetration of four Indo-Pacific species;
- Izmir Bay and Thessaloniki Gulf where the bivalve *Scapharca demiri* became dominant;
- In the western coast of the Middle Adriatic Sea with the massive development of *Scapharca inaequivalvis* and *Rapana venosa*;

- And, since the beginning of the 90's, in the north-western Mediterranean with the rapid development of *Caulerpa taxifolia* rejoined nowadays by the northern expansion of *Caulerpa racemosa*.

According to Boudouresque and Ribera (1994), the biotopes most affected by marine species (other than Lessepsian migrants) in the Mediterranean are the lagoons and ports. An equilibrium with native species often becomes established in due course, but sometimes not without changes at the community level due to shifting in ecological niches.

- *<u>Endangered and threatened species</u>*

The general issue of endangered (in immediate danger of extinction throughout all or a significant part of their range) and threatened species (likely to become extinct within the foreseeable future throughout all or part of their range) in the Mediterranean region has been well covered in the last years by authors like Ramade et al. (1990) and Boudouresque (1995).

At present, no species appear to have disappeared yet from the Mediterranean as a result of human activity. However some species are actually on the verge of extinction, either because of their rarity which makes them vulnerable, or because they rapidly decline in numbers. A list of 89 marine and freshwater species (not including birds) have been established under the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean Sea, and then revised in the Berne Convention on the Conservation of European wildlife and Natural Habitats (Table 5.2).

The species whose status at present raises more concern is probably the Mediterranean endemic *Posidonia oceanica* although it cannot be considered threatened to extinction as a species, as it still covers important seabed surfaces throughout the Mediterranean basin. Since its large meadows, spread out all over the Mediterranean basin, are considered as a crucial habitat with a high species richness (polychaetes, molluscs, amphipods, fishes, etc.), this question will be covered in the "Habitat changes and physical disturbances" section.

Among the most endangered and threatened by extinction are the Mediterranean monk seal (*Monachus monachus*), with a total population not exceeding 300 to 500 specimens, dolphin species (*Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba),* sperm whales *(Physeter macrocephalus)*, and freshwater and marine turtles (*Chelonia mydas, Trionyx triunguis, Caretta caretta).* For their protection, the Contracting Parties of the Barcelona Convention have adopted Action Plans for the Management of the Mediterranean Monk Seal (1987), the Conservation of Mediterranean Cetaceans (1991) and the Conservation of Mediterranean Marine Turtles (1989). It may also be noted that UNEP adopted a Global Action Plan for the Conservation of Marine Mammals (1984).

Birds are probably the taxonomic group for which the best information concerning the status and distribution of the different species in the Mediterranean is available. Drawing on the current available information, a meeting of experts (Montpellier, 1995) has listed 15 species of birds as endangered or threatened, all having a direct relation with the marine ecosystem.

Table 5.2 **- List of endangered or threatened marine and freshwater species in the Mediterranean**

(Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean Sea adopted in the Barcelona Convention in 1996; revised in the Berne Convention, 1998).

Magnollophyta	***Echinodermata***	Hippocampus hippocampus
Posidonia oceanica	Asterina pancerii	Hippocampus ramulosus
Zostera marina	Centrostephanus longispinus	Huso huso
Zostera noltii	Ophidiaster ophidianus	Lethenteron zanandreai
		Mobula mobular
Chlorophyta	***Bryozoa***	Pomatoschistus canestrinii
Caulerpa ollivieri	Hornera lichenoides	Pomatoschistus tortonesei
		Valencia hispanica
Phaeophyta	***Crustacea***	Valencia letourneuxi
Cystoseira amentacea	Ocypode cursor	
Cystoseira mediterranea	Pachylasma giganteum	***Reptiles***
Cystoseira sedoides		Caretta caretta
Cystoseira spinosa	***Mollusca***	Chelonia mydas
Cystoseira zosteroides	Charonia lampas lampas	Dermochelys coriacea
Laminaria rodriguezii	Charonia tritonis variegata	Eretmochelys coriacea
	Dendropoma petraeum	Eretmochelys imbricata
Rhodophyta	Erosaria spurca	Lepidochelys kempii
Goniolithon byssoides	Gibbula nivosa	Trionyx triunguis
Lithophyllum lichenoides	Lithophaga lithophaga	
Ptilophora mediterranea	Luria lurida	***Mammalia***
Schimmelmannia schoubsboei	Mitra zonata	Balaenoptera acutorostrata
	Patella ferruginea	Balaenoptera borealis
Porifera	Patella nigra	Balaenoptera physalus
Asbestopluma hypogea	Pholas dactylus	Delphinus delphis
Aplysina cavernicola	Pinna nobilis	Eubalaena glacialis
Axinella cannabina	Pinna rudis	Globicephala melas
Axinella polypoides	Ranella olearia	Grampus griseus
Geodia cydonium	Schilderia achatidea	Kogia simus
Ircinia foetida	Tonna galea	Megaptera novaeangliae
Ircinia pipetta	Zonaria pyrum	Mesoplodon densirostris
Petrobiona massiliana		Monachus monachus
Tethya sp. plur.	***Pisces***	Orcinus orca
	Acipenser naccarii	Phocoena phocoena
Cnidaria	Acipenser sturio	Physeter macrocephalus
Astroides calycularis	Aphanius fasciatus	Pseudorca crassidens
Errina aspera	Aphanius iberus	Stenella coeruleoalba
Gerardia savaglia	Carcharodon carcharias	Steno bredanensis
	Cetorhinus maximus	Tursiops truncatus
		Ziphius cavirostris

The available information on marine and coastal sites and areas having a particular importance for the conservation of biodiversity in the Mediterranean region is summarised in Table 5.3.

Table 5.3 **- Transboundary "Hot Spots" for Mediterranean marine biodiversity**

Species / site of interest	**Countries concerned**
Seagrasses	All countries Tunisia – Libya
Benthic species	All countries
Cetacean	All countries Ligurian Sea: France - Italy - Monaco Northern Adriatic: Italy – Croatia
Mediterranean Monk seal	Western: Morocco – Algeria Ionian: Albania – Greece Aegean: Greece – Turkey Eastern: Turkey - Cyprus – Libya
Mediterranean marine turtles	All countries
Green turtle:	Eastern: Cyprus - Turkey
Loggerhead:	Ionian: Italy - Greece Southern: Tunisia-Libya-Egypt Aegean: Greece - Turkey Alboran: Spain – Morocco
Mixed Atlantic and Mediterranean fauna and flora	Alboran Sea: Morocco – Spain
Representative Mediterranean marine ecosystems with endangered/endemic species	Bonifacio Straight (and western tip of Sicily) France – Italy

- ***Critical habitats***
  - *Habitat changes and physical disturbances*

The Mediterranean Sea, including its coastal zones, provides a rich diversity of habitats for biota, which are affected by human activities and their associated effects. These disturbances and effects may be permanent (e.g. effect of land reclamation and coastal construction works) or temporary (e.g. physical effect of bottom trawling or dredging, such as increased turbidity) and can be categorised as resulting in: changes in habitat size, or changes in habitat conditions, or combinations thereof.

- *Changes in habitat size*

Construction of coastal industrial structures and harbours inevitably affects ecological processes and leads to a definite elimination in breeding areas, to destruction of habitats, and to loss of biotopes.

In the last 50 years, there has been a major regression of *Posidonia oceanica* meadows all around the Mediterranean basin mainly due to human development on the coast, by coastal protection and sea defence measures, land reclamation, industrial and harbour installations, dredging or extraction of sediments, disposal of wastes and dredged material, recreational activities, military activities, aquaculture operations, etc. Consequently, the regression has been particularly strong around large industrial harbours like Athens, Naples, Genoa, Marseille, Barcelona, Algiers, and the Gulf of Gabès. Since then, and because of strict appliance of water quality regulations (collecting of used waters, sewage treatment plants, outfall deep pipes, etc), the few monitoring networks available seem to indicate that some of these regressions have been stabilised with even some meadows spreading back, especially in the northwestern Mediterranean. However, given the slow growth of its rhizomes and the rarity of its fructification, the destruction of a prairie must, on the human scale, be considered as irreversible.

Similarly to *Posidonia* meadows, *Cystoseira* forests are regressing at numerous stations mainly, as it seems, under the negative impact of pollution. For all these reasons, the Contracting Parties to the Barcelona Convention adopted recently (1999) an Action Plan for the Conservation of marine vegetation in the Mediterranean Sea.

Although very controversial, the current extension of *Caulerpa taxifolia* and *Caulerpa racemosa* has a double-edged effect : on one hand representing a serious threat in competing for space with other algae (hard bottom) and seagrasses (soft bottom) like *P. oceanica* and, on the other hand, offering a new biotope for a number of species in previously degraded areas. In such a case, it is impossible to predict when an equilibrium with “native” species will be reached and in what conditions.

Another very clear example of engineering works resulting in loss of habitats is the considerable regression of wetlands all around the Mediterranean since the Roman times. As a matter of fact, there is a long history of drainage in the Mediterranean. The main purposes of most of the drainage projects were for agriculture or to eradicate malaria carrying mosquitoes. Recently however, industry, housing and tourist developments have been the main reasons for drainage and the practices leading to wetland loss and degradation. From a total area evaluated at 430,000 Km^2 in the Roman times, it is estimated that the current total area has been reduced to about 28,500 Km^2, comprising 6,500 Km^2 of coastal lagoons, 12,000 Km^2 of natural lakes and marshes and up to 10,000 Km^2 of artificial wetlands (mostly inland reservoirs).

In 1995, within the framework of the European MedWet 1 project, an analysis of the existing wetland inventories in the Mediterranean was published. It showed that detailed inventories had been completed for only five of the 22 countries reviewed, and that for the majority there were lists only of some of the most important wetlands. Generally, there has been very little standardization of the data collected, and the results between countries are therefore difficult to compare.

Dams have had a great impact on the hydrological cycles of the rivers they bar and the wetlands and aquifers that feed off their flows. The most famous example is the Aswan dam : for thousand of years, the silt brought by the Nile has been vital to the fertility of the soils throughout its valley and delta. Since the completion of the dam, the delta coastline no longer receives annual supplies of new silt. As a result, coastal defences built in the 40’s have been washed away by waves and currents. The sand bars in front of the delta’s large lagoons of Manzalla and Burullus are eroding and face collapse. This will provoke the flooding of the low-lying delta farmland and destroy the delicate balance of the lagoon fisheries.

- *Changes in habitat conditions*

Changes in habitat conditions can relate on the long term to changes in climate but are also very often a result of disturbance by human activities and will mainly result in temporary effects. When the cause of disturbance disappears, recovery may take place, although it may stretch over several years leading to a different equilibrium.

As an example, the occurrence of “slime blooms” is well documented for the Adriatic Sea. In recent years, and in particular since 1991, similar phenomena have been reported also for the Tyrrhenian Sea, where the formation of mucilage occurs mainly in the benthic systems, among which are seagrass meadows like the *Posidonia oceanica* beds, and rocky bottom communities. Blooms of Ectocarpales, filamentous cyanophycea and benthic diatoms were in some cases responsible for the phenomenon. More research is needed on both environmental (temperature, salinity, irradiance, nutrient concentrations) and biological parameters (evaluation of epiphytic community, carbon and nitrogen content in the plant and epiphytes) in order to tackle the formation processes, the composition and evolution in time of the mucous aggregates.

In certain places, the making of artificial beaches or nourishment of existing ones lead to a segregation of sand and therefore may have a significant impact on near-shore benthic communities. Dredging to maintain harbours and navigational channels will participate to the same kind of impact as well. In addition, dumping results in increased turbidity and consequently reduced light availability, which in turn affects phytoplankton growth or seagrass beds.

Recreational activity may interfere with the natural functioning of the coastal zone as a habitat. Through recurrent disturbance, specific areas may become unsuitable for the breeding, resting or feeding of marine organisms. Disturbances during critical periods of this kind can reduce the viability of the animal population concerned by lowering reproductive success and by increasing mortality. Since coastal tourism is a huge activity in the Mediterranean, the main tourist season and its different activities have probably a significant impact on species using sand beaches or rocky shores like turtles or the monk seal or even, from the noise generated by speed boats, on marine mammals in offshore waters.

In connection with wetlands or not, lagoons represent another important and very specific habitat for a number of species. They make up approximately 40% of the non-rocky Mediterranean shoreline. In Mediterranean Europe as a whole they account for some 850,000 hectares. As wetlands, many of them have been strongly impacted by human development since numerous commercial activities depend on them.

The Thau Lagoon : a fragile balance between activities and productivity

The Thau Lagoon is one case study of particular interest. Almost all the typical human activities associated with lagoons are encountered here. Its natural productivity sustains commercial shell farming (an estimated standing stock of 35,000 tonnes with an annual production of 15,000 tonnes per year) and fish farming (40 tonnes per year), as well as commercial aand recreational fishing of both fish and shells.

This shallow (<10 m) ecosystem is sensitive to numerous inputs, both natural and anthropogenic, as well as climatic variation. At the turn of the century, when agriculture was not an important factor in the region, morphology and bathymetry were the sole determinents of nutrient's state in the lagoon. The first oyster farms appeared between 1911 and 1915. Since 1945, the increase in shell farming (700 commercial concessions) and additional human activities on the lagoon's shore lead to a significant enrichment of the bottom sediments by the 60's despite good management of the Herault River. This enrichment probably caused the strong anoxia of the 70's that drastically affected shell farming and fishing in the lagoon. More enlightened development since the early 70's and a lagunal cleanup programme initiated in 1974, have slowly had a positive effect on the lagoon in spite of the simultaneous expansion of shell farming in the region. Today, the lagoon still contains high levels of silt originating from both deep water (where organic matter accumulated) and from shell farming which together fertilise the sediments and favors *Zostera* and macrophyte growth. This in turn probably reduces eutrophication.

The hydrodynamics of the lagoon depend on the prevalent winds, but water circulation can be strongly retarded by the shell farming structures that are a common feature of the area. However water circulation between these structures (e.g. oyster tables, partitioning corridors) is of major importance for the balanced operation of this ecosystem. If filter feeders take up more particulate matters than they release (biodeposition) then regeneration processes result in the export of large quantities of organic matter to partitioning corridors. This localised enrichment can create the highest levels of phytoplanktonic productivity observed in the lagoon, and the resulting production partly sustains shell farming needs. However shell farming needs could not be sustained throughout the year without some additional exogenous source of nutrient supply. Because of this, the circulation of the lagoon as a whole plays a role in shell farming production. These exchanges occur continually except during the summer. During this season, shell farming needs are so important that they result in the depletion of phytoplankton inside the farming structures themselves, despite supply from outside. It is therefore also important to quantify the standing stock of dissolved organic matter and identify its role in initiating localised regenerated primary production.

Further studies will focus on the assessment of marine waters nearby in order to better understand the linkages between the lagoon and its neighbouring ecosystems, as well as evaluating the downstream socio-economic consequences of possible ecological degradation of the lagoonal system.

Source: Deslous-Paoli, 1998

- *Sensitive and protected areas*

In the framework of the preparation of the Strategic Action Programme, countries and their national teams were asked by the Mediterranean Action Plan to define, simultaneously with the designation of pollution hot spots, sensitive areas, i.e. estuaries and coastal waters of natural or socio-economic value that are at higher risk to suffer negative impacts from human activities. A common methodology was given for that purpose, where natural characteristics determine vulnerability of a coastal system and human activities determine the level of risk on that same coastal system. Both vulnerability and risk contribute to the “sensitivity” of a particular area or system in the context of each country assessment.

Although with uncomplete information, the national reports identified 53 sensitive areas in 16 countries, as shown in Table 5.4 (UNEP, 1999).

Table 5.4 - Priority Pollution Sensitive areas in 16 Mediterranean countries

Albania : Kuna-Vain Lagoons, Karavasta Lagoon, Narta Lagoon
Algeria : Gulf of Ghazaouet, Gulf of Arzew-Mostaganem, Bay of Alger, Bay of Annaba, Gulf of Skikda, Bay of Bejaia
Croatia : Malostonski, Limski Channel, Kornati, Mljet, Krka est.
Cyprus : Vassilikos Bay
Egypt : Lake Bardawil
France : Collioure-Cap Leucate, Cap Leucate-L’Espiguette, Rhone Mouth, Fos Gulf
Greece : Amvrakikos Gulf, Mesologgi Lagoon
Italy : Vado Ligure-Savona, Secche della Meloria, Isola d’Elba, Pesaro-Cervia, Mouth of Po, Venezia and its lagoon, Panzano Bay
Lebanon : Sour, Jbail (Byblos)
Malta : Weid Ghammieq, Cumnija, Ras il-Hobz
Morocco : Al Hoceima
Slovenia : Koper Bay, Piran Bay
Spain : Albufera de Valencia, Ebro Delta, Mar Menor
Syria : Umit Tiur, Azwad island, Wadi Qandeel, Lattakia beach (southeast), Rasl Fassouri
Tunisia : Ghar El Melh
Turkey : Adana, Izmir Bay, Içel, Mersin-Kazanli, Hatay-Samandag, Aydin, Mugla.

Most country reports underscore important gaps and constraints that are worth highlighting :

- scarcity of information on quality of receiving waters;
- difficulty of obtaining sufficient information on industrial effluents and estimates of remedial actions to reduce their undesirable impacts;
- and the need under the new orientations of MAP and the Barcelona Convention and LBS Protocol to establish good working relations between the, so far, predominantly

scientific nature of the MEDPOL national focal points and other socio-economic institutions involved in environmental protection (government, business, academia and NGOs).

In regard of these constraints and the very fragmented remedial actions proposed by countries, MAP concluded that “the national reports give the impression that there has been in many cases confusion about applying the definition of sensitive areas given in the guidelines as well as reporting on the sensitive areas identified”.

In front of this relative failure and the necessarily very limited scope of sensitive areas definition from a national perspective, it is worth mentioning a new initiative coming from the WWF, called “The Mediterranean Gap Analysis”. In order to overcome the problem of the lack of homogeneity of the biological data coming from the different areas of the Mediterranean, this latter has proposed a new methodology as follows :

- Starting from the scientific consideration that rich biodiversity is most likely to occur where the sea-bed presents high spatial heterogeneity, two different statistical approaches have been used to analyse the “indentation” of the coasts and the “roughness” of the sea-bottom, enabling the visualisation of those areas where chances of finding higher levels of biodiversity are greater within a depth range of 0 to 250 m (which is considered to include about 80% of the total marine biodiversity).
- This new information has been added to the existing data on the presence of flag-ship species like the monk seal, marine turtles, several species of whales and dolphins and the seagrass *Posidonia oceanica.* In addition, the main coastal pollution hot spots of the Mediterranean (defined by countries) have been included. The human impact on the coast has also been mapped, taking into consideration main harbours and coastal cities with more than 50,000 inhabitants.
- Through the overlapping of the above-mentioned layers of data, all the most significant Mediterranean seas and coastal areas in need of urgent protection have thus been identified. By analysing on the one hand, the areas with a high level of biodiversity, in terms of concentration and continuity, the significant presence of flag-ship species (and their habitat) and a pronounced fish species diversity – and, on the other, the presence of important threats from human pressure, a total of 13 areas have been identified.

It is concluded that “these 13 areas are in need of urgent protection or improved management” :

1. Alboran Sea (Spain, Morocco, Algeria)
2. Balearic Islands (Spain)
3. Liguro-Provençal coast (France, Italy, Monaco)
4. Corso-Sardinian coast (France, Italy)
5. Southern Tyrrhenian coast (Italy)
6. Dalmatian coast (Croatia)
7. Eastern Ionian coast and islands (Albania, Greece)
8. Aegean Sea and Anatolya coast (Greece, Turkey)
9. Cilician coast (Turkey) and Cyprus Island coast
10. Cirenaica (Libya)
11. Gulf of Sirte (Libya)
12. Gulf of Gabes (Tunisia)
13. Algero-Tunisian coast (Algeria, Tunisia)

This approach could be very complementary with the countries “sensitive areas” approach since it allows to consider the management of large ecosystems in their functional boundaries, i.e. very often from a regional perspective. In some cases, this regional approach of large ecosystem or Mediterranean sub-system is on the way like it is the case for the Liguro-Provençal region (RAMOGE agreement between France, Monaco and Italy).

- *Protected areas in the Mediterranean Sea*

- *From a national to a regional perspective*

In this direction, it is noteworthy to remind that the new Protocol Concerning Specially Protected Areas and Biological Diversity (1995) has been conceived as a tool for the practical implementation at regional scale of the most recent concepts and international legislation concerning in situ conservation. On this basis, the new Protocol decided the establishment of a list of Specially Protected Areas of Mediterranean Importance (SPAMI) which includes areas that :

- Are of importance for the conservation of the components of biological diversity in the Mediterranean;
- Contain rare, unique ecosystems and rare or endemic species in the Mediterranean area;
- Contain the habitats of endangered species;
- Are of special interest at the scientific, aesthetic, cultural or educational levels.

Following these criteria, there are 122 Specially Protected Areas designated under the SPAMI Protocol. Among these, 45 cover marine spaces exclusively (15) or as part of mixed land and sea space (30). The 122 SPAMI areas have very different definition and legal regimes, according to the legal status governing the protection of each area, as : nature reserves (52), national parks (24), marine reserves (14), natural parks (10), fishery reserves (2), game reserves (2), monuments of nature (1), etc.

In parallel with other international conventions (Bonn Convention, Berne Convention, RAMSAR, ACCOBAMS, etc.), in the northwestern Mediterranean, the EU initiatives have provided for the establishment of relevant Directives such as the EC Birds Directive for Special Protection Areas, the Habitat Directive, the so-called NATURA 2000 network where already Spain, Italy and Greece have included many marine sites.

In order to give more coherence to this rather uncoordinated initiatives between countries and regional or international organisations, several conferences have been convened under the auspices of MAP. They have produced significant outcomes relevant to the conservation of biodiversity as part of a broader approach of sustainable development in the Mediterranean basin. Two of them will be mentioned more particularly :

- the Charter on Euromediterranean cooperation for the environment of the Mediterranean Basin (Nicosia, 1990) recommending, among others, the use of integrated management of the coastal zone and the creation of a network for the exchange of information relating to the management of parks and reserves;
- the Declaration on Euromediterranean cooperation for the environment of the Mediterranean Basin (Cairo, 1992) which reaffirms many of the commitments made at Nicosia, asserting the wish of the Parties to achieve the fundamental objective of sustainable development in the Mediterranean basin by the year 2025 at the latest.

- *Protected areas are not a panacea*

In spite of all the efforts mentioned above, in half of the Mediterranean countries, less than 2% of the Mediterranean systems are under nature protection, and for the whole region coastal protection remains very low (Blue Plan, 1998).

However, whatever their number, setting aside parks and preserves as safe sites for species cannot always protect diversity, even without climate change. There is always the danger that if protected areas are treated as self-sufficient refuges, the regions surrounding them may not be managed to protect biodiversity. Given the uncertainty of future distributions of species and the relatively long time horizon for change, one should minimise species regression or extinction from existing threats and look for conservation tools in addition to protected areas.

Conservation policies needs considering the role of existing institutions and societal responses to environmental changes to be successful. When attempting to protect biodiversity outside protected areas, new policies must integrate resource law and management practices into the plans. Existing resource laws allocate rights assuming that the quantity and location of the resources are not going to change greatly. But most research, in the world as in the Mediterranean, that natural resources will probably not remain distributed as they are now. The winners and the losers are difficult to define, but for those resources that have a history of being contested, people currently controlling resources like fish and water will try to protect their rights. Resources valued for their non-market or amenity benefits do not have such powerful advocates with vested personal interests. Therefore the question is how to argue for new protected areas or for including biodiversity among the multiple uses to which over-committed coastal areas are put?

- ***Land use and tourism***

The most significant transboundary issues and problems affecting the Mediterranean Sea and its coastal zone are linked to urbanisation and tourism development. Furthermore, industrial development is regarded as an additional pressure on the Mediterranean coastal and marine environment.

Specifically, increasing sprawling urbanisation is being witnessed mainly due to rising incomes and the modernisation of transportation infrastructure further attracting population and economic activities. Although past experience has shown that along the coasts of the Mediterranean Sea there was balance between urban growth and rural development, in recent decades Mediterranean urbanisation is believed to have reached a stage of rapid expansion characterised by high population densities, environmental degradation and decline in the “quality of life”. Significant consequences are economic imbalances at the national and regional level as well as inequalities between coastal areas and the adjacent hinterland.

The Mediterranean basin is also the location of industrial activities such as oil and natural gas exploration and refining (mainly in Algeria, Egypt, Libya, Syria and Italy) as well as metallurgy and raw materials extraction (i.e. mercury, phosphates, chromite, lead, salt, bauxite and zinc). Other important industrial sectors include waste treatment plants, paints, paper, plastics, dyeing and printing, and tanneries. While most of these activities are concentrated in the northern rim of the Mediterranean, a reversal of trends has been witnessed resulting in the relative decline of heavy industry in the North to the benefit of the southern countries with the northern countries starting to develop new generation industries such as bio-technology, electronics or new materials. Industrial production is often associated with pressures on the environment for example air pollution (emissions of particulates, NO_x, CO, SO_2, TPBs, etc.), water pollution (emissions of metals, suspended solids, organic matter, HCs, etc.), soil contamination (oil and grease residues, heavy metals, HCs) and waste production.

- *Impact of coastal industrial activities*

Not only do coastal industries degrade the local marine environment where they discharge, but they also occupy the terrestrial environment in their vicinity at the expense of other biologically important critical habitats for marine and coastal species. To the extent that habitat loss and contamination depress the quality and abundance of the marine fauna, local fisheries are adversely affected by coastal industry. In the long term, the sum of all coastal industrial discharges not fully absorbed by the sea has the potential to affect adversely coastal marine fisheries in general. However, it is not always certain that fish (of economic, fishery interest) are adversely affected by some forms of chemical pollution. Nevertheless, on the whole, coastal industry (even including industrial-scale fish farming) has the potential to be prejudicial to coastal fishery interests (UNEP, 1996a).

Sea-bed mining, if it becomes widespread, and especially if some of the industrial processing is done at sea, may become important. This is because the discharge of waste rock dust into the sea could significantly increase turbidity and/or increase concentrations of elements that are normally rare in sea water but become toxic at higher concentrations. .

Such extraction adversely affects benthic organisms by destroying habitats and damaging spawning grounds of demersal and other fishes; it also interferes with trawling and other bottom-fishing methods; however, the duration of the effects, once sea-bed mining has ceased, is relatively short.

- *Urban areas*

An important issue related to transboundary pollution in Mediterranean urban areas is drinking water supply. Although documentation is limited, Mediterranean rivers supplying drinking water to urban and rural areas face several environmental problems:

- *Organic pollution*: although organic pollution is not regarded a considerable problem, several small Mediterranean rivers are still heavily contaminated when BOD is concerned while levels of DOC are generally quite low.
- *Nutrients:* nutrient levels for the Mediterranean rivers are about 4 times less than in western European rivers. However, nitrate and phosphate levels are generally increasing while ammonia concentrations show decreasing trends due to the establishment of waste treatment plants.
- *Heavy metals:* poor monitoring and documentation of Mediterranean rivers limits the ability to provide a in depth analysis. However, some general points can be made: (I) most metal fluxes are still associated with particulate matter, (ii) reservoirs are probably storing much of the metals originating from human activities, (iii) due to this retention the net inputs to the Mediterranean Sea are stable for cadmium or may even decrease for copper, lead and zinc. However, the mercury inputs are increasing due to a major contamination of particulates for this metal.
- *Organic micropollutants:* contamination by industrial products is documented on great rivers (Po, Ebro, Rhone) for polychlorinated biphenyls, polycyclic aromatic hydrocarbons and solvents. Evidence of pesticide high concentrations has been identified in many small rivers with intensive agriculture.

The degradation of surface waters in the Mediterranean region although not a significant issue compared to that of central and northern Europe necessitate elaboration of extensive waster treatment infrastructure. Furthermore, disturbing odours, degradation of coastal waters and aesthetic degradation especially near port areas and sewage limit the recreational value of urban areas for walking, swimming, etc.

- *Tourism*

Tourism development can be seen as a key element in coastal urbanisation and has for long been a significant pressure for the coastal environment of the Mediterranean Sea as it is the main source of income and employment (Table 5.5). However, tourism development although leading to local economic growth, constitutes a heavy burden for local authorities responsible to confront many of the emerging problems. Specifically, coastal mass tourism exacerbates many of the pre-existing problems in urban areas such as:

- Wetland losses and ecosystem degradation imposing risks to aquatic fauna in particular bird species inhabiting the Mediterranean coastal zone.
- Reduction of coastal places once open or available for agriculture generating land use antagonism amongst various economic agents. The general outcome is a spatial imbalance in the development between prosperous coastal areas, which are heavily

populated and characterised by high levels of land use and consumption and those inevitably weaker inland areas with a lower residential density and a less dynamic economy.

- Degradation of coastal waters by microbiological contamination and eutrophication processes, with the final result of potential health risks during bathing and consumption of shellfish.
- Increase of domestic water consumption reaching its maximum rates at the southern and eastern rim of the Mediterranean Sea. Moreover, population growth in areas facing water shortage can exacerbate the problem.
- Groundwater pollution and run off of wastewater in the sea as the geographic distribution of water consumption follows the territorial concentration of waste. It is worth mentioning that 100 priority hot spots have been identified in 19 Mediterranean countries
- Increased levels of air and noise pollution particularly in large coastal urban agglomerations.

Countries	*Contribution of tourism to GDP* (direct and indirect impact)				*Employment* (direct and indirect employment)			
	1999		2011 (foreseen)		1999		2011 (foreseen)	
	US $ bn	% on total	US $ bn	% total GDP	Jobs (000s)	% on total	Jobs (000s)	% on total
NORTHERN AFRICA								
Libya	2.88	10.08	4.01	10.83	62.11	5.30	98.71	5.69
Tunisia	3.43	16.50	6.43	17.81	356.75	11.51	520.93	12.43
Algeria	3.15	6.21	6.25	6.90	330.30	4.66	485.61	5.18
Morocco	4.48	12.88	8.51	14.24	721.51	9.05	1215.17	10.01
EASTERN MEDITERRANEAN								
Egypt	9.19	10.20	15.82	11.24	1769.30	8.51	2655.09	9.39
Palestine	NA	NA	NA	NA	NA	NA	NA	NA
Israel	9.44	9.83	18.46	9.71	157.05	7.43	196.66	7.34
Lebanon	NA	NA	NA	NA	NA	NA	NA	NA
Jordan	1.92	23.81	3.83	23.37	199.91	18.12	384.51	17.79
Syria	4.44	6.19	13.77	8.24	251.65	5.87	492.77	7.83
Turkey	17.51	9.50	53.12	9.73	203.30	5.46	1412.42	5.55
Cyprus	2.58	28.74	5.11	34.23	56.81	10.05	96.46	11.84
MIDDLE MEDITERRANEAN								
Greece	21.45	16.82	46.70	16.74	626.92	16.21	755.18	19.06
Malta	1.24	34.57	2.57	50.90	32.60	24.39	55.93	35.92
Albania	NA	NA	NA	NA	NA	NA	NA	NA
Croatia	NA	NA	NA	NA	NA	NA	NA	NA
Slovenia	2.41	11.97	3.77	12.03	80.07	8.87	82.28	8.92
Serbia	NA	NA	NA	NA	NA	NA	NA	NA
WESTERN MEDITERRANEAN								
Italy	133.32	11.39	285.95	12.57	2623.68	12.68	3023.03	14.12
Monaco	NA	NA	NA	NA	NA	NA	NA	NA
France	168.67	11.77	335.54	12.74	3076.54	13.50	3665.85	14.53
Spain	116.67	19.06	263.74	21.85	2484.52	17.98	3704.67	21.90
Gibraltar	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	**502.78**	**-**	**1073.58**	**-**	**13033.02**	**-**	**18845.27**	**-**

Table 5.5 – Contribution of tourism to national income and employment in the Mediterranean region

On the other hand, environmental degradation in a tourism destination can have negative effects on tourism. In this respect, the impacts of transboundary pollution in relation to tourism development are mainly associated with the degradation of natural and cultural resources as well as health risks for tourists and local residents. Clean beaches and bathing waters are essential to the Mediterranean coastal tourism industry. As tourists expect high quality environment, many tourism destinations in coastal areas are actively promoting the cleanliness of their coastal waters and are in fear of negative publicity from the media when beaches show signs of environmental deterioration. Also, the maintenance and enhancement of the aesthetic landscape is of paramount importance.

Transboundary pollution affects tourism development in the form of:

- *Eutrophication;* It has been already mentioned that urbanization, tourism development and agricultural activities are mainly responsible for the release of organic nutrients in the aquatic environment (mainly nitrogen and phosphorus) which can lead to eutrophication phenomena if certain conditions exist (i.e. favorable geomorphology, lack of infrastructure). Its major consequences are algal blooms, enhanced benthic algal growth and in occasions a massive growth of submerged and flowting macrophytes. Final result is the degradation of coastal waters as well as potential health risks during bathing and consumption of shellfish.

- *Oil pollution;* Due to accidental incidents of maritime transport either of merchant or non merchant nature but mainly due to oil tanker major casualties. These cargo oil spills attract the attention of the public through their wide coverage by the media showing terrific pictures if blackened beaches and of dead or decreasing oily birds, otters and seals. Oil spills have detrimental effects either by degrading the aesthetic and ecological value of an area, killing marine life or by imposing health risks reducing the potential use of beaches for swimming and often recreational activities. On average, there are about 60 maritime accidents in the Mediterranean annually of which 15 involve ships causing oil and chemical spills, The extent of the accident impact on tourism development is in relation to the accident site, type of products spilled and its quantity. However, the perception of environmental and economic impacts of oil spills and the damage assessment will depend on the socio-economic condition of the affected country. In France, Italy, Spain, Turkey, Israel, Greece and Croatia an accident could have great economic impact as well. For Algeria, Egypt, Libya, Syria and Tunisia as public pressure will be smaller, potential damage is likely to be underestimated.

- *Contamination from heavy metals;* the presence of heavy metals in the marine and freshwater environment has gained global significance as they may pose several threats to marine life and human health mainly through the consumption of seafood.

- *Microbiological contamination;* pathogenic and other micro – organisms enter the aquatic environment mainly through municipal wastewater discharges from the immediate coastal zone. Other possible sources of microbiological contamination are atmosphere through air currents as well as bathers.

To summarize the above, although there is no detailed information available to identify the specific impacts of transboundary pollution on tourism development for the Mediterranean region, several general remarks can be made. In this respect, transboundary pollution is regarded responsible for:

1. Environmental deterioration of coastal waters and beaches and in particular for:

   - Degradation of the quality of bathing waters.
   - Aesthetic degradation of beaches due to the presence of dead animals, large concentrations of oil, etc.
   - Nauseating odors of coastal waters due to eutrophication phenomena and microbiological contamination.

- Degradation of ecosystems with high environmental value (i.e. estuaries, lagoons) as well as loss of protected and/ or endangered species.

2. Health risks to tourists, local residents and bathers from the:

- Intake of pathogenic micro – organisms from infected sea water.
- Consumption of polluted/ contaminated freshwater.
- Direct contact of polluted sea water and beach sand.
- Consumption of seafood contaminated by pathogens (i.e. the presence of dinoflagellate algae can be considered as pathogenic due to their ability to produce various toxins to which man is exposed primarily through the consumption of contaminated shellfish).
- Consumption of seafood polluted by heavy metals and chemicals, especially in bioaccumulating organisms such as filter feeders and carnivorous fish.

The deterioration of the natural environment, the degradation of the attractiveness of the tourism destination as well as health impacts imposed from transboundary pollution result in the decrease of the number of tourist arrivals in the tourism destination, decrease of the income generated from tourism activities as well as to the abandonment of economic activities supporting tourism (i.e. fisheries) leading to monoculture.

▪ *Concluding remarks and case studies*

Intense human activities in areas surrounding enclosed or semi – enclosed seas such as the Mediterranean Sea usually have significant impacts, especially in the long – term, leading to the degradation of the coastal and marine environment at the local and regional level. On the other hand, environmental degradation can have significant impacts on economic development and quality of life. Specifically, transboundary pollution in the Mediterranean Sea is regarded as an important issue and is a result of coastal urbanization, industrial and agricultural activities, tourism development as well as maritime transport in relation to its unique characteristics. The identification of the impacts of transboundary pollution on the environment and human health are necessary to assess the potential of Mediterranean tourism destinations and urban areas for recreational and residential purposes. Considering the above, two examples follow which show the interrelationship between transboundary pollution - environmental degradation and land use - tourism.

• *Impacts of transboundary pollution: the case of the Bay of Izmir*

The bay of Izmir is one of the largest bays of the Turkish Aegean coast extending about 24 km in the East – West direction and with an average width of approximately 5 km. A continuing high increase of population in the Izmir Metropolitan Area has been the main demographic feature in the recent past. From 1960 to 1990, the population grew more than threefold, from 520 thousands to more than 1.78 million. However, the average annual rate is declining for the 1980 – 1990 period. The overall increase of population in the Metropolitan Izmir Area has been influenced by both migration and natural population growth.

A large scale extensive industrial development has been the supporting force behind the vigorous economic growth of Izmir over the last 40 year period. Industrial establishments in the Metropolitan Izmir Area have reached 1,353 in 1986 although the actual number could be higher (according to the Aegean Region Chamber of Industry the number of industrial units in the Izmir agglomeration is 6,500 for 1990). Besides being an important industrial centre, Izmir is the second largest port accounting for 25% of annual exports and 55% of imports of Turkey. The average annual number of commercial ships stopping in the harbour is approximately 2,000 while its storage capacity is 200,000 tonnes. Furthermore, due to its rich natural resources, Izmir has extensive agricultural activities contributing to the national total agricultural production by almost 15%. Regarding commercial fishing, it has been estimated that the fish stock and the catch level in the Bay area are at 217,6 tonnes/year and 65 – 87 tonnes/ year respectively. Last but not least, tourism is an important economic sector for the metropolitan area hosting a variety of tourism resources such as historic sites, archaeological monuments, tourist resorts and nature reserves. For the mid 90's the coastal (summer) tourism was the dominant tourism development pattern where foreign tourists accounted more than 70% of the total overnight stays.

According to various monitoring programs, especially the inner Bay area is heavily polluted by nutrients (the most serious problem), organic matter suspended matter, hydrocarbons, metals and pathogenic organisms due to (PAP, 1993):

- Domestic and industrial wastes: 50%
- Rainfall: 15%
- Bay activities and ship traffic: 4%
- Rivers and streams carrying mainly industrial discharges : 10%
- Erosion: 8%
- Agricultural sources: 10%
- Other sources: 3%

Although marine pollution is caused primarily by discharge of untreated domestic and industrial waste waters, transboundary pollution is, also, regarded responsible for environmental deterioration and contributes to:

- Tourism losses: in mid 50's the Bay had a high recreational value; The cumulative losses up to 1990 can be put between 1.55 and 3 million tourists or between 9 and 18 million overnight stays.
- Recreation losses: the local residents of the Metropolitan Izmir Area cannot use the Inner and Middle Bay and have to travel to the Aegean coast for weekend recreation.
- Dredging costs are incurred to keep the shipping channels open and free from siltation. The siltation is largely caused inappropriate land management practices in the watershed basins around the Bay.
- Ground water losses can be attributed to leakage from tributaries from domestic waste waters and solids, from surface wastewater and intrusion of sea water. Reduction of pollution from all these sources with the help of the sewerage system and separate industrial treatment would reduce damage to ground water.
- Izmir Bird Sanctuary is threatened by the degradation of the Bay.
- Fishing losses are caused by pollution and include loss of shellfish as well as finfish. Pollution also affects potential for aquaculture in the Bay area. Both the quantity of fish caught and the variety of fish species declined.
- Salt production losses (the Bay area produces 1 million tonnes of salt) may considerably affect the area economy.
- Damage to human health occurs due to the lack of sewerage particularly in the gecekondu areas and due to water based activities in the Bay: swimming, wind surfing , boating and fishing. No such activities should be allowed in the Inner Bay.

- *Impacts of eutrophication on tourism: the case of the Northern Adriatic coast*

The northern Adriatic Sea represents 20.3% of the Adriatic Sea which has a total surface area of approximately 136,000 km^2 and a volume of approximately 35,000 m^3. The Northern Adriatic is the most important area of offshore extraction of natural gas in Italy with more than 500 wells since 1959. Development programs foresee an increase in activity in the more populated waters of the Ravenna and the extension of drilling activities towards the Southeast and Northwest. Fishery is, also, regarded as an important economic activity as the area is the origin of more than half of the national fish catch. The Adriatic constitutes an important transit corridor for navigation. More than 30 harbours are located along the 1150 km Italian Adriatic coastline, with limited advanced technology for pollution abatement. Finally, it should be mentioned that, until a few years ago, no control was exercised over the amount of silt dredged from port basins and channels which was systematically discharged into the Adriatic.

Last but not least, tourism development is a vital economic activity for the northern Adriatic coast. Broadly speaking, in the region two types of tourism dominated until the early 90's: (a) a hotel based, mass type of tourism attracting, mainly, national tourists and visitors, and (b) a type of tourism based on private houses, flats for rent and camping sites attracting foreign tourists. However, trends in tourist behaviour characterised by a reduction in the average length of holidays and greater attention to the quality of the natural environment, services offered and value for money as well as the emergence on the market of new seaside holiday resorts, the impact of large tour operators and air transport on tourist flow patterns, affect tourism development in the northern Adriatic Sea and have led to a restructuring process in major upper – Adriatic resorts aiming to combat three major issues (a) environmental degradation and overcrowding, (b) the need to improve the quality of existing services, (c) the need to diversify services and resources offered.

During the late 80's – early 90's, this already complex picture was further complicated by the issues of eutrophication which first started gaining importance in the Italian Seas in the mid – 70's. This form of pollution is caused by the large inflow of freshwater to the basin from the catchment area of the northern Adriatic Sea, great part of which is Italian territory. On a national scale, coastal and inland waters receive about 48,000 tonnes/ year of phosphorus and 660,000 tonnes/ year of nitrogen. The most critical situation is encountered south of the Po River delta near Ravenna in a marine area for about 100 km, where the polluting effects of Po's waters are serious especially during summer months. Furthermore, the widespread appearance of phenomena of mucilage (*mucillagine)*, associated with "cloudy sea" or "marine snow" in many parts of the upper – Adriatic coastal waters in the summers of 1988 and 1989, resulted in the significant reduction of the number of tourists to the area of the order of 20 – 30% which has been reversed since. Also, the figure of total night stays for the province of Rimini declined from 17.777 thousands (1988) to 11.724 thousands (1989) and has not fully recovered since possibly indicating a trend for shorter length of stay. In fact, eutrophication and mucilage worsened a situation that was already becoming critical since many northern Adriatic resorts were entering the maturity stage. However, the extent to which eutrophication was a result of transboundary pollution and the degree to which tourism development in the region was affected by transboundary pollution or by the dominant trends in the tourism market cannot by fully appraised and needs further investigation.

- ***Human health risks***

  - <u>*Pathogens in waste and coastal waters*</u>

In the Mediterranean, as elsewhere, the two main types of human exposure to microbiological pollutants in the marine environment are through direct contact with polluted seawater and/or beach sand, including ingestion of the former while swimming or bathing, and consumption of contaminated seafood by pathogens and phytoplankton toxins (e.g. from dinoflagellates, usually related to a red tide condition).

- *Sources of microbiological contamination*

The pathogenic micro-organisms that can be found in water bodies have a wide range of sources. These include sewage pollution, organisms naturally found in the water environment, agriculture and animal husbandry and the recreational users themselves

(Bartram and Rees, 2000). Municipal sewage carries a heavy load of micro-organisms, including bacterial protozoan and viral pathogens. In the Strategic Action Program to address pollution arising from land-based activities there is a guideline for all cities with a population greater than 100,000 to install, by 2005, secondary treatment in sewage plants. However, rivers may add a considerable amount of microbiological pollution, mainly from upstream wastewater discharges. The atmosphere may also serve as a pathway for the entry of pathogenic and other micro-organisms into the coastal marine environment. Winds blowing from the continents towards the sea carry, *inter alia*, bacteria, viruses and parasites, and rain facilitates the descent of these pollutants into rivers and oceans. Recreational waters not affected by sewage effluent discharges can be contaminated with enteroviruses (Shuval, 1986). Another possible source which affects mainly coastal recreational areas is bathers themselves. There is currently an increasing amount of evidence linking adverse health effects with bathing in high-population-density beaches, and bathers themselves are a source of pathogenic micro-organism pollution in recreational waters. The beach sand may contribute significantly to the dispersion of pathogens (Papadakis et al., 1997).

The wide range of pathogenic micro-organisms isolated from water bodies are listed in Table 5.6, although some of them have not been directly implicated in recreational water infections. A recent assessment of pathogenic micro-organism pollution in the Mediterranean Sea (WHO/UNEP, 1996) listed the records available so far. It should be noted that, up to the present time, the majority of records are from the northern coastline of the Mediterranean, and efforts have recently commenced to obtain more information regarding the situation in other areas. *Salmonella spp*., *Vibrio parahaemolyticus, Staphylococcus aureus, Pseudomonas aeruginosa, Clostridium perfringens, Campylobacter sp*p and *Aeromonas hydrophila* are widespread throughout the region, while *Vibrio alginolyticus* has been recovered in Spain, *Vibrio cholerae* in Algeria, Morocco, Egypt, France, Italy and Spain, and *Shigella spp* is endemic in the eastern and the southern areas.

Table 5.6 - Pathogens and indicator organisms commonly found in raw sewage *(Bartram and Rees, 2000).*

Pathogen or indicator[1]	Disease or role	No. per litre
Bacteria		
Campylobacter spp.	Gastro-enteritis	37,000
Clostridium perfringens[2]	Indicator organism	6×10^5–8×10^5
E. coli	Indicator organism	10^7–10^8
Salmonella spp.	Gastro-enteritis	20–80,000
Shigella	Bacillary dysentery	10–10,000
Viruses		
Polioviruses	Indicator	1,800–5,000,000
Rotaviruses	Diarrhoea, vomiting	4,000–850,000
Parasitic protozoa		
Cryptosporidium parvum oocysts	Diarrhoea	1–390
Entamoeba histolytica	Amoebic dysentery	4
Giardia lamblia cysts	Diarrhoea	125–200,000
Helminths		
Ascaris spp.	Ascariasis	5–110
Ancylostoma spp.	Anaemia	6–190
Trichuris spp.	Diarrhoea	10–40

1 Many important pathogens in sewage have yet to be adequately enumerated, such as adenoviruses, Norwalk/SRS viruses and Hepatitis A

2 From Long and Ashbolt, 1994

Source: Adapted from Yates and Gerba, 1998

Salmonella species, particularly *S. typhi, S. paratyphi A* and *S. paratyphi B,* have frequently been isolated in the region. In a study in the Gulf of Trieste 37.8% of the samples were positive for Salmonella. A total of 220 Salmonella strains have been isolated form sewage effluents in Alexandria, Egypt (WHO/UNEP, 1995). The most frequently isolated serotype in a study in Spain was *Salmonella enteritis* (16.1% of the isolates from seawater) followed by *S. hadar,* with a significant increase during the 5 years of the study period (Polo et al., 1999).

Shigella is endemic along the eastern and southern shores of the Mediterranean. Its presence has been reported in Egypt with survival times similar to those of *S. typhi* and *E.coli* (WHO/UNEP, 1995).

Staphylococcus aureus is salt-tolerant and can survive in the marine environment. Ear, skin and naso-pharyngeal infections are suspected of being transmitted by bathing activities. Its origin in the water and the beach sand is attributed to human activities. A comparison between counts of *St. aureus* in heavily populated and lightly populated beaches in Greece showed positive readings in the samples (Papadakis et al., 1997). In 628 samples monitored in Israel 61% contained *St. aureus* (WHO/UNEP, 1995).

A high number of epidemiological studies indicate that many environmental strains of *Vibrio spp*, besides *Vibrio cholerae*, can cause illness to humans. *Vibrio alginolyticus* has been reported from a large number of Mediterranean counties. *Vibrio alginolyticus* and *V. parahaemolyticus* were recovered from samples of seawater from North Adriatic bathing waters in 1989 (Maini et al., 1990).

Non-enteric bacterial pathogens in the Mediterranean include *Aeromonas hydrophila*, which causes septisemia in immuno-suppressed hosts, diarrhoea, pneumonia, abscesses and wound infections. It can be transmitted through contact or ingestion of water or through consumption of contaminated seafood. In Spain levels in non-polluted beaches were 0-50 cfus/100 ml and in polluted ones 80-11,800 cfus/100ml (WHO/UNEP, 1995).

One current area of concern is that of viruses. The following viruses have so far been isolated in the Mediterranean marine environment: *poliovirus* (Greece, Italy), *echovirus* (France, Greece, Italy), *Coxsackie virus A* (France, Italy), *Coxsackie virus B* (France, Greece), *Hepatitis virus A* (France, Greece, Spain), *adenoviruses* (France, Greece, Italy) and *Rotavirus* (Spain). In the case of viral pollution, the geographical imbalance of data is more acute, as a result of the relative difficulty involved in the isolation and quantification of viruses, as opposed to bacteria. Even in the northern part of the Mediterranean, virology is still beyond the reach of most laboratories performing microbiological analysis of seawater on a routine basis (UNEP, 1999).

Thus, enteroviruses have been recorded in seawater in many parts of the Mediterranean. According to available literature, isolates include all three serotypes of polioviruses, serotypes 1-5 of Coxsackie B virus and serotypes 1, 7 and 30 of Echovirus, Hepatitis A and a large number of either untyped or unspecified serotypes. Seven serotypes of adenoviruses have also been isolated together with a number of unidentified isolates (Vantarakis and Papapetropoulou, 1998). In a study carried out in Western Greece, 17% of the samples in what, according to the EU Directive, were clean swimming areas were positive for enteroviruses, while 83.4% of the samples from a “dirty” area were positive (Vantarakis and Papapetropoulou, 1998).

On the other hand, adenoviruses are the only human enteric viruses containing DNA and they are human pathogens. Their presence in coastal waters and their role as originators of gastroenteritis have probably been underestimated. Numerous studies have also documented the presence of adenoviruses in coastal and recreational waters (Girones et al., 1993, Puig et al., 1994, Enriquez and Gerba, 1995). In Western Greece 28.3% of samples in clean areas were positive for adenoviruses while 90% of samples in contaminated areas recovered adenoviruses (Vantarakis and Papapetropoulou, 1998).

Raw fish and mussels are possible sources of infection for a number of pathogenic bacteria with longer survival time in the sea. These bacteria are bio-accumulated in the flesh. Micro-organisms endemic to seawater, such as *Vibrio parahaemolyticus, Clostridium perfringens, Hepatitis A* virus and *Norwalk* viruses have been associated with epidemics worldwide (WHO/UNEP, 1995). As many as 19% of Hepatitis A cases occurring in Frankfurt were attributed to the consumption of contaminated mussels in the Mediterranean by German tourists. Cholera is one of the main diseases associated with the consumption of sewage-contaminated shellfish, and *Vibrio cholerae* was discovered by Koch in Egypt during the 1883-84 epidemic. A major epidemic occurred in Italy in 1973 causing 277 cases and 24 deaths (WHO/UNEP, 1995). A total of 214 Vibrio serotypes were analysed and identified during a recent study in Toulon comprising effluent, seawater and mussel samples (Martin and Bonnefont 1990). Between 18 October and 4 December 1994 a total of 12 indigenous cases of cholera were registered in the southern Italian region of Puglia. All patients were infected by the consumption of raw fish or mussels (Maggi, 1997). High levels of *Aeromonas hydrophila* were recorded in Italy (36,000-740,000 cfus/100ml in various shellfish species.). Human adenovirus, Norwalk-like virus Hepatitis A and enterovirus were identified as contaminants in shellfish in Spain and Greece in a multinational study for the presence of viruses in shellfish. Norwalk-like viruses appeared to be the only group of viruses that presented seasonal variation with lower concentrations during the warm months (Formiga-Cruz et al., 2003).

A number of fungi species are pathogenic to humans, causing superficial, sub-cutaneous or deep mucoses, depending on the eventual location of the pathogen within the host after infection. The most common one associated with infection through contact with beach sand is *Candida albicans*. It has been isolated in the south of France, Israel and Greece (WHO/UNEP, 1995). A strong correlation between the presence of *Candida albicans* and the number of swimmers on the beach has been indicated in a study in Greece (Papadakis et al., 1997). In the same study a number of other genera have been isolated from seawater and sand samples (*Aspergillus niger, Mucor, Fusarium* and *Rizhopus*). In Spain 80% of the total number of fungal isolates from seawater and beach sand were *Penicillium, Aspergillus* and *Cladosporium.* In a study in Spain, sediments from 8 river mouths of the Catalonian coast were examined for keratinolytic fungi. Of the samples, 39.9% were positive for these fungi (Ulfic et al., 1997).

- *Dispersion and fate of micro-organisms in the Mediterranean marine environment*

Seawater is not the natural environment for most of the micro-organisms discharged into the sea. Parameters such as water and ambient temperature, light intensity, light wavelength, lack of nutrients, antagonism with autotrophs and planctonic cells, sedimentation and dilution factors have an effect on the die-off rates of lymatic bacteria. The die-off rates of lymatic bacteria, usually expressed as T_{90}, vary in the Mediterranean according to the marine ecosystem as shown in Figure 5.2 (Kosacoy, 1987 in WHO/UNEP, 1995).

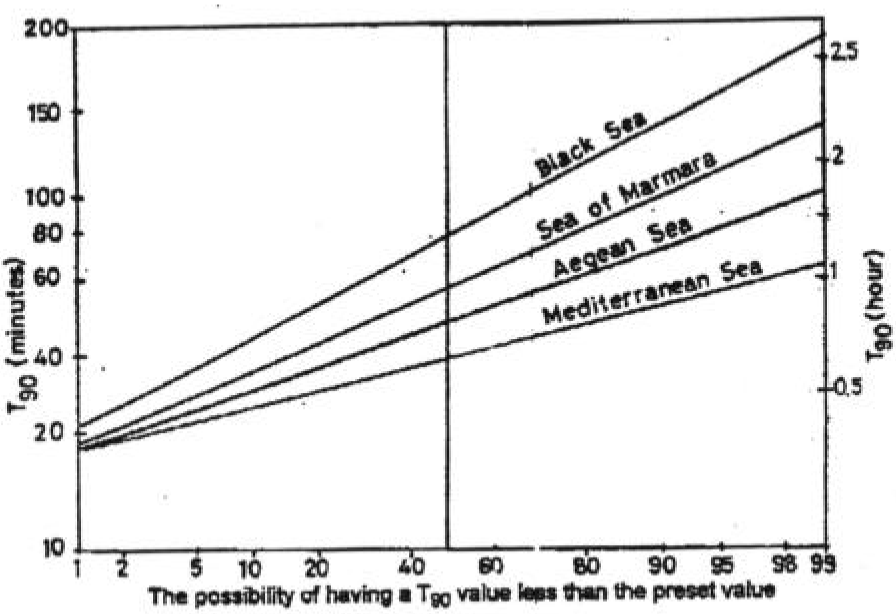

Figure 5.2 - The variation of T_{90} in the Mediterranean and adjacent seas

Viruses may survive for a considerably longer period. Whereas bacteria discharged from a sewage outlet might no longer be detectable in the samples within a few days of their release, enteric viruses might be present in an infective state for several months (Wheeler, 1990).

- *Assessment of microbiological contamination*

The assessment of monitoring results and trends leads to the conclusion that microbiological pollution is, in the vast majority of cases, the defining factor in achieving good bathing water quality. The European Commission now proposes a drastic reduction in a number of parameters, from 19 in the present directive on bathing water quality to 2 key microbiological parameters in the proposal for a new directive complemented by visual inspection (algae, bloom, oil) (CEC, 2002). This is significant for the quality of Mediterranean waters, as four Mediterranean countries are members of the European Community.

Monitoring programmes in the Mediterranean aiming to establish the level of pollution of marine recreational and shellfish waters continue to rely largely on concentrations of one or more bacterial indicator organisms as an index of sanitary acceptability. In line with global practice, recreational and shellfish water quality standards in the Mediterranean are based on acceptable concentrations of bacterial indicator organisms.

Various attempts to assess the relationship of indicators with bacterial pathogens in the Mediterranean have been reported in the past and more recently. All indicators have been shown in the Saronic Gulf, Athens, Greece, to have a strong positive correlation with Salmonella and moderate positive correlations with *Staphylococcus aureus* and *Candida albicans* (Efstratiou et al., 1998). Salmonella has been investigated in 5.9% of seawater samples in Spain. The sporadic presence of Salmonella (<30%) on beaches with low concentrations of faecal streptococci (mean 25 cfu/100ml) may represent a potential risk for bathers. Absence of Salmonella was observed only in beaches with very low densities of indicator organisms (25 total coliforms, 13 faecal coliforms and 17 faecal streptococci/100ml of sample) (Polo et al., 1998). The comparison between the presence of faecal bacterial indicators and the presence of enteroviruses and adenoviruses, on the other hand, did not show any significant correlation in a study carried out in western Greece (Vantarakis and Papapetropoulou, 1998).

Standards and criteria for both recreational and shellfish waters exist in practically all countries of the region but, particularly in the case of recreational waters, differ to a large extent both as to the particular micro-organism(s) monitored, and the acceptable levels of each (WHO, 1989). Mediterranean countries have adopted interim environmental quality criteria for recreational waters based on microbiological parameters (faecal coliforms, faecal streptococci). The European Community's Directive on the quality of bathing water (EC, 1976), which affects four Mediterranean countries, contains both microbiological (total coliforms, faecal coliforms, faecal streptococci, Salmonella, enteroviruses) and physico-chemical parameters. The two faecal indicator parameters retained in the revised directive are intestinal enterococci and *E.coli*. These two parameters are representative of the most frequently reported episodes of contamination and they are correlated with health problems (CEC, 2002). These European directives and the Mediterranean quality criteria differ considerably as regards the evaluation of laboratory results and the number of samples taken per site.

The quality criteria and standards for Mediterranean shellfish waters vary from country to country. Mediterranean countries that are member states of the European Union are bound by the limits set for faecal coliforms, *E. coli, Salmonella*, and PSP and DSP toxins produced by dinoflagellates in the Council Directive 91/492/EEC. In 1987 the Mediterranean countries adopted, on a common basis, recommendations identical with those set out in the Council Directive 79/923 EEC, which required the monitoring of faecal coliforms (EC, 1979).

- *The state of microbiological pollution in Mediterranean coastal areas*

Within the framework of the Mediterranean pollution-monitoring programme, an assessment based on the availability of data was carried out (WHO/UNEP, 1996). Due to different standard values used in Mediterranean European Union and non-European Union countries, a comparative evaluation of the microbiological quality of recreational waters in the stations monitored is not accurate, although it can provide an overall picture of the situation. In Figure 5.3, the number of stations complying and not complying with the respective microbiological quality parameters over the years is indicated (UNEP, 1999).

Outbreaks and cases related to swimming in recreational waters have long been reported. A Swedish study has reported that 63% of the Salmonella cases reported in the country were the result of infections contracted overseas, mainly in the Mediterranean. European tourist authorities have estimated that 40% of tourists on vacation in the Mediterranean became ill (UNEP/WHO, 1995).

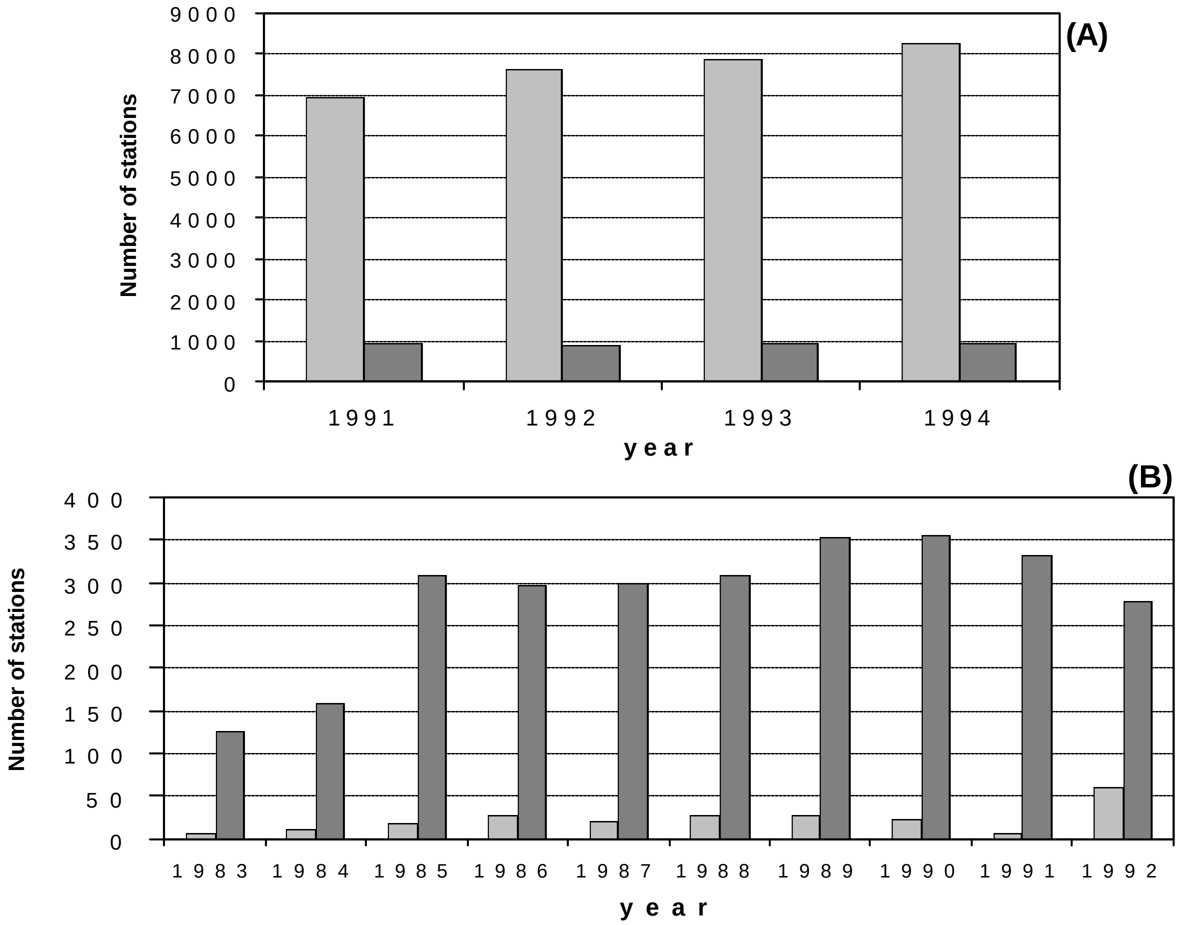

Figure 5.3 - Number of stations in Mediterranean European Union (A) and non- European Union (B) countries complying
(☐) and non-complying (■) with microbiological standards.

Epidemiological studies have investigated mainly gastrointestinal symptoms, eye infections, skin complaints, ear, nose and throat infections and respiratory illness. These studies have been performed using two different approaches, namely "case-control studies", where exposure to bathing is compared between cases and unaffected people and "cohort studies", where cohorts of bathers and non-bathers are identified and classified into subgroups according to recreational water quality. Two types of cohort studies have been reported. In "prospective studies" the cohort is followed up to see how the subsequent development of new cases of the disease differs between different exposure groups. In "retrospective studies" exposure and outcome have already taken place when the study begins. The prospective cohort studies have difficulty in following up on the tourists. In the retrospective cohort studies the water quality cannot be accurately assessed. In the randomised controlled trials the approach is essentially an experiment which involves allocation of exposure to water. A randomised design would optimise the chance of similarity between the groups to exposure and water quality is accurately assessed.

A review of epidemiological studies regarding exposure to recreational waters includes several case studies carried out in the Mediterranean (Israel, 1987 and 1991; Spain, 1982 and 1991; and Egypt, 1988) (Pruss, 1998). Some of the review results are listed below:

- The rate of certain symptoms was significantely related to the counts of faecal indicators. An increase in outcome rate with increasing indicator counts was reported by 19 studies.
- Increased symptom rates in lower age groups were reported by several studies.
- The most frequent health effect associated with exposure to recreational water is gastrointestinal symptoms. These are most often correlated with faecal streptococci/ enterococci in marine waters.
- A few studies reported associations with other health outcomes, such as ear infections, respiratory symptoms or more severe health problems.

Certainly, a sound health basis exists for a causal relationship between faecal contamination and adverse health outcomes. There is evidence from the epidemiological studies that mild to moderate self-limiting symptoms are reported amongst user groups ingesting faecal-contaminated water.

Enteric illness is the most frequently reported adverse health outcome reported in the published literature. The one randomised trial (Kay et al., 1994), which should yield the most accurate relationship, suggested a threshold of 33 faecal streptococci/100 ml for increased risk of gastroenteritis.

Associations occurred between acute febrile respiratory illness (AFRI) and microbiological indicators of both faecal pollution and of bather load. A significant dose-response relationship with faecal streptococci has been reported in the randomised study with a threshold of 59 faecal streptococci/100 ml (Fleisher, 1996).

Associations between ear infection and indicators have been reported. When compared with gastro-enteritis, the statistical probabilities are generally lower and are associated with higher counts than gastro-enteritis or AFRI (Fleisher, 1996). No credible evidence for an association of skin disease with either water exposure or microbiological water quality is available (WHO/UNEP, 1995).

Sero-prevalence studies for Hepatitis A and leptospiral antibodies among windsurfers and water skiers exposed to contaminated waters have not identified any increased health risks (Philip et al., 1989).

Exposure to faecal pollution through contaminated recreational waters leads to detectable health effects of varying nature and severity and there is a clear dose-response relationship linking faecal pollution with both enteric and non-enteric illness. Thus, national authorities have to take account of a number of interacting factors to ensure that waters used for recreation are safe. As water quality assessment relies substantially upon the use of microbiological enumeration, local authorities should consider a number of limitations:

- Such data are considered expensive to collect in many Mediterranean countries.
- They are of questionable value given the local spatial and temporal variability in recreational water quality (there are many sampling protocol problems).
- Comparability of laboratory results may be extremely poor.
- Owing to the lapse in time before the microbiological analysis is completed, approaches relying primarily on microbiological water quality are always retrospective (WHO, 1998).

  - *<u>Persistent toxic substances</u>*

Persistent toxic substances (PTS) are present in many of the transboundary sources described in chapter 4, namely atmospheric deposition, freshwater systems, urban and agricultural runoff and industrial emissions. For many PTS toxicological effects are still unknown or not fully clarified, and mechanistic information is lacking. Moreover, even for those PTS whose human health hazard has been characterised (i.e. PAHs), no risk assessment is actually feasible due to the lack of exposure data in most countries. Food being the main exposure route to PTS, data on PTS daily intakes are of major relevance and represent the necessary basis to develop an adequate risk assessment. Food exposure estimates, at present available only for some compounds and for a few Countries, are reported below.

- *Pesticides*

Aldrin, Dieldrin, Endrin and Heptachlor

Exposure to these pesticides mostly happens from eating contaminated foods, such as root crops, fish, or seafood, but also from water. Human breast milk may be a major route of exposure for nursing infants. The total daily intake of aldrin and dieldrin from food has been estimated to be 0.5 µg/day (aldrin + dieldrin) per person in Spain in 1990-91 (Urieta et al., 1996); in one study in Egypt in 1995 (Zeinab et al., 1998) aldrin and dieldrin were found to be completely absent in the composite diet. In the same studies, the daily intake of endrin, heptachlor and heptachlor epoxide were found to be completely absent in the composite diet.

At high levels of exposure, Aldrin, Dieldrin and Endrin mainly affect the central nervous system (EHC 91, 1989; EHC 130, 1992). Ingesting moderate levels of aldrin or dieldrin over a long period may also cause convulsions as a consequence of their bioaccumulation. The effects of exposure to low levels of aldrin or dieldrin over a long time are not known. Some workers exposed to these insecticides had reversible nervous system effects with excitation leading to convulsions. Studies in animals indicated that these compounds may be immunotoxic. The International Agency for Research on Cancer (IARC) determined that aldrin, dieldrin and endrin are not classifiable as to their carcinogenicity to humans (Group 3, IARC 1987).

Heptachlor and heptachlor epoxide are moderately toxic to humans and animals and can damage the nervous system (EHC 41, 1984). There are some human data on brief exposures to high levels. A few reports showed that people who accidentally swallowed pesticides containing heptachlor, or who spilled pesticides on their clothes became dizzy, confused, or had convulsions. IARC has classified heptachlor as possibly carcinogenic to humans (Group 2B, IARC 1991).

DDT

Exposure to DDT, DDE, and DDD occurs mainly from residues in food. The total daily intake of DDT, DDE, and DDD from food has been estimated to be 1.4 µg/day (DDT+DDE+DDD) per person in Spain in 1990-91 (Urieta et al., 1996) and 2.01 µg/day (DDT) in Italy in 1997 (Camoni et al., 2001). In one study in Egypt in 1995 DDT was found to be absent in the composite diet and only DDE was present: 2.18 µg/day (Zeinab et al., 1998). InSerbia and Montenegro the daily intake for new borns in the period 1993-94 was estimated in 3.29 µg of DDE and 0.21 µg of DDT (Vukavic et al., 1997).

Acute exposure of DDT mainly affects the nervous system (EHC 9, 1979). Animal studies show that long-term exposure to DDT may affect the liver, while short-term exposure to DDT in food may have a harmful effect on reproduction. DDT has been shown to have an estrogen-like activity, which is probably responsible for its impacts on reproduction in laboratory animals. As a consequence, it has been classified as a substance for which there is evidence of endocrine disruption in an intact organism (COM 1999).

In animals, oral exposure to large amounts of DDT over a short time mostly affects the nervous system and can cause liver cancer. Tests in animals also suggest that short-term exposure to DDT in food may have a harmful effect on reproduction. DDT has been shown to have an estrogen-like activity. Studies of DDT-exposed workers did not show increases in deaths or cancers, but these studies are considered biased by a number of factors and hence inconclusive. IARC has determined that DDT, DDE, and DDD are possibly carcinogenic in humans (Group 2B, IARC 1991).

- *Industrial compounds*

Hexachlorobenzene (HCB)

The intake of HCB by adults in the general population is predominantly from the diet (about 90%). HCB is highly lipophilic and bioaccumulative. In utero exposure occurs through mother's blood; breast lactation may also be a significant route of exposure. The total daily intake of HCB from food has been estimated to be 0.2 µg/day per person in Spain in 1990-91 (Urieta et al., 1996). In one study in Egypt in 1995 HCB was found to be completely absent in the composite diet (Zeinab et al., 1998).

HCB has little capability to induce directly gene mutation, chromosomal damage and DNA repair (EHC 195, 1997). However, it has been tentatively shown that it may paly a role, together with other organochlorine compounds such as p,p'DDT, p,p'DDE and some PCBs, in the pathogenesis of exocrine pancreatic cancer through modulation of K-ras activation (Grimalt et al., 1993; Porta et al., 1996). Hexachlorobenzene has been classified as substance for which there is evidence of endocrine disruption in an intact organism (COM 1999) and as possibly carcinogenic to humans (Group 2B, IARC 2001).

PCBs

Human exposure to PCBs mostly results from the consumption of contaminated food. Total daily intake of PCBs from food has been estimated to be 3.72 per person in Italy (Zuccato et al., 1998). Infants are exposed through lactation and a study carried out inSerbia and Montenegro with 88 newborns estimated in 1.75µg the daily intake of PCBs (Vukavic et al., 1997).

The toxicological evaluation of PCBs presents many problems. PCBs usually occur as mixtures of many congeners each characterised by a range of toxicological activities strictly depending on degree and pattern of chlorosubstitution. "Dioxin-like" congeners are characterised by dioxin-like activity, while other congeners may cause more subtle effects, among which endocrine disruption (COM 1999). The acute toxicity of commercial PCB mixtures (Aroclors etc.) is generally low (EHC 140, 1992). PCBs induce various enzymes in the liver and can produce changes in the immune system, behavioral alterations, impaired reproduction, liver, stomach, and thyroid gland injuries. Some PCBs can mimic or block the action of hormones from the thyroid and other endocrine glands.

The most commonly observed health effects in people exposed to large amounts of PCBs are skin conditions such as acne and rashes. Studies in exposed workers have shown changes in blood and urine that may indicate liver damage. Few studies of workers indicate that PCBs were associated with certain kinds of cancer in humans, such as cancer of the liver and biliary tract. Both EPA and IARC have determined that PCBs are probably carcinogenic to humans (Group 2A, IARC 1987).

- *Unintentional by-products*

PCDD/Fs

Over 90% of human exposure to PCDDs and PCDFs is estimated to occur through the diet, with food from animal origin being the predominant source. The daily intake of PCDDs and PCDFs from food has been estimated to be 210 pg I-TE per person in Spain (Domingo et al., 1998) and 97 per person in France (EU SCOOP, 2000). For Italy, a daily intake of 45 pg I-TE per person has been calculated (EU SCOOP, 2000) considering the only contributions from food of animal origin (a daily intake of about 60 pg I-TE may be assumed when contributions from the other foodstuffs are added).

Toxicological effects reported for PCDDs and PCDFs refer to the 2,3,7,8-substituted compounds. A variety of effects have been reported in animal studies following exposure to these compounds (IARC 1997; WHO, 1998). The most extensive data set is available for 2,3,7,8-TCDD; less information is available for the other congeners. Among the most sensitive endpoints of 2,3,7,8-TCDD are endometriosis, neurobehavioral, developmental and reproductive effects, immunotoxic effects.

The lowest doses giving rise to statistically significant effects in the most sensitive endpoints following exposure, have resulted in body burdens (3 to 73 ng of TCDD/kg) in the exposed animals that overlap, at the lower end, the range of body burdens expressed as TEQ that are found in the general population in industrialised countries exposed to background levels of PCDDs and PCDFs.

Of the many non-cancer effects evaluated in exposed adult populations (e.g. herbicide producers and subjects exposed in incidents like Seveso, Italy) many were transient effects disappearing after the end of exposure. The only effect that correlates consistently with high exposure of humans to TCDD was cloracne. A few conditions appear to be in excess among the exposed cohorts when compared to unexposed referent groups including alterations in metabolic parameters, as well as mortality from cardiovascular and non-malignant liver disease.

PCDDs and PCDFs have been classified as substances for which there is evidence of endocrine disruption in an intact organism (COM 1999). 2,3,7,8-TCDD has been shown to be carcinogenic in several species of laboratory animals at multiple sites. In humans, the epidemiological evidence from the most highly exposed cohorts studied produces the strongest evidence of increased risks for all cancers combined, along with less strong evidence of increased risks for cancers of particular sites. IARC concluded that 2,3,7,8-TCDD is carcinogenic to humans (Group 1), other polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans are not classifiable as to their carcinogenicity to humans (Group 3, IARC 1997).

- *Other PTS of concern in the region*

<u>HCHs</u>

The exposure of the general population mainly occurs via food: diet accounts for over 90% of the total exposure in industrialised Countries. The total daily intake of lindane from food has been estimated to be 2.9 µg/day per person in Spain in 1990-91 (Urieta et al., 1996)), 1.75 µg/day in Italy in 1997 (Camoni et al., 2001); 11.9 µg/day per person in Egypt in 1995 (Zeinab et al., 1998). InSerbia and Montenegro the total daily intake of lindane in newborns was estimated in 1993-94 in 0.35µg (Vukavic et al., 1997). In France, despite the wide occurrence of lindane in the environment and food chain, neither the limit of maximum residues nor the acceptable daily intake were exceeded in recent years (Bintein and Devillers, 1996).

The acute oral toxicity of lindane is moderate: the central nervous system is the main target of toxicity (EHC 124, 1991). Mutagenicity was not shown in a number of studies. Lindane has been classified as substance for which there is evidence of endocrine disruption in an intact organism (COM 1999), and as a possible carcinogen for humans (IARC, 1987).

<u>PAHs</u>

The main sources of general population exposure are: vehicular traffic, residential heating, smoke from open fireplaces and cooking, environmental tobacco smoke, contaminated food and drinking-water, and the use of PAHs-contaminated products. The calculated total daily intake of PAHs from food has been estimated to be 3 µg/day (1.4 µg/day carcinogenic PAHs) per person in Italy (Lodovici et al., 1995).

The acute toxicity of PAHs appears to be moderate to low (EHC 202, 1998). Short-term studies showed adverse haematological effects. Systemic effects caused by long-term treatment with PAHs have been described only rarely, because the end-point of most studies has been carcinogenicity. Significant toxic effects are manifested at doses at which carcinogenic responses are also triggered. In studies of adverse effects on the skin after dermal application, non- or weakly carcinogenic PAHs were inactive, whereas carcinogenic compounds caused hyperkeratosis. Benz[*a*]anthracene, benzo[*a*]pyrene, dibenz[*ah*]anthracene, and naphthalene are embrotoxic to mice and rats. Benzo[*a*]pyrene also have teratogenic and reproductive effects.

PAHs have also been studied extensively in assays for genotoxicity and cell transformation; most of the PAHs are genotoxic or probably genotoxic. The only compounds for which negative results were found in all assays were anthracene, fluorene, and naphthalene. Owing to inconsistent results, phenanthrene and pyrene could not be reliably classified for genotoxicity. PAHs have generally been reported to have immunosuppressive effects.

Because of the complex profile of PAHs in the environment and in workplaces, human exposure to pure, individual PAHs has been limited to scientific experiments with volunteers, except in the case of naphthalene which is used as a moth-repellant for clothing. After dermal application, anthracene, fluoranthene, phenanthrene and benzo[*a*]pyrene induced specific skin reactions, which were classified as neoplastic proliferations.

IARC (IARC, 1987) has determined the following: benz[a]anthracene, dibenz[*a*,*h*]anthracene and benzo[*a*]pyrene as probably carcinogenic to humans (Group 2A); benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, dibenzo[*ae*]pyrene, dibenzo[*ah*]pyrene, dibenzo[*ai*]pyrene, dibenzo[*al*]pyrene, and indeno[1,2,3-*cd*]pyrene as possibly carcinogenic to humans (Group 2B); and anthracene, benzo[*ghi*]perylene, benzo[*e*]pyrene, dibenzo[*h*,*rst*]pentaphene, chrysene, fluoranthene, fluorene, phenanthrene, and pyrene as not carcinogenic to humans (Group 3).

Alkylphenols

Exposure to alkylphenols occurs mainly from food. The dietary daily intake of alkylphenols has been estimated to be 80 µg/day per person in Italy in 1995 (Ferrara et al., 2001). The acute oral toxicity of alkylphenols is usually low. Long-term oral exposure causes an increase in liver and kidney weight without significant histopathological alterations. Alkylphenols are not genotoxic. Nonyl-phenol and 4-tert-octyl-phenol have been classified as substances for which "there is evidence of endocrine disruption in an intact organism" (COM 1999) because of their estrogenic activity.

Organomercury compounds

Mercury compounds are neurotoxic. The clinical manifestations of methylmercury poisonong are quite extensive and include disturbances in sensory, motor and cognitive functions. As seafood is the main source of mercury for humans, and because of the often reported high levels of methylmercury in fish and shellfish, monitoring of the general population exposure is needed, expecially aimed to define the risk for some groups of the general population, as heavy fish consumers and vulnerable groups (in particular young children and pregnant women). On this basis, a study was initiated by MED POL in early 80's, aimed to assess the risk for the Mediterranean population in general. Italy, Croatia and Greece were the countries selected for this study. The investigation was carried out on the high-risk group of fishermen and their families. After preliminary screening of more than 4000 people through dietary surveys, a total of 1,098 hair samples (659 from Greece, 241 from Italy and 198 from Croatia) were analysed for total mercury and, where appropriate, for methyl mercury. The results confirmed that there is a positive correlation between seafood consumption and levels of total mercury and methyl mercury in hair.

On the basis of the levels of methylmecury in hair, corresponding to blood concentrations which do not result in any detectable adverse effects in the adult population, no at-risk individuals were identified in Croatia. Only very few people in the other countries exceeded these levels, without reaching the hair concentrations associated to a 5% risk of neurological damage (WHO/FAO/UNEP, 1989).

- *General assessment of health criteria*

Except for professionally exposed workers, diet is the main route of human exposure to PTS (up to 90 %). As a consequence, a risk assessment may be carried out by comparing PTS dietary intakes with their pertinent Tolerable Daily Intakes (TDIs) established at the international level by expert groups considering the probability of specific health damages. The results for some EU countries are shown in Table 5.7.

For chlorinated compounds, mean intake levels are far below (less than 5%) the corresponding TDIs, except in the case of PCBs and dioxins for which recent data available for France and Italy indicate mean intakes close to TDIs. In this regard it is worthwhile to emphasise that exposure of specific groups of the population (infants, fish consumers) may largely exceed TDIs (3-4 times as reported by AFSSA).

For DL-PCBs expressed as TEQs, the food exposure is twice the WHO (1998) TDI for dioxins and DL-PCBs. For total PCBs, the dietary intake based on Italian TDIs study is about 2 times the TDI recently revised by the WHO and given in Aroclor equivalents. This observation is well correlated with the over-exposure found for DL-PCBs. Thus, the new TDI of PCBs revised by the WHO appeared to be pertinent for risk-assessment of total PCBs. The EU SCOOP report indicated that fish and fish products contributed to 70% of the food exposure of DL-PCBs.

Table 5.7 - PTS TDIs vs/ corresponding dietary intakes

PTS	**TDI xg/kg/day**	**Organisation**	**Food intake Mean /adults**	**Source**
DDT	20 µg	WHO	16 ng (0.08%)	Italy
HCHs	0.3 µg	WHO	5.3 ng (1.8%)	Italy
Chlordane	0.5 µg	WHO		
Dioxins (I-TEQ)	1 pg	WHO	1 pg (100%)	Italy
			1.03 pg (103%)	France
			3.5 pg (350%)	Spain (Catalonia)
PCB-DL (I-TEQ)	1.3 pg	WHO	2.5 pg (192%)	EU
S PCB (Aroclor 1260 Eq)	0.02 µg	WHO*	36.8 ng (180%)	Italy
PAHs (BaP Eq)	14 ng	DVS 10-4 RIVM	5 ng (36%)	France
Hg	0.7 µg	WHO	0.25 µg (36%)	France
Me Hg	0.47 µg	WHO	0.34 µg (72%)	France

**Temporary TDI proposed at the international PCB meeting in Brno, May 2002.*

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For PAHs and mercury, the mean exposure is about 30% of TDI but for methylmercury, the food intake is more close to the TDI. In this case, certain consumers can exceed the TDI, such as young children 3-8 years old (133%) and the high consumers of pelagic carnivorous old fish (2500%).

There is no systematic data for most of the other countries of the region. However, an interesting study made in FRSerbia and Montenegro in 1993-94 concluded that the estimated average daily intake for healthy new-borns was significantly lower than in 1982-83 for DDE, DDT, total DDT and total PCBs; significantly higher for β-HCH but not for γ-HCH; and nearly equal in both periods for α-HCH. Estimated average daily intake (ADI) of total DDT and γ-HCH was below the WHO values in both periods, and decreased to below the limit values for PCBs in 1993-94 (Vukavic et al., 1997).

The data from the monitoring of PTSs in different areas of the Balkans (see section 3.5) clearly show levels of some PTSs in environmental matrices (mainly soil and sediment), and eventually biota, higher than the background levels generally found in the environment. Therefore, the ability of PTSs to enter the foodchain and to biomagnify along them makes the hypothesis of a high human exposure to these compounds highly plausible, and the correlated damage for health worthwhile to be explored.

o *Coastal zone management (CZM)*

- <u>*Type of transboundary character*</u>

CZM transboundary related issues are connected firstly, to the absent or problematic application of CZM as the major tool when addressing transboundary issues and secondly, to several specific sectorial issues that require a specific CZM approach adapted to certain problems, as summarised in Table 5.8 and discussed below.

Table 5.8 - CZM transboundary related issues and type of transboundary character

Issues	**Type of transboundary character**
1. Limited application of CZM when addressing single major transboundary issues	Regional issue with cumulative effect
2. Insufficient geographical coverage – differentiated and insufficient implementation of CZM in the region	Regional issue with cumulative effect
3. Low level of experience of CZM when addressing transboundary issues	Regional issue with cumulative effect
4. Insufficient confrontation of impacts from large urban/ industrial coastal agglomerations	National issue with cumulative effect
5. Insufficient confrontation of impacts from mass tourism	National issue of common interest
6. Insufficient confrontation of impacts	Regional issue with cumulative effect

from climate change and sea level rise	

- *Related to absent or problematic application of CZM when addressing transboundary issues*

Limited application of CZM when addressing single major transboundary issues affecting the Mediterranean Sea mainly due to insufficient legislative and institutional CZM framework in the region.

Insufficient geographical coverage – differentiated and insufficient implementation of CZM in the region; need to strengthen and upgrade the implementation of CZM, extend its geographical coverage to all Mediterranean coastal states and harmonize procedures and instruments.

Low level of experience in CZM when addressing transboundary issues, non - specific and properly adapted CZM procedures and tools related to transboundary issues; need to deepen and better elaborate relevant methodology, to gain more practical experience as well as identify and test best suited instruments and tools.

- *Sectorial related issues*

Confrontation of impacts of large urban/ industrial coastal agglomerations; Result of the specific phenomenon is a spatial dichotomy between heavily populated coastal areas and poorer, thinly populated inland areas with lower housing density and less dynamic economies. Coastal urbanization is interrelated with biodiversity losses, stable increase of water demand, waste production and pollution.

Confrontation of impacts of mass tourism; not harmonized with the environment and disregarding the carrying capacity of exploiting resources.

Confrontation of impacts of climate change and sea level rise; Long term natural and human induced changes in the hydrological cycle constitute a major problem for the Mediterranean region especially due to the variation of precipitation for many surrounding states, possibly a result of climate change. Sea level rise is a result of several factors such as reduction in river sediment supply, the destruction of natural shoreline defences and the overpumping of groundwater.

- *Causes of CZM transboundary related issues*

  - *Limited application of CZM when addressing single major transboundary issues*

1. Absence of strategic view of the Mediterranean Sea leading to ineffective interventions despite the success of CZM in defining general goals and intentions.
2. Vague and poorly defined legislative and institutional CZM framework at the regional level resulting to absence or problematic implementation of CZM at the national level when addressing transboundary related issues.
3. Lack of awareness of the need for and benefits when applying CZM within transboundary related initiatives.
4. Lack of experience in implementing CZM at the regional level.
5. Prevailing sectorial or single topic approach to decision making, coastal area planning and management.
6. Limited number of transboundary related programs and projects facing significant uncertainties during their implementation.

7. Insufficient tools appropriate for the application of CZM at the regional level.

- *Insufficient geographical coverage–differentiated and insufficient implementation of CZM in the region*

1. Lack of flexible mechanisms for ensuring that national administrations adopt CZM goals and principles as existing mechanisms are in the form of very formal and rigid administrative procedures.
2. Inappropriate administrative systems and poor enforcement of CZM; typically there are multiple authorities and responsibilities with ensuing problems of limited coordination, gaps and overlaps.
3. Prevailing classical sectorial approach and limited influence of environmental aspects in development planning for many Mediterranean states jeopardizing the possibilities of achieving the establishment of national CZM systems.
4. Transitory character of many Mediterranean economies, mainly of eastern and southern states.
5. Limited awareness for the great value and unique nature of coastal resources necessitating differentiated decision making and management systems than the ones applied in continental areas.
6. Poor public participation in CZM; In most Mediterranean states, civil society is not accustomed to active participation in public affairs so there are constraints in mobilizing it to contribute to and aid with the task of managing coastal areas. In addition the primacy of development needs does not yet allow Mediterranean societies to adopt a broader view in terms of CZM.
7. Insufficient human capacity for implementing CZM.

- *Low level of experience of CZM when addressing transboundary issues*

1. Insufficient methodological basis, not transboundary specific tools and/ or not tested to Mediterranean conditions.
2. Absence of mechanisms for smooth project succession at the regional level.
3. Insufficient experience of national authorities for the implementation/ coordination of CZM transboundary related initiatives.

- *Confrontation of impacts from large urban/ industrial coastal agglomerations*

1. Absence of applying the ICZM coastal urban component and the relevant urban specific ICZM tools
2. Priority given to short run benefits and sectorial/ partial interests.
3. Weak enforcement of adopted plans and regulations, illegal construction.
4. Inadequate waste treatment
5. Absence or limited public participation in the decision making process.

- *Confrontation of impacts from mass tourism*

1. Uncontrolled and unsustainable development of mass tourism in coastal zones.
2. Disregarding of the cumulative impacts of various parallel tourism activities

3. Disregarding of the significance and values of coastal zone resources, specifically environment, landscape, architectural and cultural values, of their limited carrying capacity and the need for rational utilization, conservation and protection.
4. Influence of international tour operator promoting short term economic interests and policies, imposing conditions alien to identify of Mediterranean coastal zones.
5. Weak awareness of tourists on the need to protect the coastal environment and resources, inappropriate behavior, increased risk of natural hazards (i.e. forest fires) due to uncontrolled tourism activities.
6. Illegal activities implemented by inappropriate tourists: theft, damaging, destruction of environmental, biological, cultural and other values; killing/ taking/ damaging rare, endemic or endangered species.
7. Absence of necessary infrastructure (i.e. for waste management).

- *Confrontation of impacts from climate change and sea level rise*

1. Limited experience and understanding of climate change implications.
2. Reduction of river sediment supply.
3. Destruction of natural shoreline defences such as sand dunes and coastal ridges for coastal urban development relating to commercial or tourist activities.
4. The excessive pumping of groundwater which may increase subsidence due to the lowering of piezometric surfaces of confined aquifers as well as to compaction phenomena.

- *Geographic coverage of CZM issues*

From the above analysis, it is evident that CZM transboundary related issues are linked either to the Mediterranean Sea as a whole, or to certain larger geographic areas or systems. “Hot spot” areas are smaller areas affected by CZM related issues which have significant consequences of a transboundary nature.

Entire Mediterranean system

- *Limited application of CZM principle and context when addressing single major transboundary issues;* in particular need for a strategic view of the Mediterranean Sea, integration of the decision making processes and harmonization of actions with other interrelated initiatives, proactive approach, public participation.
- *Insufficient geographical coverage – differentiated and insufficient implementation of CZM in the region;* need for creating institutional, legal, methodological and capacity related conditions for a harmonized approach, for establishment of the relevant institutional and legal arrangements, for development of tools related to transboundary issues.
- *Low level of experience of CZM when addressing transboundary issues;* need for appropriate methodological framework and tools, for mechanisms for smooth project succession.

Subsystems – subregions

- *The Mediterranean islands;* resources affected insular ecosystems and habitats, biodiversity, cultural identity, soil and water resources needing for sustainable development (i.e. tourism), protection of insular identity, implementation of Integrated Coastal Zone Management framework.

- *Sub regional groups needing differentiated approach when dealing with ICZM* in order to minimize impacts on affected coastal and marine resources:
    - Slovenia, Croatia, Greece, Malta, Cyprus, Turkey, Egypt (need of an advanced but differentiated approach).
    - France, Italy, Spain
    - Algeria, Morocco (need of an advanced but differentiated approach).
    - Albania, Syria, Lebanon, Libya, Bosnia and Herzegovina (need of a basic approach).

"Hot spot" areas

The ICZM related "hot spot" areas are referred to in other chapters of the Transboundary Diagnostics Analysis (issues and impacts) but still need the ICZM context for successful management. The most important categories are:

- Sub regional areas affected by transboundary pollution; Northern Adriatic, Ebro – Rhone area, Eastern Mediterranean (Greece – Turkey, impacts from the Black Sea), Gulf of Gabes.
- Big river basins and their estuaries needing Integrated River Basin and Coastal Area Management; Nile, Po, Rhone, Ceyhan, Drini, Neretva, Buna, Ebro, Tevere, etc.
- Areas of big coastal cities/ ports subject to pollution from one or more points or diffused land sources needing the application of the coastal urban component of ICZM; the main pollutants or impacts of concern are: municipal sewage (including micro – organisms), urban solid waste and air pollution; Persistent Organic Pollutants ?including pesticides , PCBs and PAHs, heavy metals, oils, radioactive substance, nutrients and suspended matter in addition to physical alterations and habitat destruction.
- "High risk" areas suffering from impacts of sea level rise needing the development of an innovative component of ICZM addressing emerging issues.

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• Future perspectives of development in the region and potential impacts on the transboundary issues

o *Demography and urban settlements*

▪ *Urbanisation in the Mediterranean and its link to the environment*

After half a century of intense urbanisation (1950 – 2002), the Mediterranean has become one of the most urbanised areas in the world. Often population density and pollution concentration rise together, so that mixed industrial urban areas account for half of all pollution hot-spots in the Mediterranean (see section 4.6.3). In the future, the mixed industrial urban pollution problems will rise due to the ongoing process of urbanisation, especially in the Southern and Eastern parts of the Mediterranean. In the South, the urbanisation rate is expected to rise from 62% today to 74% in 2025. Although fertility rates have decreased in areas to the South and East of the Mediterranean, demographic growth will continue. By contrast in the North, the urbanisation rate is likely to increase only marginally from 70%. In total, by 2025 seven out of ten inhabitants in the Mediterranean basin will probably live in a town and the population of urban areas could go from 274 million inhabitants today to about 378 million.

The prospect of increasing urbanisation and the weight of towns in the national economies and in environmental issues, leads to consider towns and urban areas as strategic sites for environmental management, because:

- they consume of the largest part of renewable and non-renewable resources
- they are responsible for producing most of the waste e.g. sixty hot spots having mixed urban industrial sources of pollution account for 81.4% of total BOD load and about three-quarters of COD load (see section 4.6.3)
- they are responsible for a significant part of pollution in the air, soil, and fresh and marine waters
- they contribute to global environmental problems such as the greenhouse effect, linked to emissions of carbon and other greenhouse gases or the problem of acid rain
- they locate the majority of economic growth and therefore funds to finance pollution abatement
- they locate a high concentration of human expertise to take decisions and apply measures to mitigate pollution

▪ *Urban issues from a North and South standpoint*

The urban profiles in the North and, South and East have many differences. In the South and the East there is continued growth of some very large cities such as Alexandria and Cairo, alongside growth of medium and small cities. Unemployment, and a large unregulated job sector is a poignant problem in South urban centres, especially for the younger generations. By comparison, the population of Northern urban centres is only rising moderately. Unemployment in the North includes a large fraction of population that is long term unemployed, a decrease in the labour force and ageing populations.

On both shores of the Mediterranean a top ranking dissatisfaction of inhabitants is shortage of affordable housing, especially in city centres, and shortage of social housing. Illegal building, a form of urban sprawl proliferates in most big cities. On another front, cities in the North and South are faced with new issues stemming from globalisation of urban services, disengagement of the State from providing urban services, sometimes accompanied by slashing of public budgets. Across the Mediterranean, the difficulties of managing cities cluster in the following areas:

- redefining the control of government over local communities in view of increasing self sufficiency of municipalities
- shortage, especially in emerging countries of elected representatives and municipal administrative personnel with sufficient training o awareness to tackle the increased complexity of urban issues

The tools of urban planning of the 60’s and 70’s, Master Plans have been proved insufficient to contain urban sprawl. A major draw back was that they were out of step with the informal urban economies such as unregulated city quarters and informal job sectors. In addition, they focused resources excessively to build urban extensions but overlooked the decay in existing urban stock, especially in harbour towns, public housing or old city centres.

- *The environmental stakes of urbanisation*

  - *Cities with moving borders: urban sprawl*

A negative environmental impact of urban sprawl, is that it increases distances covered by car transport, with negative consequences for air pollution and global warming. It also involves loss of natural space which is quality environmental space, deterioration of landscape, and loss of biodiversity. In addition urban sprawl is seen as leading to the segregation of towns/cities and devitalisation of city centres, hence representing a loss of wasted urban space.

Where urban sprawl is illegal, due to the failure of markets or states to supply housing, it involves risks to public health and safety. Spontaneous districts are deficient in terms of public services, water supply, drainage, waste collection, which puts public health at risk. Seismic safety features in unregulated housing are likely to be overlooked compiling concerns for public safety in an earthquake prone region such as the Mediterranean. The risks for public health and safety are magnified by the fact that unregulated construction is rampant in big cities. More than half of greater Cairo is illegally built (58%), and the proportion is even higher for Greece (70%). The percentage of illegal buildings is estimated at 30% in the cities of Morocco and Algeria and at 40% in Alepo.

The drawbacks against increased productivity which in principle is linked to urban concentration, include disappearance of farmland. In Cyprus, the build up of 3,200 ha around Nicosia has resulted in a loss of more than $8 million in agricultural production. In Lebanon, uncontrolled urban sprawl over the last twenty years has led to the disappearance of 7% of the cultivated land and 15% of irrigated land.

Although there is no uniform response to the diverse types of spontaneous quarters, which often represent highly hierarchised micro-societies, the general steps to regularise them involve:

- regularisation of the property status. This process, started by states 20 years ago involves temporal tolerances, lump sum payments by property owners to the state, obligations of tax payments to communities e.g. in 1995 in Elyssar an outer Beirut area, the steps involved a population census and socio-economic survey; regulating property claims; building new quarters
- according to a plan; supplying loans for up to 20 years to enable families to purchase the new homes.
- improving housing and making it conform with public safety and health
- standards e.g. as in the Balat and Fener quarters in Istanbul, works include bringing the housing stock to standard, connection to natural gas, insulation as a pilot project that depends on owners prior savings, government credit and EU subsidy for funds. Similar projects took place in refurbishing the districts of the old city of Barcelona and with the Euromediterranean operation in Marseilles, France

- building urban infrastructure and supplying urban services including school buildings, dispensaries, transportation networks, sewers, drinking water

- *Toxic cities*

Risks of industrial technological accidents together with pollution from nearby industry are major local and transboundary pollution concerns in urban areas e.g. the accident of Seveso in Italy 1976 releasing a cloud of dioxins. The narrowness of the coastal zone in the Mediterranean brings urban spaces into direct competition for space with industries that need great quantities of water in the production processes e.g. iron, steel and paper industries, as well as a large pool of labour, also to be found on the coastal areas. Of the substances released by the industry the most harmful to human health, marine ecosystems and biodiversity are the toxic, persistent and bioaccumulative pollutants (TBPs), which include the persistent organic pollutants (POPs). Marine life is harmed by the presence of heavy metals that enter the Mediterranean from mixed municipal and industrial sources in a number of pollution hot-spots in the Mediterranean (see section 4.6.3).

Automobile pollution, a relevant urban problem, results in local air pollution but also in the contribution to the greenhouse effect. There is, accordingly, a need for global solutions to local urban problems. Local solutions alone may fail to improve global pollution aspects, as in the example of switching cars to lead free fuel that leaves the local environment better off but brings no improvement to the global climate change problem. In global terms a good solution to urban traffic congestion is one that reduces automobile use, e.g. developing highly performing public transport as an adequate substitute to private car use. In the case of Athens the role of traffic in urban air pollution is amply illustrated. The city's photochemical smog, carrying among others carbon, sulphur dioxide and nitrogen oxides, is due to car traffic by up to 75%.

Traffic congestion with long waiting queues is not only harmful to the environment but also to economic growth. The economic losses associates to congestion in the OECD countries are as high as 5% of the GNP. This situation appears to be critical in all of the major eastern cities like Istanbul or Athens, where public transport services are especially weak.

Apart from land transport, sea transport is an alternative option of public in cities that have a waterfront, e.g. the Bosphorus boat transport network in Istanbul. Sea transportation is more economical on energy and adds less to the greenhouse effect. In this respect, it is also an appropriate means to carry out coastal trade between Mediterranean towns.

In some European towns, urban traffic plans are being set up as an innovative approach to considering improvements in city traffic. Their purpose is to program investment in transport policies to reduce car traffic in a differentiated way depending on the different urban zones. The main issues involved are quality public transport, sharing of public space, parking lots, and transportation of goods inside the urban area.

- *Cities and water: more trouble in the horizon*

Water scarcity, a serious problem in unregulated residential areas, is going to become a general problem as water consumption in Southern urban centers increases by about 40% by 2025. Growing farming and household demand for water in the Mediterranean combine to make water a non renewable resource in what are more or less arid environments. At present the water supply meets the essential needs of urban residents, as in the example of Cairo, where consumption is 289 liters/day / inhabitant.

However, the pricing of drinking water is an open issue as higher pricing, seen positively as it dissuades water wastage, involves investment in water meters, which may make water too expensive for some. Access to drinking water, being a primary social issue, can be achieved by adopting a free minimum consumption level designed to meet the fundamental needs of man (estimated at about 40 litres/day/person) or using differential tariff rates according to income levels.

Pollution of the Mediterranean by untreated or partly treated sewage water is a main cause of microbiological contamination, as described in section 5.4.1. The warm climate of the Mediterranean renders the health risk from microbiological contamination particularly high from exposure to sea water for recreation or from consuming contaminated sea food. Contamination by heavy metals, mercury, cadmium, lead and chlorinated hydrocarbons all being persistent, toxic and bio-accumulated (PTBs) substances is partly due to municipal and mixed municipal and industrial sources and can affect coastal waters at distances upto 20 km from the outfall. Contamination by mercury however, is observed in sediments and biota even in open waters where concentration of other PTBs is low. Discharges of untreated urban and mixed waste also cause eutrophication especially in enclosed coastal bays, lagoons and estuaries and particularly if they show low flushing of water into the sea. The most serious consequences are the appearance of toxic algal blooms and fungal growth and, oxygen depletion due to the decomposition of algae and seaweed, that kills fish. Most Mediterranean countries are affected by eutrophication although documentation concerns primarily the Northern shore.

Treatment of waste water is low due to lack of equipment. Wastewater treatment plants serve around 55% of 545 coastal cities with more than 10,000 inhabitants. As a result the annual discharge of untreated wastewater from coastal cities in the Mediterranean is very high, and in fact is slightly higher than the quantity of wastewater treated before being discharged (treated 2,933 against untreated 3,285 million cubic meters per year) (UNEP/WHO 2000).

- *Cities and waste*

Waste management ranks among the most common failings in urban services i.e. refuse removal, storage in the dumps and street cleaning. Today, Cairo generates 3 million tonnes of waste per year, against 1 million in Alexandria and 350 kg per inhabitant per year in northern cities. The cause lies primarily with a shortage of funds. In the Maghreb and the Machrek countries the World Bank estimated the investment needs for going from the existing illegal dumps to controlled dumps by 2010 to amount to $2,5 – 3 billion dollars. At present however, these countries spend between $292 and $365 million for waste management.[6]

- *Rethinking urban management as a way to fight environmental degradation*

Over the past 20 years environmental criteria have been making their way into urban management much more slowly than desired in Northern Mediterranean Countries and are even more scarcely applied in the South and East Mediterranean. In Italy, after the failure of the National Sustainable Development Plan in 1993 to create a network of sustainable towns, such a network came into being at the initiative of Ferrara and Modena in 1999, including 150 towns. In France, the state initiative went from facilitating co-operation between municipalities, with the Urban Ecology Charts that had no legal implications, to incorporating a set of sustainability objectives in plan contracts negotiated between the state and regions, according to the SRU law. On the other hand, in the Southern Mediterranean it is only since 1990 that environmental affairs became legislative provisions in Egypt while in Tunisia, during the 90's, there was a commitment to accompany every industrial, agricultural and commercial project with an environmental impact assessment. Across the Mediterranean, the following questions concern the future of urban management:

- Getting regional, local and national management to work together in new ways towards solving local and transboundary pollution.

[6] Synthesis and Proposals for Action, prepared for the Mediterranean Meeting on "Urban Management and Sustainable development" in Barcelona, September 3-5, 2001 by the MCSD

Currently there is little mobilisation of local populations and municipalities to work for more sustainable urban environments. In all Mediterranean cities there is growing support towards greater municipal autonomy which would be one way to mobilise local potential. At present, municipalities are dependent by up to 80% on State finances, in the context of very old tax systems (half a century or a century old sometimes). Municipal finance is constrained by shortage of funds which leads to providing insufficient services, e.g. in Morocco between 1997-2001, the annual average amount needed for municipal investment was 1.4 billion Euros, while the global investment budget of communities in 1995 was 0.21 billion Euros. A change in the tax systems that allows local populations to mobilise finance for local investments would be useful in this context. Towards this, local environmental taxes may be levied according to the "polluter pays" principle, or an 'eco-tourism' tax applied on urban tourism. The rational for the 'eco-tourism' tax is that tourists are particularly sensitive to the quality of the environment as well as the fact that tourism generates waste.

- Establishing administrative territories that correspond at once to the effective confines of activity and its environmental impacts e.g. job basins, life basins.

The idea is to define the areas of cause and effect to avoid environmental externalities from being born by areas outside the confines of the administrative unit. A classical problem that arises in which polluters free ride on neighbouring communities is waste management. Experience shows that a good standard of living and city cleanliness in one area may have the effect of polluting the surrounding areas in which waste is being dumped.

- Improve monitoring of private performance in the supply of public urban services

For lack of own resources as well as increasing numbers of private sector operators, municipalities chose to delegate management of services to experts. However, in emerging countries in particular, concession or stewardship formulae have led to problems of cost recovery, for instance in Greater Beirut where the waste treatment plan organised by private operators is faced with great financial problems. Case studies of Dubrovnik in Croatia, Limassol in Cyprus, Tetouan in Morocco and Tripoli in Lebanon confirm the need to increase the vigilance of public authorities. In the case of the waste in Egypt and Lebanon, cost slippages led to 15 to 25% increase in the cost of waste management by private operators. Contracts must define clearly the performance goals to be reached along a time frame. The indicators can describe economic, environmental, and operating efficiency, for instance, efficiency of new against old networks, population rates to be served.

The way to improve public monitoring and control, is by adequate training the relevant officials. Personnel that is already operational can be offered vocational training to upgrade specific skills. National training cycles can be brought into international networks like the Association of European Schools for Planning (AESOP). An option could be to set up a Mediterranean training program designed along the model of the UN International training centre for local participants (the CIFAL). Other options include exchanges of trainees between towns, Med Campus type sessions and international programs such as HABITAT (CNUEH), "towns Alliance", "Urban Habitat Forum", "International Forum on Urban Poverty".

- *Participatory urban management: making a city for all*

Choices between the often opposite interests of town dwellers will involve trade-offs by individuals and can not be imposed from above. Partnerships are ways of arousing adhesion in a vision of the future, which will then increase its chances of success,

To improve the "interfaces" between the inhabitants of a city, several steps can be taken:

- Revise public survey procedures. Public survey documents are overly technical and fail to involve others than property holders.
- Social exclusion prevents the voices of parts of the urban population from being heard. Social intermediation, as conducted by ENDA Maghreb in Morocco and those

of Advocacy planning type (Cairo) are possible ways to increase participation among socially excluded groups

- *Bringing cities into focus in the Euro-Mediterranean partnership*

The Euromed process can set up a specific co-operation programme for sustainable urban development adapted to the institutional contexts of southern and eastern riparian countries. The new framework of European co-operation captured in the European Parliament's decision in May 2001 should be extended to southern and eastern Mediterranean countries (it now covers local authorities in community countries, Central and Eastern Europe, Cyprus, Malta as well as countries having signed agreements with the European Community).

Decentralised co-operation should be strengthened between North-South but particularly on a South-South levels, as these exchanges constitute less than 5% of inter-mediterranean exchanges today.

o ***Agriculture***

- *Intensified Mediterranean agriculture: testing the limits of ecosystems*

Intensification of agriculture in the Mediterranean over the last half century has made agriculture the largest non point contributor of pollution of the Mediterranean Sea. Natural soil constraints, such as low levels of soil nutrients have led to increased use of fertilisers and manure which are responsible for runoff of nutrients (N and P), contamination if waterways by pathogens and metals. The struggle against lack of water and unreliable rainfall patterns, most pronounced in arid North African regions has led to expand irrigation which unfortunately exacerbates problems of agricultural run-off. Fertiliser and pesticide residues along with animal waste leach into waterways and degrade water quality. Increased tillage has exacerbated further the degradation of water, by intensifying sedimentation that is erosion of the top fraction of soil, carrying adsorbed chemicals, pesticide residues and most metals and deposition into waterways.

The changing trends in Mediterranean agriculture are apparent by looking at country data on fertiliser consumption, total surface of irrigated land and number of tractors. An overview of the region was already presented in section 4.3.

- *North and South trends in intensification of agriculture*

In terms of total quantities of fertilisers used, Northern Mediterranean countries consume more than the South and Eastern Mediterranean countries. However, South and Eastern Mediterranean Countries (SEMCs) are catching up in fertilisers consumption per cropland surface. In 1993 consumption of fertiliser per hectare of cropland in Israel was slightly higher than that of France that is 150 kg per hectare of cropland, which is also the highest level used in Northern Mediterranean agriculture. Fertilisers consumption in Cyprus and Lebanon came close behind that of Israel and were higher than the average Northern Mediterranean levels. The increasing use of fertilisers is most visible in the case of Egypt where consumption levels were nearly 400 kg per hectare that is more than double those of France (The World Bank, 1996). The increasing trend in the use of fertilisers indicates that the share of the SEMC region in pollution of the Mediterranean waters will increase in the future.

One of the reasons for the rapid increase in agrochemicals used in SEMCs has been State support in the form of subsidies. In the course of the liberalising Structural Adjustment Policies (SAP) of the 80's, these measures came under criticism and SEMCs took steps to cut down this practice to varying extents. Manure subsidies in particular were reduced if not altogether dismantled, especially in Egypt, Algeria, Morocco and Lebanon. The result has been a modest reduction in manure applied in some countries, with the exception of Turkey, where the reform failed and subsidies returned.

Agricultural run-off is transported by soil erosion and enters the hydrological cycle causing contamination of waters. Soil erodibility depends on local environmental features such as rainfall intensity, soil type, slope gradient, cover, the amount of tillage and water management. All across the Mediterranean, the highest degree of soil erosion is connected to agricultural practices. A ranking of areas according to the volumes of soil loss due to erosion shows the top risk basins to be Syria, Sicily, Corsica and Crete, joined by Greece and Sardinia when the top ten are considered.

In the future, erosion is likely to increase over both South and North, but for different reasons. In the North, abandonment of terrace cultivation without reforestation is increasing erosion risks in hill and mountainous slopes. The replacement of traditional farming by mechanised methods has practically led to a vanishing of the skill of terraces-building, which today is revived sporadically within environmental protection schemes.

In the South, by contrast, erosion risks stem from replacement of forest and grazing land by farmlands, which offers less protection against erosion. Forest cover and permanent meadows protect soil from erosion almost completely, whereas agricultural cultivation can reduce soil loss by erosion (in relation to non-tilled fallow taken as 100) from 57% (continuous corn, conventional plant and till, harvest for silage) to 7% (corn without cultivation). As shown in section 4.3, it can be seen that in all SEMCs the total arable and permanent cropland rose, whereas in all Northern Mediterranean countries, with the exception of Greece, the surface of arable and permanent cropland fell. For instance in Morocco, total arable and permanent cropland increased from 6.97 to 9,595 million hectares whereas in Spain decreased from 20.73 to 19.16 million hectares. Moreover, erosion risks in SEMCs are increased because new farming may occur in marginal soils, where erosion risks are higher. In Morocco, about 25% of total cereal farmland, or about 17% of total farmland is on marginal soils.

- *Intensified agriculture as a result of urbanisation*

To compensate for farmland lost to urban sprawl, intensive farming is taken up in other parts of a country, with subsequent impacts on water from high use of fertilisers, pesticides, tillage and irrigation. Across the Mediterranean losses of good agricultural land are high due to expanding urban built up surfaces. The loss is estimated at 7,500 ha/year in Turkey, against 25,000 ha/year in Egypt, especially around Cairo, reducing the ratio of farmland per capita from 0.3 to 0.14 feddans. In Lebanon, 7% of cultivated land has been lost to urbanisation over the past two decades which amounts to 15% of irrigated land. In Greater Algiers, urban sprawl has absorbed 1,400 square km of fertile land, especially in the Mitidja plain.

In the case of Egypt major decisions to improve desertic land were taken in relation to urbanisation and the need for irrigated land. Two giant projects, the Tochki project and the Charq Al Ouweinat project aim to use Nasser Lake water and recent discoveries of water reservoirs close to Aswan to irrigate desertic areas, including the Kharga Farafra oasis.

- *Water scarcity*

Water scarcity seems certain to constrain further use of one of the hallmarks of agricultural intensification, irrigation. A global problem, the “world water gap” describes the shortage of available supplies of water for irrigation by 17% against demand by 2025, according to experts. Groundwater levels in the Mediterranean are declining widely, resulting to among other things, salt water intrusion into coastal aquifers. The dramatic and continuing growth of tourism and industry are competing with intensive agriculture, which however remains by far the largest consumer of water, being responsible for some 80% of the region’s available freshwater.

Although irrigation increases farming productivity dramatically, the impacts of run off of salts, fertilisers and pesticides have a heavy environmental cost. Moreover, commercial water is currently under-priced and does not reflect the environmental costs of agricultural run-off.

OECD predicts that by 2020, fertilisers, organic contaminants, and other pollution from agriculture will saddle waterways in OECD countries with a 25 % increase in nitrogen loads and demand for oxygen. Non-OECD countries by comparison, are likely to experience a 100-200 % increase (OECD, 2001).

The environmental problem of agricultural run-off through irrigation, and the imminent water shortage have a common solution that is to increase efficiency of water use. Currently, irrigation efficiency is very low, with less than half the irrigation water on average actually reaching the crop and an estimated 30-60 % returned for downstream use. Increased water efficiency for example, through drip irrigation can control the problem of aquifer pollution and help meet the expanding needs for water. Experts indicate that one half of the expected increase in the demand for water could be met by increased water efficiency (Shah and Strong, 1999).

- *Precision agriculture: the future of environmental sustainability?*

Although currently a tool for the few, with only about 4% of farms in the US and even less in Europe using it, precision farming are giving a new meaning to intensified agriculture. Tools like global positioning systems, communication links, and digital sensors aim to give precision information to farmers to match variable conditions in the field with the best possible response. For instance, digital control systems on a tractor can determine how much fertiliser and pesticide to apply and to apply them where needed. The benefits are reduced costs for the farmer and reduced negative impacts of agriculture on the environment.

The initial costs of precision agriculture are high both in terms of financial costs and in terms of technical infrastructure necessary for the maintenance and operation of sophisticated machinery. The technical and financial constraints that are present in many developing countries, shared by SEMCs make precision agriculture a remote possibility. Eventually, however, these precision tools can help extend the Green revolution's gains into a new era of intensive agriculture by giving farmers better access to information on crop varieties, soil conservation and water systems, and bridge the knowledge gap that separates the world's farming regions today.

o ***Industrial activity***

- *Growth: a pollution trap for the Mediterranean*

An economy experiencing industrial growth will inevitably face high environmental consequences. The most common pollution problems encountered are increased waste and water pollution, air pollution problems and an increase in the mixed industrial urban types of pollution. Industrial wastewater is responsible to a great extent for marine pollution by oil, heavy metals, detergents, solvents and organic chemicals, as well as heated cooling water. Industrial solid wastes consisting of sludge from processing of ores, dust and combustion ashes and of slag from coal mining may end up on land as landfill, in rivers or in the Mediterranean sea directly. Human health is affected heavily particularly by the release of substances that combine high toxicity, persistency and bioaccumulation (TPBs).

Another feature of this growth is that all countries respond too slowly with environmental regulations whereas pollution problems pile up quickly. In Spain, for instance, despite significant mobilisation of the state in pursuing environmental protection, the accumulated detriment to the environment due to increased waste, polluted water, rise of industrial-urban type of pollution is still present (Chatelus, 2000).

Looking at the size of each country's manufacturing sector, the composition of output and the environmental friendliness of production provides an overview of the pressures currently exerted on the Mediterranean on a country per country basis. When the size of industry is examined, the North is by far the source of the greater part of pollution; France Italy and

Spain alone account for 87% of the combined total Mediterranean production. However, the share of the Mediterranean south in manufactures is expected to rise fast in the 21st century, driven by population growth and a rise in living standards.

Heavy industries that are highly polluting are likely to stagnate in the North and expand in the South. Southern and Eastern countries are going to see a new expansion in the mining industry, of which mercury mining is a prime source of environmental pressure. The Mediterranean holds half of the world total trade in mercury, although the mining countries only account for 0.5% of the Earth's surface. Iron and steel production is likely to remain constant in the North while in the South and East it could increase from 8.5 million tonnes to more than 50 million tonnes in 2025. Cement production is likely to decline in the north and increase by more than 150% in the south. Production of petrochemicals, which is responsible for highly polluted sea waters from petroleum hydrocarbons is likely to remain constant in the north but stands chances of expanding activity in the southern oil producing countries, Egypt, Libya, Algeria and Syria. Although oil terminal accidents may be low, routine discharge into the sea of petroleum hydrocarbons combines to render the 40 or so oil related sites on the Mediterranean prime pollution sources (UNEP/WHO, 2000). The three highest oil pollution sources are by order of magnitude, Larymna Bay (Greece) industry discharging 940 tonnes of oil load into the sea annually as against 438 t/year discharged by a mixed industrial urban source in Banias (Syria) and 425 t/year by a mixed source in Haifa (Israel). In addition to petrochemicals some chemical industries such as ammonia and chlorine industries are shifting southwards. As a result of this change in composition of output together with an increase in the southern share of heavily polluting industries, environmental pressures linked to southern industrial production will rise in the future.

Although the Southern and Eastern Mediterranean Countries (SEMCs) look set to enter the pollution trap linked to industrial growth just as Spain and Portugal have, they also have an advantage against their predecessors, the so called 'late-industrialiser' advantage. Exemplified in South East Asian industrialisation in the 80's the advantage lies in replacing old polluting production techniques with environmentally sounder ones. For instance, production of steel by direct reduction instead of highly polluting charcoal furnaces, or production of paper by thermodynamic processing are two examples of technological upgrading that were used by the new Asian 'dragons'. Due to the existence of cleaner alternatives to old production technologies, late industrialisers in South East Asia show an 'ecological turning' point at much lower income levels in the economy.

- *Pollution-less growth*

The South East Asian example shows that environmental policies can bring considerable improvement when there is a strong pro-environmental commitment and moreover when the commitment is taken up in the long run. Generally the obstacle observed in environmental protection is that results may not be observable in the short run, however, financial costs may incur from the start. The commitment to protect the environment can be broken down in several key commitments and various additional factors that are country specific.

- *Preferring preventive to curative measures of pollution abatement*

Today, better knowledge of environmental thresholds makes compliance to standards less costly. It is calculated that for OECD countries, the cost to the industry of environmental compliance represents 1-2% of total industrial costs. Moreover, the longer the delay in introducing efficient production standards, the higher the costs of adopting new technology will be, because fixed costs in equipment will have been made. If new industries are allowed to invest in highly polluting technologies, the future political costs of enforcing environmental regulations will also be high and act as a deterrent to any government to enforce environmental regulations.

- *In SEMCs mobilisation against industrial pollution is low*

Despite the decreasing economic cost of environmental standards may be, it is still too high for SEMCs. As many as 40% of the firms in the Maghreb can not afford EU level environmental standards and break even.

In addition, in SEMCs there is low mobilisation over environmental issues in industrial production. The notions of best available techniques and best available practice, developed by the MAP have not yet found their way into the legislation or investment decisions. The exception of MEDPOL's tool to identify and assess opportunities for waste minimisation indicates that some progress has been achieved, although on a relatively small scale. Environmental legislation is often strict in words but weak in practice and lacks weight especially in the area of industrial monitoring and control. Public enterprises are no exception to environmental laxism, and hence send the wrong signal to the general public about the commitment to environmental protection. The existing lack of signals of non compliance and sanctions could be improved by strengthening laws on:

- Classification of industry according to the magnitude of its environmental impact
- Authorisation procedures appropriate in each class of industry
- Regulation and management of hazardous waste
- Evaluation of pollution caused by the industry

- *Lack of technological transfer to SEMCs blocks progress to environmentally sound practices*

Technological upgrading of production technologies presumes a solid knowledge on the sources of pollution, of existing technological options, of the costs of undertaking the transition and costs of no-action, all of which are beyond the capacities of SEMC economies today. Moreover, once such an informed choice has been made, the country must have access to environmentally sound technology, which is usually the property of firms in more advanced economies.

So far, direct foreign investment has yielded very low levels of technology transfer to SEMCs not least because the levels of direct foreign investment itself are extremely low for the whole region, amounting to approximately 2% of total EU direct foreign investment.

Transfer of 'green' technology, an item of Agenda 21, has caused controversy first over the legal / financial barriers to transfer (particularly patents) and, recently, it has been understood that facilitating transfers is not enough to make them happen. Those who support patent protection of northern technology, mainly the businesses that develop and own the technology, stress that besides being a piece of information, technology is in fact, a fundamental business commodity. With regards to patent protection business and industry therefore think that the international patent system is not a "constraint to the availability of environmentally sound technology". Rather, strong patent protection is necessary in order to encourage the research that will lead to the development of more environmentally sound technologies in the future. What is more often missing in developing countries, they stress, is the lack of a supportive infrastructure, including educational and technical skills, machinery and equipment, a recognition of the need for maintenance training and support. Overall this realisation has gained ground in the official revision of Chapter 34 of Agenda 21 on technology transfer, co-operation and capacity building. In actual conditions, effective transfer requires on-going effort by recipients to build the domestic technological structures that can hold new incoming technology, as well as long term partnerships. In other words, capacity building is a necessary condition for technological transfer.

- *Energy inefficiency at the root of SEMC industrial pollution*

High energy efficiency is at the base of environmentally sound industrial growth. Unless efficient ways of production and consumption of energy are in place, waste of energy adds to the pollution problem. Currently, old technologies result in wasteful energy consumption and production in SEMCs captured in the countries' high ratio of carbon emissions and energy use per unit of GNP. In all likelihood the demand for energy in SEMCs will rise dramatically, following population growth, increased revenues and industrial growth. The main risk comes from the slow speed of upgrading technologies which is due to the lack of finance and technical means in the region. According to estimates for the period 1990 to 2010 the total demand for energy in SEMCs will rise from 144 to 337 tonnes of petrol equivalent, out of which 40 % will be industrial demand. By 2025 the share of SEMCs in the Mediterranean total is likely to rise from 20% to 35%. The needs for electricity in SEMCs in particular are estimated to increase threefold between 1990 and 2020 and raise concerns about placing large central electricity plants on the crowded littoral.

The growth in energy use is a cause of environmental concern because the basic fuels used are petrol and gas, which are both highly polluting and responsible for global warming. However, given the importance of petrol to oil producing SEMCs and the marginal role of clean forms of energy as yet, the best realistic response for SEMCs consists in improving the efficiency of the petrol based economy and orienting energy use towards natural gas, which is relatively cleaner compared to petrol. There is a cluster of favourable conditions at present to promote natural gas, starting with Turkey's leadership in switching from petrol and lignite to gas, which offers considerable practical guidance on the costs and benefits of transition. In addition, a highly efficient new technology is linked to gas, and is gaining ground in Europe. Combined cycle co-generation technology can supply electricity very efficiently, and the technology is appropriate for small size plants which is desirable to avoid congestion of the Mediterranean littoral by large electricity plants.

Apart from lack of financial and technical means to upgrade energy technologies, what underlies the pollution problem in the whole of the Mediterranean is the bad design of energy prices. Keeping the price of fossil fuel artificially low by subsidies and low energy prices does not take into account the non renewable nature of the resource or the health and environmental costs associated to its use. Currently the EU, including Mediterranean EU countries spends US $10 billion per year on subsidies in the fossil fuel sector. By comparison, renewable energy only receives US $1.5 billion per year. Increasing energy prices on the other hand, gives the right signal to producers and consumers of energy to improve energy efficiency. Energy taxes are a direct way of encouraging the development of clean energy forms and protecting the environment e.g. France attempted to bring carbon dioxide down to 1990 levels by 2008, by increasing energy taxes. The EU has increased the share of energy taxes progressively from 5,2% of the total tax budget in 1993 to 11% today although the green tax reform leaves much to be desired still. Namely, the main failure of all EU countries that implemented green tax reforms has been to bring industry, the biggest energy consumer into the tax base.

- *Pollution from transport growth*

An indirect impact of industrial growth on the environment is linked to the growth of commercial and individual road transport. Individual road transport increases sharply for the range of $1500 to $3000 per capita in the Mediterranean, according to a Blue Plan study (Chatelus, 2000). SEMCs have a large potential for increased road transport, because of the current low levels compared to richer economies. In Syria, the car fleet expanded by 4.2 in six years following a partial liberalisation of car prices. In Lebanon where no real market obstacle has existed, the ratio of cars per inhabitants is on a par with Italy (500 cars per 1000 inhabitants, as against 48 in Morocco, 81 in Turkey). Commercial road transport is also on the rise everywhere in OECD countries. Between 1990 and 1997, 84% of the transport is carried out by road haul and only 7% by rail. The best response to the imminent increase in road transport is to plan public transport well in advance. Boat transport can be developed to substitute road haul over short distances along the coast. Urban public transport and roads can be developed. Transport taxes and tariffs can be used to control traffic. Recent reports by SEMCs on transport policies however, show that environmental concerns have yet to appear in the transport agenda (Chatelus, 2000).

- *Choosing the location of new industries*

Given the high number of existing hot-spots on the coastal areas, the accumulation of air pollution or pollution of water are more likely to reach points of irreversibility. Hence considerable effort must be made before any decisions for new investments in these areas, to assess the costs of increased concentration over the benefits in productivity. A policy of industrial zones may help to come up with new ways of sharing the costs of pollution abatement between the State, the industries and local communities the concerned actors, on encouraging technological transfer and controlling the size of the industrial zone.

- ***Free Trade***

- *An overview of the free trade process and the stakes for the Mediterranean environment and society*

European integration, Euro-Mediterranean partnership agreements and association agreements including EU-Turkish customs union are paving the way to a unified Euro-Mediterranean trade area, starting in 2010. At present 4 Mediterranean countries are part of the EU zone and another 4 are discussing accession; the Euro-Mediterranean partnership brings 15 EU countries and 12 South and Eastern Mediterranean countries together while association agreements exist between the EU and 5 Mediterranean non EU-member states.

The main aim of a Euro-Mediterranean free trade project is to accelerate liberalisation and economic restructuring, including industrial restructuring, to improve the competitiveness of SEMC economies. Studies indicate that there are good opportunities for SEMCs to restructure their industrial sector so as to produce higher added value goods whose demand is growing. The current performance of SEMC in exports of high added value products is weak given that they represent under 4% of the worlds total exports in high value added goods (Chatelus, 2000). A Moroccan study observes that with direct foreign investment (DFI) contributions and an active policy of sectorial restructuring, a Moroccan electronics and telecommunications industry could boost GNP by 13.81% and employment by +11.98% (Mahjoub, 2000). Likewise, the example of Mexican manufactures which rose from 25% to 90% of exports after NAFTA stand to show the potential of growth that may be realised within a Euro-Mediterranean free trade area.

In practice, the results of free trade are not always captured in growth figures but involve social hardship experienced as a consequence of dismantling some sectors and rising others. In addition, growth scars the environment, as is well witnessed in the environmental problems experienced in countries that joined the EU recently, Spain, Portugal, Greece. The issue of environmental degradation in the Mediterranean is all the more vital given that it is already a problem of large proportions: for example, Morocco has estimated the cost of environmental degradation at about 8% of GDP and the World Bank has valued the health impact of air and water pollution in the MENA region at US $9 billion.

The sectors for which the socio-environmental stakes of free trade are very high are SEMC traditional farming and SMEs. Under free trade, the revenue of farmers of protected crops which represents about 50% of total agricultural production, would fall by 50%-100%. For SMEs it is estimated that approximately 40% of the Maghreb SMEs could not break even if EU environmental standards were to be enforced.

From an environmental point of view, the stakes of dismantling the traditional farming sector are high. Replacing traditional farming with mechanised intensified monocultures will lead to a rapid depletion of soil's nutrients by efforts to increase output; reduced ability of water retention by the soil due to break up of soil structure in intensified tilling; pollution of surface and ground soils and waters by chemical fertilisers and pesticides; loss of local genetic variety as international high yield crops are introduced; loss of biodiversity and deteriorating landscape. As the case of Mexican maize farmers shows, marginal soils are not abandoned in the wake of liberalisation, but rather environmental pressures increase in the short run, due to increased poverty among small farmers. These negative effects are compiled by heavy unemployment in the traditional farming sector that makes up most of the jobs in SEMCs, increased income inequality among small and large farmers, dislocation, poverty and increased regional inequality between fertile irrigated plains and rainfed country.

The main risk of trade liberalisation for SEMC industry is high unemployment among SMEs that can not face up to the economic cost of higher environmental standards or higher competition. Environmental risks arise from the pollution that trade related growth will generate, adding to the enormous existing problems of managing industrial pollution. In addition, the possibility of direct foreign investment in heavily polluting sectors is considerable for SEMCs although in general the pollution haven risks have declined in the world overtime. The petrol refining sector and certain chemical industries are stagnating in the northern shore of the Mediterranean but are likely to experience increased growth in the south, hence there is a distinct opportunity for investing excess or new northern capacity to produce for southern markets. This possibility exists for other heavy industry sectors such as iron and steel or the mining sector, which are also stagnating in the north Mediterranean but are likely to increase in the SEMCs in the future.

On a macro-economic level, customs dismantling in the course of creating a free trade area may have direct repercussions on environmental expenditure in SEMCs. The large size of EU import tariffs as part of government revenue, it represents on average 17% of the total budget, creates a cash shortage which may be relieved by cutting down on water treatment, enforcement of environmental regulations etc.

- *Free trade and agriculture*

Talks to include farm products in the Euro-Mediterranean association agreements were not scheduled to start until 2000. The reason for this delay was that agriculture is recognised as a multifunctional sector by means of its role in keeping a high proportion of the population employed, keeping the country side populated and production spread over large surfaces, preserving the Mediterranean landscape, biodiversity and maintaining local traditions alive.

In reality, despite cheap labour in SEMC agriculture exports of SEMCs to the EU are not likely to expand significantly under free trade, and in any case represent only a small fraction of total SEMC output, which is increasingly absorbed by the home demand. The fruit and vegetables sector is the only one that is suited to international trade whereas the harsh conditions of the Mediterranean environment, namely aridity and poor soils, make it impossible for farmers of cereal and animal breeders to compete in exports with other areas in the world. In fact, SEMCs, apart from Turkey, are faced with a chronic food deficit in basic foods (cereal, oil, sugar, meat) and have only achieved food sufficiency in fruit and vegetables due to intensified farming techniques, at the expense of environmental degradation.

- *Environmental consequences of free trade in agricultural goods*

Lifting protection to cereal farming would have a number of environmental effects stemming from recourse to environmentally aggressive farming, in an effort to extract high competitive yields. Pressures on soils in the fertile irrigated parts of the country would rise creating problems of soil over-exploitation and rapid depletion of nutrients that sustain fertility. As a supplement to efforts for increased yields use of pesticides and fertilisers would rise with adverse effects for the environment e.g. pollution of aquifers as is seen in the extreme case of Gaza; or discharge of nutrients into the sea through erosion. Over irrigating soils is another form of environmental risk, as it leads to soil salinisation, a problem already present in many SEMCs as for instance in the Gaza strip or in the Haouz plain in Morocco. Lastly, deep tilling of soils increases erosion which depletes the top-most fertile soils. Notably all the above form a vicious circle in which losses in fertility lead to ever more intensified use of agro-inputs to compensate for it, leading to increasingly depleted soils and polluted environment etc.

Another dimension of the environmental problem is the loss of local genetic variety as international high yield varieties replace local ones. The magnitude of this problem is highly revealing in Greece where 95% of local crop varieties have been lost after half a century of transition to intensified farming. A Moroccan study warns against a possible alteration in habitats caused by clearance, over grazing and mechanised farming as opposed to traditional farming. According to the study, less than 1% of the area of the country is protected, whilst 30% of identified vertebrates and 41% of plants listed are rare or endangered species. The author stresses that liberalising markets could push SEMCs towards an “all export drive” to increase competitiveness which would take place to the detriment of biodiversity (Akesbi, 2000).

Studies on NAFTA and its effects on maize farming in Mexico indicate that liberalisation may not decrease pressures on marginal soils upon its introduction. Small Mexican farmers did not abandon maize farming on marginal lands despite the fall in price after NAFTA, to levels even below world levels. They maintained their activity to sustain themselves and their families, since they had little other employment alternative. Widespread poverty however had an adverse impact on the environment: environmentally friendly farming methods became too expensive for farmers. The Mexican example is applicable in the case of SEMC country side, where small size farming is typically the only employment opportunity. Liberalisation of prices would lead to up to 30% loss in revenue, as indicated by a study on Tunisia. The prospect of SEMC cereal farming catching up in productivity with the EU is illusory, even for the long run. Once the real cost of water is taken into account, SEMC cereal farming even in irrigated areas, cannot compete with EU production. Although liberalisation would not provide a solution to the low cereal yield that makes up for the food deficit in SEMCs, it would increase pressure on marginal soils from impoverished small farmers.

In contrast to the above, some studies indicate that liberalisation may have positive impacts on the environment, which suggests that a country specific approach should be followed to assess the impacts of liberalisation. Roux indicates that increased pressure on water from intensified agriculture may lead to higher water prices and increased rationalisation in water use (Roux, 2000). In the case of Egypt, free trade could lessen pressures on the environment as export crops (fruit and potatoes) are less water intensive than the crops they would replace (Sherif et al., 2000). In addition, export products are forced to comply with environmental standards set out by the EU, for instance cadmium thresholds, and this may act as a deterrent in the use of fertilisers and pesticides.

- *Social impacts of free trade of agricultural goods*

Liberalisation would aggravate the inequalities that separate small from large farmers and intensified, irrigated perimeters from rainfed parts of the country which give rise to the ‘dual structure’ in CSEM agriculture. The majority of small farmers are confronted by heavy constraints ranging from remoteness of commercial exchange points, exploitation by middle men and lack of employment opportunity other than farming, as the vast rural spaces of SEMC lack basic amenities (health care, schooling, electricity) that prevent any economic activity from taking root other than farming. As a consequence, studies predict that dismantling traditional farming would lead to migrations from rural areas to urban centres, adding to the existing social and environmental pressures from over-concentration.

- *Free trade and agricultural exports*

On the other hand, the gains for the economy, from hoped increases in the export of fruit and vegetables to the EU will not be significant. One reason is that SEMC production is being absorbed by the home demand and has little excess to trade internationally. Then the cheap labour that makes SEMC fruit and vegetables so competitive, cancels out against high transportation costs to Europe, as in the case of SEMC tomatoes. Moroccan produce initially has a cost difference of 30% however by the time it has been transported across the Mediterranean and overland to European consumers the difference has decreased to 5%. Extra SEMC exports in addition to these can not be absorbed by Europe because its demand has reached saturation levels.

- *Free trade impacts on the industrial sector and the environment*

"There can be no industrialisation without opening", is how expert opinion sums up the importance of forging new partnerships for industrial growth in SEMCs (Chatelus, 2000). However, the more successful is liberalisation, the higher the environmental impacts from increased growth. One way to counter them is by introducing environmentally sound techniques of production in new activity. 'Greening' the energy and transport sectors is also vital to avoid pollution associated with expanding demands for transport and energy that are to be expected in a growing economy. Finally the issue of monitoring polluting DFI's is still relevant, despite an overall decrease of pollution haven risks overtime, for this purpose, setting up records of DFI is a basic step.

- *Environmental impacts of increased scale of industrial activity*

The risks of pollution from an increased scale in economic activity which are imminent for SEMC due to population and revenue growth, will be further increased by growth brought by free trade. Namely, coastal crowding by new industrial plants, polluted effluent dumped into the Mediterranean sea, toxic waste disposal, air pollution from emission of particles will increase unconstrained by the present laxism in environmental standards. Moreover, contrary to the belief that growth pays to clean up the environment in the long run, growth cannot restore losses in biodiversity or some types of pollutants such as sulphur dioxide. In addition, industrial waste disposal is a problem that advanced Mediterranean industrial states, such as Israel, Spain, Portugal, repeatedly fail to escape, despite high income per capita.

'Clean' technologies: a potential benefit of free trade

Unavoidably, the more free trade succeeds the more crushing will the grip of growth be for the environment. One way to alleviate the conflict between free trade, growth and the environment is if foreign investment pulls in newer cleaner technologies of production. This is all the more so if South partnerships develop, to cater for specific South needs, e.g. manufactures of waste treatment systems, water sanitation, etc.

- *Free trade and pollution through transport and energy*

This 'technical' effect of free trade, has a big potential to alleviate pollution by industrial production but not transport or energy pollution. National, international and urban transport increase heavily with growth. In the case of North America it is estimated that due to NAFTA, transportation by van will increase 7-fold between 1995 and 2005. Moreover, that transportation of hazardous and other wastes is already beyond the capacity of the US and Canadian governments to supervise. SEMCs, being far less able to monitor compliance to environmental standards will experience higher pollution risks from movement of hazardous and other waste. By way of indication, in recently presented transport policies of SEMC states, environmental concerns have not been in the transport agenda in some cases. The growth in revenues and living standards together with growing needs for commercial transport however, produce a steep increase in car ownership and road transport and consequently increased carbon emissions and urban congestion.

In Morocco, for example, it has been shown (Jorio, 2000) that car purchase depends strongly on lowering of import tariffs on cars, while in Lebanon (El Kareh, 2000), where no real barrier to imports has existed the ratio of cars to inhabitants is on a par with Italy (500 cars per 1000 inhabitants, against 64 in Tunisia, 81 in Turkey, 52 in Algeria). The studies show that in the absence of an alternative policy on transport and land use planning, the SEMCs will see a great increase in road transport in the near future.

The energy sector will play a great role in magnifying the effects of pollution from growth, unless energy efficiency in SEMCs is improved. Currently, the ratio of pollution per unit of GDP is high, reflecting old and wasteful technologies of energy production and consumption. Given the high projected increase of SEMC energy demand from 20% to 35% of the total Mediterranean demand for energy, prospects of even higher increases make the upgrading of SEMC energy sector all the more vital an issue.

- *Polluting relocations: a risk of free trade*

The risks of relocation of polluting industries from advanced to developing economies are lower today than in the past, because technological advances have reduced the costs of compliance to environmental standards, hence the incentive to relocate is reduced. As pointed out in an OECD study, it costs 1-2% out of the total industry costs, to comply to environmental regulations today. In addition, DFI to SEMCs is currently very low and unless a dynamic North South partnership stimulates it, both DFI and pollution from DFI will remain a remote issue. Currently, SEMCs attract 2% of European DFI, and in terms of GNP, DFI generally represents under 1% of GNP.

However small, the risk of polluting relocation exists, particularly in the case of production by foreign investment aimed for the domestic market of a developing country where environmental standards are low. Moreover, there is the risk of South competition to attract DFI by environmental laxism e.g. in petrol refining, which can have grave consequences for pollution of the Mediterranean sea.

It is noteworthy that the role of NAFTA in Mexico's pollution problems, remains unknown, because of lack of data. The same will be true for the SEMC, unless effort is put in setting up a monitoring system of DFIs. The main questions that such a system needs to address are:

- Changes in the stock of DFI
- Are there increased environmental pressures due to relocations?
- Is there technology transfer?
- Do firms involved in DFIs use uniform standards across borders?
- Does concentration per sector grow?

- *Free trade and the macro-economy*

Customs dismantling has a large effect on environmental expenditure, because it cuts government revenue. Tariffs to EU imports represent on average 17% of total government revenue in SEMCs, while in Lebanon and Algeria the percentage is even higher (28% and 19% respectively). The repercussions may be a drop in expenditure on environmental projects such as waste water treatment, enforcing compliance with standards etc.

Another effect of lowering trade barriers will be to worsen the problem of trade deficits that already burdens SEMCs. The experience of accession to the EU of Northern Mediterranean states underlines the acuteness of the deficit effect, since they all experienced a worsening position as imports increased heavily over exports in the years following trade liberalisation. Moreover, the possibility to alleviate this problem by devaluating the exchange rate is not available to SEMCs as their production sectors depend on cheap imported inputs. Besides this, the burden of interest on foreign debt does not leave room for manoeuvre with the exchange rate.

- *The role of the Port State control*

The available data on pollutant loads (mainly oil spillage) showed that the ship-related marine pollution in ports presented a decreasing trend during the last decade of the 20th century, in spite of the increasing trend of the maritime transport. This result comes mainly from the progressive implementation of the relevant conventions by the ship-owners and the constant improvement of navigation aids, provide in the area. Also, the consciousness for the marine environment issues has steadily progressed among the Mediterranean ship's crews and passengers. Nevertheless, the battle for safer ships and cleaner seas never ends.

As the increasing trend of the maritime transport persists and is combined with a constant pressure for economic competence of the Mediterranean shipping activity, the alert in the field of ship-related pollution remains. Moreover, the water quality improvement in many port areas, resulting mainly from the installation of urban and industrial waste treatment plans, makes the ship-related pollution more "visible". Thus, a greater effort has to be done by the Port and City Authorities for the improvement of port facilities and other infrastructures protecting the environment.

During the first decades of the 21st century, in order to maintain the trends of improvement of the port receiving facilities (which where noticed in the Mediterranean from 1985 to 1995), a spectacular increase of the investment and operational costs is needed. Also, the education level and training of the involved personnel have to be raised. As the environmental quality is an issue of priority, at least for the inhabitants of the north Mediterranean countries, the cost of the ship-related pollution in ports has to be sheared between the ship-owners and the social partners who take benefits from shipping activities (tourism, ship-repairing etc). An international funding of the environmental protection infrastructure for the countries of the south Mediterranean could have benefit results at the basin scale.

The Mediterranean coasts receive yearly 200 million tourists. Thus, the finance of the environmental improvement could be considered as an investment in the tourism industry. Financing the port receiving facilities and other infrastructure related to the port environment protection, has three main targets:

- Makes the port attractive for people who use it or lives and works in the nearby area.
- Discharges the ships from wastes, avoiding their dumping at the open sea.
- Makes the navigation to and from the port more safe, avoiding collisions and grounding.

The legal instruments for the environmental protection in ports are strong enough to achieve their mission. Nevertheless, the appliance of the convention requires a severe control by the Port State Authorities. With very rare exceptions, in the Mediterranean ports a lot of supplementary effort has to be done in this domain, in order to arrive to a level of convention appliance comparable with this of the north European or USA ports.

In order to motivate and facilitate this effort, scientific research has to promoted, because is worth to note that there is:

- Lack of accurate information about port receiving facilities.
- Insufficient primary data from port pollution monitoring.
- Need for risk assessment research.
- Need for scientific research on specific issues (e.g. effects of the ship-related alien species introduction in ports) and comprehensive statistics.

The International Organisms could have a key role in the promotion of applied scientific research and the present report could be considered as a modest contribution towards this direction.

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• Overview of the applicability of burden sharing principles for land-based pollution reduction in the Mediterranean

The amended *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources and Activities* (LBS) represents a turning point in the effort manifested in the current version of the SAP by:

a) Linking the pollution abatement efforts to the concept of sustainable development of the region.

b) Extending the geographical area of concern to include 'the entire watershed area within the territories of the riparian states draining into the Mediterranean Sea, the waters on the landward side of territorial boundaries, as well as communicating brackish waters, marshes, coastal lagoons and ground water'.

c) Securing the financing from the GEF and executing specific country reports on existing hot-spots along with a *Transboundary Diagnostic Analysis* (hereafter TDA) to identify main pressures, driving forces and institutional responses to the problem at hand (UNEP, 2001).

Up to now, and within the above-mentioned SAP, the measures to achieve cleanup have taken the form of uniform abatement targets, that is, a proposal to all signatories to undertake the same percentage of abatement within specific timetables and for specific pollutants. For example, a target of 50% reduction over a period of 10 years in the inputs into the Mediterranean of BOD, nutrients and suspended solids from industrial installations is proposed. Similar targets are proposed for municipal sewage, urban solid waste, air pollution, agricultural runoff, toxic, persistent and bioaccumulable substances etc. (UNEP, 1999).

However, accruing evidence from the performance record of international environmental agreements, consistently fosters the idea that uniform (or 'flat') rates of abatement are neither a fair, nor an equitable basis for international co-operation and national self-commitments. Documentation of negotiations in environmental agreements abounds with remarks and statements invoking the principles of fairness and equity that should guide the international relations among sovereign states.

Calling upon the principles of fairness and justice in international environmental agreements means supporting a scheme of <u>shared</u> but <u>differentiated</u> responsibility in achieving common abatement targets. This fact, in spite of the already mentioned proposed uniform targets for the Mediterranean, is plainly described in the SAP:

> "The SAP is addressed to all Contracting Parties and proposes common objectives. However, it is evident that the implementation of the proposed activities should take into account the state of the environment of each country. The timing for targets and for activities may also be different for different countries, taking into account e.g. of the capacity to adapt and reconvert existing installations, the economic capacity and the need for development." (UNEP, 1999).

This chapter addresses the issue of burden sharing in the context of the Barcelona Convention for the Protection of Mediterranean in an effort to draft a framework in support of future negotiations.[7] The line of reasoning relies heavily on the existing literature concerning the BS controversies within the FCCC and its Kyoto Protocol. The objective is, therefore, to explore the possibility of transferring and/or adapting existing knowledge regarding burden sharing to the issue of Mediterranean marine pollution. To this purpose, a number of relevant tasks have to be accomplished, such as:

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[7] For a similar work in relation to the Baltic Sea, see Torvanger and Godal 1999

a) Systematise existing knowledge referring to burden sharing in international environmental agreements.

b) Draw conclusions as to the nature of the link between burden sharing patterns and stability of international agreements.

c) Assess the suitability and desirability of burden sharing in the Mediterranean within the framework of the Barcelona Convention.

d) Design possible burden sharing schemes applicable to the Mediterranean context.

e) Assess their efficiency and effectiveness and draw conclusions for future research.

For reasons of data availability and comparability with existing work (Kayal, 2002), the discussion is focused on BOD discharges at the hot spots by industrial point sources. On this basis, a number of specific cases illustrate the consequences for Mediterranean countries of burden sharing under different rules.

o ***Fairness and equity in multilateral environmental agreements (MEA)***

Transnational commons, on a regional or planetary level, are shared resources of outmost importance for the functioning of world societies and economies. It is beyond doubt, that a number of such shared resources are today in danger from uncontrolled and inefficient use. Recognising this fact, sovereign national states express their willingness to co-ordinate their actions and therefore to enter a Hobbesian state of restricted autonomy through international environmental agreements.

Environmental agreements to protect the global commons are the historically inevitable upshot caused by the interplay of two factors:

- The character of global commons as open access resources.
- The non-binding nature of international law

A typical environmental agreement concentrates on the triple of: efficiency, distribution and implementation while being guided by the legal principle that prompts national states to use the resources on their territory in a manner non harmful to other states and therefore inflicts the sovereignty principle with a degree of responsibility and care. The dogma of *community of interest* takes this further by recognising the interconnection of ecosystems and the duties of stewardship derived there from.

Geopolitical realities, the inherent uncertainty in costs and benefits of environmental protection, along with a typical asymmetry of information among the bargaining states lead nevertheless to situations where success depends purely on concentrating on a simplified agenda ('focal point'):

> "More impressive, perhaps, is the remarkable frequency with which long negotiations over complicated quantitative formulas or ad hoc shares in some costs or benefits converge ultimately on something as crudely simple as equal shares, shares proportionate to some common magnitude (gross national product, population, foreign-exchange deficit, and so forth), or the shares agreed on in some previous but logically irrelevant negotiation".

The effectiveness and stability of international environmental agreements usually rest on a long list of specific (endogenous or exogenous to the negotiation process) features, both of the country itself as well as the international setting, the problem itself, economic and technological transfers, the timing and linkage with other treaties, the implementation rules etc. (Weiss and Jakobson, 1998, Milich and Varady, 1998, IVM, 1999). Therefore, in the context of international environmental agreements, it is to date not possible to be conclusive as to the main ingredients of a successful treaty. The use of focal points in negotiations, as described by Schelling above, seems to capture an essential prerequisite of success as does the linkage issue, highlighted in recent game theoretic literature on this topic (IPCC 2001).

What does all this tells us about the motivation of national states in the process of environmental negotiations? A starting point is to recognise the reality of self-interested states and the pursuit of national interests. Given this fact, the next step is to realise a certain degree of deviation from this line towards a behaviour based on normative considerations concerning (distributive) justice and fairness in environmental affairs (e.g. Ringius et al 2002). Still, the question remains:

- *Why are MEA bound to produce holdouts?*

The root of the problem lies in the non-appropriateable nature of the ensuing benefits from protection and is facilitated, if not prompted, by a central characteristic of environmental agreements, the *sequential acceptance* (Swanson, 1991). By sequential acceptance we mean the possibility offered by the majority of international agreements to non-signatory countries to enter the agreement on a latter stage. This in turn springs directly from the *contractual* nature of international law requiring that each state finds the term of the agreement to be in its own interest before entering the convention.

Consequently, incentives to holdout are generated either from a rent seeking behaviour (opportunistic strategy) or from perceiving the terms offered an unfair. Unfortunately, in both cases the incentives not to participate increase with the number of countries that already participate while at the same time the value of waiting for a latter accession increases: free-riding on others' expenses becomes the rational option. To mitigate this pervasive problem, international regimes are forced to address the heart of the problem: The variety of economic, social, cultural and geographic features of individual states leading to a variety of national aspirations, capabilities and responsibilities.

Principles of fairness and equity enter the scene of environmental negotiations through the accentuation of differences in a wide spectrum of dimensions. In a world with identical partners, the problem of fee riding in international environmental agreements, though not eliminated, would be minimised. In such a case, the attainment of a full co-operative outcome would not prove difficult, given the identity of both cost and benefit functions for each state respective the environmental protection of a global resource (Barret, 1992). In spite (or because of!) intense globalisation of economic and social structures, states are far from being homogeneous. Even in this case, a symmetric (or flat rate) solution to the burden-sharing problem would prove advantageous from the point of view of easiness of negotiation (Parson and Zeckhauser, 1995) but hardly equitable: 'equal' burdens on unequal states creates unequal burdens! [8]

A logical consequence of the differential nature of states would be their continuous differentiation on a cardinal scale, on the basis of the chosen criterion. In practice, the road usually followed is to group states in distinctive categories and treat them accordingly. To differentiate in groups, one needs both a criterion and a threshold value delimiting each group's range. In practice though the threshold is seldom made explicit. The grouping in 'Annex 1 countries', economies in transition, and 'non-Annex 1 countries' within the climate change negotiations is the most prominent example met in MEA. In a regional setting, as for example in the Mediterranean region, an obvious categorisation can be based on the North-South dimension. The last two examples are ideal in demonstrating that a grouping can be based on more that one criterion simultaneously: in this case on responsibility, capability and

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[8] For a strong statement of the idea of easiness of flat rates, see FCCC/AGBM/1996/7 (1996), p. 4: 'Some Parties have spoken in favour of "flat rate reduction" objective, because of the difficulty they perceive in negotiating a differentiated regime. They also see such an approach as equitable, by virtue of the fact that progress is measured against a Party's own national emissions in the base year.'

need.[9] On similar lines, Claussen and McNeilly (1998) propose a threefold grouping based on the criteria: Standard of living, responsibility and opportunity. Countries that score high on all three dimensions are grouped as 'must act now' countries, those on the opposite spectrum (low score on all dimensions) are the 'could act now' countries, where countries in between are those that 'should act now but differently'.

An interesting, and important for the scope of this study, differentiation can be conceived on the base of hydro-geopolitical sub-units, a scheme proposed in UNEP, 2000. This last differentiation is based on the criteria of: 1) population change, 2) water resources per capita, and 3) water demand per capita. Although not directly related to the problem of burden sharing, this approach clearly demonstrates the possible range and variety that state grouping might demonstrate.

For differentiation to serve as a premise of successful environmental negotiations, it has to be perceived as 'objective' (Swanson, 2001). If countries were treated differently, this would enable the widest possible range of untenable and insupportable positions to be taken. Therefore, and in order to reduce the incentive for future rent seeking, differentiation should be allowed only in exceptional cases and at the same time be based exclusively on factors exogenous to the bargaining process. Swanson (2001) proposes to base the differentiation of states on such exogenous factors as physical location and development status.

Once the differentiation of states on the basis of agreed criteria and thresholds is in place, the next step is to treat groups differently while at the same time allow for the same rules to be applied within each group. While this procedure limits substantially the degrees of freedom in negotiations, it by no means generates a dominant choice among the conceivable international environmental regimes. Consensus on matters of differentiation is a necessary, though not sufficient, condition for achieving agreement also on matters of burden sharing. Once a state has accepted a certain differentiation, it is forced, at least logically, to adhere to the same principles in the subsequent rounds about burden sharing. Such a consensus would restore the uniformity of individual states and contribute towards solving the problem created by the contractual nature of international law and the sequential character of multilateral bargaining. Therefore, in the process of achieving a consensus on the necessary allocation of the overall mitigation efforts, the notions of equity and fairness play a dominant role, since: 'the use of different criteria to share the cost of a given emission target crucially affects the size of the equilibrium coalitions, that is the number and identity of signatory countries.' (IPCC 2001)

- *General principles of fairness and equity as applied in MEA*

A common accepted definition of fairness is 'being impartial'. According to Ringius et al. (2002), 'principles of fairness' are 'generally acknowledged norms of fairness that have traditionally been seen as valid across a wide range of issue areas and at different levels – from interpersonal to international relations." As such, principles of fairness constitute 'a soft core of accepted ideas on fairness', invoked but also (tacitly or explicitly) applied in environmental negotiations. Nevertheless, pinpointing the fairness principles behind negotiations, proposals and approved texts, is a difficult task. Agarwal and Narain (1999) are sceptic about the role of fairness principles used in international environmental agreements, pleading for the use of certain amount of 'pragmatic adhocism'. Yanagi et al. (2001) depict and bring to fore the tacitly applied fairness principles in the Kyoto protocol by regressing a number of basic national indicators as independent variables on the emission reduction rates (agreed in the Protocol) as depended variable. Their conclusion is suggestive: 'Of all the proposals on burden-sharing rules during the AGBM [Ad Hoc Group on the Berlin Mandate, see section III, MS] process, only GDP per capita was taken into consideration. Many of the proposals were not chosen for the determination of the Kyoto protocol because they were beneficial for some countries but at the same time disadvantageous for others.'

[9] These notions are discussed in details in the next section.

The question immediately posed is this: Are there any widely shared principles of fairness and equity among sovereign states? If yes, do we have to abandon the idea of self-interested states? We skip the esoterics of the latter question by assuming that in the context of international environmental agreements self-interest and fairness are strong complements with fairness acting as: 1) a soft constraint on self-interest, or 2) a decision premise when self-interest provided no guidance (ECN/CICERO, 2001).

We opt to embark our discussion on general principles of fairness by looking first at rights. The obvious reason is the logical sequence between rights (and duties) and the corresponding ideas on fairness: Ideas on fairness are based on logically previous notions of rights and duties. On the other hand, in order to be realised in everyday life, rights and duties demand the establishment of the corresponding principles of fairness. Within our context, rights are categorised in two major groups:

1) Inalienable human rights
2) Acquired rights

By inalienable human rights we mean a set of rights deemed necessary in order for basic needs to be fulfilled. In the context of environmental disputes and within the frame of sustainable development, basic needs are operationally defined in an absolute manner by comparison to a threshold of material wealth per capita already achieved by industrialised countries. A direct version of this idea is to translate the basic needs into amounts of pollutants emitted and call these amounts ‘subsistence’ pollution. All emissions, over and above the ‘subsistence’ ones are characterised as ‘luxury’ emissions. The right to the fulfilment of basic needs for LDC would then translate into an amount of emission allowance for present and future use. We call this a vertical approach to inalienable human rights. Another way to make the approach of inalienable human rights operational consists in the calculation of ‘equal emission entitlements’ for all citizens of the world. This horizontal version of the general principle consists in dividing the overall emissions target by the relevant population [10] in order to define the emissions entitlement per capita.

The notion of acquired rights has a long tradition in international (mostly economic) disputes. By acquired rights we mean rights to a resource acquired *de facto* through traditional and legitimate exercise of economic or other kind of activity. Past emissions of air pollutants during a period of non-management is a typical example of acquired rights by the corresponding polluting sources. The norm of ‘grandfathering’ in allocating emission allowances is a prominent practical illustration of this principle. An economic argument in favour of its application is the fact that acquired rights are logically exercised through sunk investments in the use of the resource. A second, legal argument is based on the inappropriateness of assigning liability for pollution to persons, firms or nations acting in a period *ante* the regulation of the polluting activity. The principle of ‘foreseeability and liability’ thus defined should therefore prevent environmental agreements from penalising past emissions (Ridgley, 1996).

Rights manifest themselves in norms about fairness and equity, usually grouped into: allocation-based, process-based, and output-based principles. Table 7.1 gives an overview of the main fairness and equity principles discussed so far in the literature for global warming policy. In this Table fairness principles are traced from general criteria to basic definitions of equity to general operational rules to specific operational rules for designing burden sharing schemes. The resulted typology uses both costs and benefits of emissions reductions for differentiation as well as causes and the consequences of actions. This is a rather complex framework for analysing the corresponding pro and contras of the possible burden sharing rules so let us proceed in simplifying matters. We follow in this respect the categorisation proposed in ECN/CICERO 2001 and reproduced here in Table 7.2. From all logically possible stands on fairness three basic notions are distilled: equality, equity and exemption.

[10] The world in the case of FCCC, the Mediterranean countries in the case of MAB

The notion of equality implies equal obligations to all states involved in the negotiations. It is logical to constraint equality to relative equality as it is done in agreements using a flat rate of abatement as expression of (relative) equality among the states. Equality in this sense is an allocation-based criterion expressed in Table 7.1 by the principle of sovereignty.

We mentioned earlier that applying the equality principle in a strongly differentiated world is essentially contradictory. When this is generally accepted, equity replaces equality in environmental negotiations and the focus is shifted to a number of important dimensions of fairness, this referring to both the focus of each principle as well as the specific object to be shared. Under these aspects, Table 7.2 generates four general principles of fairness.

Table 7.1 *- Alternative equity criteria for global warming policy (Source: Rose et al., 1998)*

Criterion	Basic definition	General operational rule	Operational rule for CO2 permits
Allocation-based			
Sovereignty	All nations have an equal right to pollute and to be protected from pollution	Cut back emissions in a – proportional manner across all nations	Distribute permits in proportion to emissions
Equalitarian	All people have an equal right to pollute or to be protected from pollution	Allow emissions in proportion to population	Distribute permits in proportion to population
Ability to pay	Mitigation costs should vary directly with national economic well-being	Equalise abatement costs across nations (gross cost of abatement as proportion of GDP equal for each nation) [a]	Distribute permits to equalise abatement costs (gross cost of abatement as proportion of GDP equal for each nation) [a]
Outcome based			
Horizontal	All nations should be treated equally	Equalise net welfare change across nations (net gain or loss as proportion of GDP equal for each nation) [b]	Distribute permits to equalise net welfare change (net gain or loss as proportion of GDP equal for each nation) [b]
Vertical	Welfare gains should vary inversely with national economic well-being; welfare losses should vary directly with GDP	Progressively share net welfare change across nations (net gains (loss) proportions inversely (directly) correlated with per capita GDP) [b]	Progressively distribute permits (net gain (loss) proportions inversely (directly) correlated with per capita GDP) [b]
Compensation	No nation should be made worse off	Compensate net losing nations	Distribute permits so no nation suffers a net loss of welfare

Process based			
Rawls' Maximin	The welfare of the worst-off nations should be maximised.	Maximise the net benefit to the poorest nations	Distribute largest proportion of net welfare gain to poorest nations
Consensus	The international negotiation process is fair	Seek a political solution promoting stability	Distribute permits in a manner that satisfies the (power weighted) majority of nations
Market justice	The market is fair	Make greater use of markets	Distribute permits to highest bidder

[a] Gross cost refers to abatement cost only and does not include benefits or permit transactions

[b] Net welfare change (gain or loss) is equal to the sum of mitigation benefits – abatement costs + permit sales revenues – permit purchase costs

Table 7.2 *- Key principles of equity*

Focus on:	Object to be distributed	
	Costs (obligations)	Benefits (goods)
Cause of pollution	Guilt: responsibility for causing the problem	Contribution to solving the problem
Consequences for actors	Capacity: ability to pay	Need

Source: ECN/CICERO 2001

When the costs of cleanup are to be distributed and the focus is on the cause of the problem at hand, then 'guilt' is a logical equity principle to be applied. Moreover, it is also a straightforward application of the generally accepted *Polluters Pay Principle* (PPP), enabling a cost-effective solution to the burden-sharing problem. On the other hand, the extent of 'guilt' is a controversial subject, as it can be based on past (cumulative) emissions, on current emissions or on future emissions, or a combination of these. Past emissions ('natural debt'), besides practical problems in quantifying them, raise also the problem of foreseeability and liability mentioned earlier. 'Guilt' is invoked widely in international environmental negotiations, mostly in its version of future emissions.

When the costs of cleanup are to be distributed and the focus is on the consequences for actors, then 'capacity' is the logical equity principle to be applied. Capacity is also an allocation-based principle, with a straightforward meaning as ability to pay. Wealthy countries are expected to contribute relatively more than less developed countries.

Concentrating on the benefits of abatement and the cause of he problem leads us to the contribution principle. Countries that contribute more towards cleanup should bear fewer burdens proportionally to those contributing less. In order to fit into a burden sharing formula, this principle should be interpreted as referring to past contributions to cleanup. Giving credit for past cleanup is nevertheless subjected to analogous critic with applying past emissions in the 'guilt' principle.

The last and most interesting case in Table 7.2 is crystallised in the principle of 'need'. We have here the direct reflection of the inalienable rights doctrine, according to which all individuals should be granted the pollution permits needed in order to secure 'basic needs'. There are numerous variants of the principle of 'need'. The Rawlsian maximum principle, implying that the welfare of the worst-off nations should be maximised, is one, as it is the Annex 1 – Non Annex 1 distinction in the Kyoto Protocol. In a more refined way, Swanson 2001 translates the notion of basic needs to the amount of resource use required by a LDC in order to catch up with DCs. By comparing the development trajectory followed by DCs before constraints on the use of the resource were enacted (the non-management period) with the one followed after the regulatory regime was enacted (joint management period), Swanson depicts both actual and baseline behaviour. In a given period, the difference between actual and baseline behaviour represent 'the difference between choices countries (i.e. LDCs, MS) are making in any given period and those that they would have made in that period *if they had been allowed to choose as those countries* (i.e. DCs, MS) *had done in the period before*'. This gap is the quantification in terms of resource use of emission allowances within a burden-sharing rule based on the principle of need.

But even equity rules are not always fair! In cases when the countries in question vary considerably the application of any of the above equity rules on the poorest ones could impose an extreme burden on them. In this case, exemption is the only fair rule the world community would opt for.

A conclusion at this point is that a number of fairness principles, alone or combined, can be applied to derive burden-sharing rules in the context of an environmental agreement. On a first level, these principles are conditioned on the degree of differentiation among countries (see Table 7.3): Non-differentiated countries, that is countries whose variance is below a certain threshold x, are expected to rely on (relative) equality of burden. Differentiated countries exhibiting a variance between x and y should on the contrary opt for the application of some equity principle while countries at the outmost spectrum of the line (variance >y) are seen as exemptions to the rules.

Table 7.3 *- Domains of different principles of fairness*

Principle	Domain
Equality	Relevant differences < x
Equity	x < relevant differences < y
Exemption	Relevant differences > y

Source; Ringius et al. (2002)

- *Operational rules and indicators of differentiation*

Within the framework of environmental negotiations, operational rules (or *formulas*) and indicators of burden sharing supply signatories with the possibility to access practical consequences of proposals and recognise problems of implementation. In this sense, indicators provide the metrics needed to 'help Parties take decisions on how the commitments adopted […] might differ. Indicators for differentiation thus have a specific purpose that distinguishes them from other indicators, such as indicators for sustainable development or other environmental indicators' (FCCC/AGBM/1996/7, 1996). As seen in Table 7.1, operational rules or formulas derive from general fairness principles in a codified manner while generating specific algorithms for the allocation of burden between signatories. A summary of the main formulas and indicators of differentiation proposed so far in the literature is presented in Table 7.4. In Box 1, the indicators used in the implementation of burden sharing rules are listed.

Table 7.4 makes explicit that extracting formulas from general fairness principles is not always a straightforward exercise. Practically all rules can be cast in more than one fashion, depending on specific operational meanings given to responsibility, ability to pay, well-being, welfare etc. In general, the following points should be kept in mind when attempting the implementation of burden sharing rules:

- ✓ Formulas for burden sharing rules are conceived either as single, undifferentiated concepts or as composite concepts based on more than one principle. A multitude of simple concepts can in principle implement the same formula while on the other hand more than one combination of principles have been proposed. To enhance transparency, all rules that support one indicator should be made public. More authors agree that for reasons of negotiation tactics simple formulas are usually preferred over composite ones, although the latter capture a bigger part of the differentiation parameters while manifesting the interplay among them.
- ✓ Composing individual concepts and principles into a formula presupposes some sort of weighting. This in turn can take the form of a full-blown multicriteria decision analysis or be tackled with simpler weighting procedures.
- ✓ In order to avoid 'double counting' and handle computational needs, rules that are dominated by some other rule may be eliminated without loosing information. For example, all tree rules of responsibility, ability to pay and need lead practically to the same progressive allocation of burden towards wealthy countries. If outcome rather than process is what matters in the negotiations then a country should be indifferent between

applying any of the three equity principles above in isolation and opting for some combination of them.

- ✓ Responsibility can take many forms: Present, past or future total emissions, emissions per capita, emissions per GDP, emissions per territory. It might be more accurate (though impractical) to define responsibility not on the base of emissions but on the base of concentrations or effects (damages). Alternatively, responsibility can be derived from status and economic power. Last but not least, responsibility can be cast in terms of the Polluter Pays Principle. In all cases, ambiguity in the definition of responsibility is raised by the choice of the substance emitted, the time frame (or 'budget period') and the inclusion of auxiliary effects (Ridgley 1996).
- ✓ Needs are based on fundamental rights, especially the right to develop. Standard of living is synonymous with developmental needs and rights.
- ✓ Ability to pay is based on some notion of wealth and/or welfare. Both in theory and in practice these two concepts may diverge (Sen 1979). From an economist' point of view, the Net National Product (NNP) comes closest to a correct welfare measure, as it measures 'the (hypothetical) constant level of consumption for an infinite time horizon that would give the same total utility as the feasible future optimal consumption path' (Aaheim 1995, p. 11). Nevertheless, GDP per capita is most frequently used as wealth indicator, optimally adjusted for national differences in purchasing power (as Purchasing Power Parity).
- ✓ A relevant question at this stage is how to define and quantify the cost of achieving the allocated burden. Two approaches are here available: Top-down and bottom-up approaches: The first represents a macroeconomic (partial or general equilibrium) approach whereby abatement costs are calculated on the basis of equations modeling the supply and demand balance in individual sectors. In this approach all direct and indirect effects of the control measures are evaluated in a market-clearing process. On the other hand, bottom-up approaches rely on (detailed) engineering cost accounting of individual technologies and measures; no indirect, market-clearing processes are here taken into account. As a consequence, bottom-up approaches overestimate national abatement cost of a policy, assuming of course that technological substitution feasibilities are taken into account in top-down approaches (Aaheim 1995, Christensen et al 1998). In burden sharing proposals, welfare loss (consumption forgone) is accordingly measured in a top-down approach by the relation of abatement costs to GDP.
- ✓ Taking opportunities for cost-effective emission reductions into account represents a practical way to approximate least-cost solutions while at the same time stay within the principle of equity.
- ✓ An important feature of the proposals is the issue of convergence to the same per capita emissions. Convergence can be combined with other principles so as to enhance their political appeal.
- ✓ It is understandable that the allocation of benefits derived from abatement does not usually appear in burden sharing rules. The difficulties in quantifying even approximately global benefits from climate change are notorious and therefore they can hardly serve as a basis for practical algorithms of burden sharing.

Table 7.4 - *Overview of principles, rules, formulas and indicators of differentiation*

General Principle or Criterion	Specific principle	Operational rule	Formula
Equality	Sovereignty	Allow discharges in a proportional manner to acquired rights	$D_i^T = D^T (D_i^0 / D^0)$
	Equalitarian	Allow discharges in proportion to population	$D_i^T = D^T (P_i / P)$
	Horizontal	Allow discharges so as to equalise net welfare change across countries	$D_i^T : C_i / GDP_i = a \quad \forall i$
Equity	Responsibility (Guilt)	Cut back discharges in relation to (past, current or future) discharges (total, per capita, or per GDP)	$D_i^T = D_i^0 - [(D_i^0 / D^0)(D^0 - D^T)]$ or $D_i^T = D_i^0 - [(d_i / Sd_i)(D^0 - D^T)]$
	Capacity (Ability to Pay)	Allow discharges so as to equalise abatement costs across countries	$D_i^T : C_i = (GDP_i / SGDP) SC \quad \forall i$
	Need (Rights)	Allow discharges in relation to developmental status and, accordingly, in relation to basic needs to be fulfilled	$D_i^T = (d_i / Sd_i) D^T$ or $D_i^T = (d_i^* / Sd^*) D^T$ or $D_i^T = (dP_i / SdP) D^T$ or $D_i^T = (SGDP^* / GDP_i^*) D^T$
	Opportunities	Allow discharges proportionally to cost-effective options available to countries	$D_i^T = (Sd^* / d_i^*) D^T$ or $D_i^T = (S_i / SS) D^T$ $D_i^T = (E_i / SE) D^T$ $D_i^T = (D_i^{exp}{}_i / SD^{exp}) D^T$
	Vertical	Cut back discharges proportionally with national economic well-being	$D_i^T = (SGDP^* / GDP_i^*) D^T$ or $D_i^T = (SI^* / I_i^*) D^T$
	Need, responsibility, capacity	Cut back discharges in relation to developmental status, to (past, current or future) discharges (total, per capita, or per GDP), and so as to equalise abatement costs across countries	$D_i^T = A [x(d^*/d^\wedge) y(GDP^*/GDP^\wedge) z(d/d^{\wedge\wedge})]$
	Responsibility, capacity	Cut back discharges in relation to (past, current or future) discharges (total, per capita, or per GDP), and so as to equalise abatement costs across countries	$D_i^T = A [y(GDP^*/GDP^\wedge) z(d/d^{\wedge\wedge})]$
	Rawl's maximum	Cut back discharges so as to maximise net benefits (minimise net cost) to the poorest countries	$D_i^T : Min (C_i / GDP_i) \quad \forall GDP_i < k$
	Convergence	Cut back discharges in relation to developmental status while converging to the same level of discharges per capita	$d_{i\,t} = d_{i\,0}^{(T-t)/T} \times d_T^{\,t/T}$
Market justice	**Pareto optimality**	Cut back discharges so as to compensate net loosing countries	$C_i < 0 \quad \forall i$
	Cost-effectiveness	Cut back discharges so as to equalise marginal costs to all countries	$D_i^T : MC_1 = MC_2 = \ldots MC_n$

Legend: See Box 1. Source: Adapted from ECN/CICERO (2001), FCCC/AGBM/1996/7 (1996), Ringius et al. (2002)

Box 1: Indicators used in operational burden sharing formulas

P = Total population of signatories
P_i = Population of country i
dP_i = Population growth of country i
D^o = Total discharges in the base year
D_i^o =Discharges of country i in the base year
D^T =Total discharges in the final year
D_i^T =Discharges of country i in the final year
D_i^{exp} = Discharges of country i resulting from production of goods for export relative to total discharges
d_i = Discharges per capita of country i
d_i* = Discharges per GDP of country i
d^ = Average d*
d^^ = Average d
$d_{i,\ t}$ = Discharges per capita of country i in t years from now
GDP_i = Gross Domestic Product of country i
GDP_i* = GDP per capita of country i
GDP^ = Average GDP
I_i* = Income per capita of country i
S_i = Share of polluting sectors in GDP for country i
E_i = Share of polluting sectors to employment for country i
C_i =Abatement cost of country i
MC_i =Marginal abatement cost of country i
A = parameter for adjusting total reductions to overall target
a, k =constants
x, y, z = weights adding to 1

- *Issues and choices in the design of a shared responsibility regime*

Let us at this point summarise the essential elements necessary for the design of a practical and coherent burden-sharing rule. First, decide on an overall objective and the year to be achieved. Second, decide on the unit of the burden-sharing rules: nations or states? Second, establish a criterion for differentiation and the range of variance for individual units. The criterion should, if possible, be exogenous to the burden-sharing rule in order to qualify as 'objective' (Swanson, 2001). The rule for grouping units can be decided either in relation to the average or on the basis of units' standard deviation from the mean. The last method should be preferred in cases where units exhibit a skewed distribution of differentiation. It is helpful at this stage to check if units are clustered in groups that satisfy more than one criterion. In this case, burden-sharing rules can be simplified considerably. Third, define the baseline for abatement and translate the overall target either as limitation or reduction target.[11]

Looking for a feasible set of options is our next concern. On the one hand, feasibility of burden-sharing rules is enhanced by separating efficiency and equity principles clearly. This may seem irrational, as both the magnitude and the allocation of total abatement cost depend crucially on the fairness principle applied for burden sharing. As a matter of fact, the more the outcome of negotiations is perceived by signatories as fair and equitable, the more stable and enlarge the coalition of countries joining the scheme is going to be. Accordingly, the overall target is achieved with a lower cost (IPCC, 2001). On the other hand, as the

[11] We remind the reader that a limitation target refers to limiting the anticipated future growth of emissions under the baseline scenario. As such, limitation may well imply positive growth of emissions in the final year. A reduction target on the contrary starts from the base year's emissions and calculates a desired level of reduction from this in the final year. A reduction target implies therefore always an absolute reduction in emissions.

experience from proposals put forward within the *Berlin Mandate*-process shows, least-cost solutions among heterogeneous countries are hard to defend.[12] A compromise solution, bringing equity and efficiency considerations closer while preserving a high political appeal lies with the equity principle of opportunities (see previous section). The gap between proportional and efficient burden for a country i (its 'efficiency claim' E_i) can be easily assessed as:

$$E_i = D_i^T - D_i^{least\ cost} \qquad \text{with } SE_i = 0$$

where D_i^T represents the emissions allocated to a country I and $D_i^{least\ cost}$ the emissions the same country should have been allocated under a least-cost solution.

Most burden sharing rules consider multiple equity principles. Different equity principles though may result in similar substantive implications, which bring us back to the issue of dominance of some principles over others. Multiplicity of equity principles applied should therefore be treated carefully and always checked for (practical) reluctance of some principles.

Practical formulas demand appropriate indicators in order to be applicable. Where indexes rather than indicators are used, they should exhibit certain properties: simplicity, transparency, and data availability.

Distributional neutrality is often advocated for domestic environmental policies but by definition this cannot be the case in non-proportional burden-sharing rules. Moreover, equitable rules are necessarily progressive and as such they tend to improve existing distribution of wealth among the participating countries. Measurement of wealth inequality before and after the implementation of a burden-sharing scheme should in principle be taken *inter alia* into account in evaluating relevant proposals. Here again (see Atkinson 1998), an 'equity claim' E_i*for country i can be assessed as the difference between emissions allowance for country i under an equitable and fair scheme (D_i^T) and the one under a proportional burden-sharing rule ($D_i^{uniform}$):

$$E^* = D_i^T - D_i^{uniform} \qquad \text{with } SE_i^* = 0$$

o ***Burden sharing within the Barcelona Convention***

Projected or anticipated future plans for sharing the burden in the Mediterranean will depend on the physical milieu and the socio-economic geography of the region, including the institutional and financial environment created by international organisations and donors. We proceed by reviewing briefly the main factors liable to constraint and delimit the potential for co-operation in an effort to calibrate as good as possible the transferability of insights gained in the climate change arena.

Mediterranean is a regional sea with a valuable ecological and cultural heritage of mankind. On the other hand, Mediterranean is a highly vulnerable region due to the combined effect of climate change and economic transformation (Conti and Segre, 1998; EEA, 1999; Vallega, 1999; UNEP/MAP/PAP, 2001; UNEP, 1999b and 2001b). Basic information on the Mediterranean basin include (Pavasovic, 1996):

- An almost enclosed sea, with turnover period 80-90 years, weak tides, deficient hydrological balance, low biological productivity and estimated sea-level rise 12-18 cm by 2025.
- A total surface area of 8 million km^2 and a 45,000 km coastline out of which 17,000 km islands coastline. Only 40% of the coast can be deemed 'useful' for human activities and settlements.
- A total of 21 countries and one autonomous territory (Gaza Cis-Jordan entity)

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[12] Or even to implement. See N. Zealand's proposal in FCCC/AGBM/1996/7 (1996)

- A projected population growth from 417.4 mills in 2000 to over 520 mills in 2025 of which an ever-growing proportion will be settling at the coast.
- A share of 33% in world tourism amounting to 147 mills visitors in 1990
- A share of 80% of pollution originated from land-based sources
- Good quality of open sea but a total of 117 priority hot spots and 51 sensitive areas at the coast, located in semi-enclosed gulfs and bays near important harbours. Economic cost of pollution remedial actions estimated at 3,518 millions USD.
- A proportion of 33% of population not yet served by municipal wastewater treatment.
- A trade regime fully protected in the non-European Union countries of the Mediterranean but at the same time under strong pressure for liberalization within (inter alia) the Euro-Mediterranean Partnership.

The evidence so far indicates a coastal and marine environment under heavy pressure from anthropogenic, land-based sources of pollution - especially tourism and urbanization of coastal cities - threatening its ecological integrity and socio-economic prospects. The problem becomes more intriguing when one realises the multiplicity of starting points of the states involved, as it shown in Table 7.5. Economic capabilities, as shown by GDP per capita, ranged in 2000 between 852 and 28,959 USD, whereby responsibility, measured in annual BOD discharges to coastal hot spots, range between 0 and 213,160 tonnes! Furthermore, 'needs' measured tentatively by population, ranged in 2000 between 0.4 and 67.9 millions. More refined measures and suitable grouping of the signatories may reduce the existing variance and contribute towards a feasible burden sharing agreement. For example, if a clear correlation existed between discharges of BOD and per capita wealth in the Mediterranean, as it is the case for greenhouse gases and GDP per capita on a world scale, a straightforward fairness principle combining responsibility and capabilities would immediately be available for negotiations.

Unfortunately, as the reader may easily verify from the relevant data in Table 7.6, this is not the case. By using the differentiation strategy proposed by Claussen and McNeilly (1998), we may even try to detect some regularity by pooling together three criteria/principles: those of responsibility, standard of living and opportunities.

Table 7.5 - *Grouping of Mediterranean countries (Claussen and McNeilly 1998)*

Score*	**Countries**
All high ('must act now')	Malta
Mixed ('should act now, but differently')	Algeria, Bosnia H, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Morocco, Slovenia, Syria, Turkey
All low ('could act now')	Albania, Libya, Turkey

* Responsibility on the basis of current industrial BOD discharges. Standard of living on the basis of GDP per capita (2000, revisited for PPP). Opportunities based on BOD discharges per unit of GDP.

Table 7.5 is instructive for it reveals the fact that differentiation of burden could in principle be applied only to 14 Mediterranean countries exhibiting a mixed scoring on the relevant criteria while 3 countries could be exempted from any burden at all. Within the differentiated group though the variance of central characteristics are still considerable. Malta is the only country falling into the category of 'must act now' countries, a factor that complicated things as far as political feasibility of the proposed scheme is concerned.

Table 7.6 - *A Profile of the Signatory Countries to the Barcelona Convention*

Countries	Area (1000xhectares)	Population (2000, mill)	Annual population growth (2000-15)	GDP (2000, $ bill)	GDP (2000, PPP, $ bill)	GDP p.c.(2000, $)	GDP p.c. (2000, PPP, $)	Industry share in GDP (%, 1999)	FDI (1999, in $1995 mill)	Exports (2000, % of GDP)	Manufacturing exports (as % of merchandise exports, 2000)	Human devel. Index (2000)	Hot spots (no.)	BOD discharges at hot spots (tons/year)	Annual BOD discharges p.c.(ton/year/mill)	Discharges per GDP (ton/years/bill $)	Abatement cost ($ mill)
Albania	2,875	3.1	0.600	3.8	12.0	863	3,506	26.0	51.7	19	82	0.733	3	540	174	142	44
Algeria	238,174	30.3	1.500	53.3	161.3	1,564	5,308	50.7	8.8	42	2	0.697	8	113,590	3,749	2,131	180
Bosnia H.	5,113	3.9	0.284	6.2		1,594		26.7	0.0				5	4,710	1,208	760	126
Croatia	5,654	4.7	-0.044	19.0	35.4	4,102	8,091	32.0	1,777.3	45	73	0.809	11	4,100	872	216	269
Cyprus	925	0.8	0.700	8.7	15.8	13,247	20,824	28.0	82.5	45	52	0.883	9	190	238	22	7
Egypt	100,145	67.9	1.500	98.7	232.5	1,191	3,635	31.5	1,344.4	16	37	0.642	5	213,160	3,139	2,160	163
France	55,150	59.2	0.300	1,294.3	1,426.6	28,959	24,223	23.3	49,001.3	29	81	0.928	5	390	7	0	200
Greece	13,196	10.6	-0.100	112.6	174.3	12,652	16,501	20.4		20	50	0.885	9	8,960	845	80	195
Israel	2,106	6.0	1.600	110.4	125.5	16,438	20,131		2,982.0	40	94	0.896	5	5,150	858	47	237
Italy	30,134	57.5	-0.300	1,074.0	1,363.0	20,174	23,626	26.2	8,560.6	28	88	0.913	15	27,140	472	25	750
Lebanon	1,040	3.5	1.300	16.5	18.6	8,577	4,308	26.5	315.5	13		0.755	6	4,090	1,169	248	336
Libya	175,954	5.3	1.900	11.7				59.0				0.773	5	2,160	408	185	117
Malta	32	0.4	0.400	3.6	6.7	9,000	17,273	33.0	0.0	103	97	0.875	3	8,430	21,075	2,342	48
Morocco	44,655	29.9	1.500	33.3	101.8	1,359	3,546	32.7	3.4	31	64	0.602	4	5,180	173	156	97
Slovenia	2,025	2.0	-0.200	18.1	34.5	11,128	17,367	38.4	228.6	59	90	0.879	5	450	225	25	36
Spain	50,599	39.9	-0.200	558.6	768.5	16,989	19,472	27.6	11,762.9	30	78	0.913	5	*	0	0	0
Syria	18,518	16.2	2.400	17.0	57.6	1,238	3,556	22.0	114.8	38	8	0.691	4	580	36	34	169
Tunisia	16,361	9.5	1.200	19.5	60.8	2,390	6,363	28.1	441.6	44	77	0.722	4	7,250	763	372	365
Turkey	77,482	66.7	1.100	199.9	455.3	2,965	6,974	24.3	988.1	24	81	0.742	6	3,200	48	16	179
TOTAL	**840,138**	**417.4**		**3,659.2**	**5,050.2**				**77,663.5**				**117**	**409,270**			**3,518**
AVERAGE		**22.0**	**0.813**	**192.6**	**297.1**	**8,579**	**12,041**	**30.9**		**37**	**66**	**0.797**		**21,541**	**1,866**	**472**	**185**
S. D.		**24.4**		**373.9**	**456.7**	**8,172**	**7,994**					**0.103**		**53,014**	**4,761**	**795**	**171**
Median		**9.5**		**19.5**	**101.8**	**6,340**	**8,091**					**0.791**		**4,100**	**472**	**142**	**169**
Maximum		**67.9**		**1,294.3**	**1,426.6**	**28,959**	**24,223**					**0.928**		**113,590**	**21,075**	**2,342**	**750**
Minimum		**0.4**		**3.6**	**6.7**	**863**	**3,506**					**0.602**		**0**	**0**	**0**	**0**

* Data not provided it is considered O in the Calculation

The role of the Barcelona Convention and its Protocols in successfully implementing a policy of differentiated responsibility in the Mediterranean should by now be seen in context of the unique and highly differentiated profiles of the signatories to the Convention. What we have learned from the history of Mediterranean environmental protection and the MAP (Haas, 1990; Musu, 1997; Skjaerseth, 1996; Vallega, 1995, 1996) points to an important generalization: In terms of geographical coverage and effectiveness of the Barcelona Convention, '..the Mediterranean states did not find it difficult to adopt measures to prevent or mitigate marine pollution, while they have been quite reluctant to protect the environment through actions in the coastal area, involving land settlements and ecosystems' (Vallega, 1996). This points to the inherent difficulty of accepting burdens, which affect the most precious developmental asset of coastal Mediterranean countries: the coast itself. The goal of gaining consensus on what constitutes a fair and equitable sharing rule is thus from the very beginning beset with considerable difficulties.

- *Some possible rules for burden sharing within the Barcelona Convention*

In this section we apply seven of the formulas presented in Table 7.4 (six simple and one synthetic) in order to quantify and illustrate a number of burden sharing rules for the Mediterranean countries. The exercise is conducted with a considerable lack of empirical data. The data problem will eventually be solved when the Baseline Budgets of Pollutants Releases (see UNEP, 2002) are in place. For the time being, and for the needs of the present paper, we rely on estimates of BOD discharges and clean up costs used in a similar work by Kayal (2002). We follow the Strategic Action Programme of MAP/MEDPOL (UNEP, 1999a) in fixing the overall abatement target as 50% reduction of nutrients and suspended solids over a period of 10 years. Accordingly, we set 2002 as base year and 2012 as terminal year.

Without any loss of generality, one may also assume that in the future, as far as new industrial installations are concerned, Mediterranean countries will be able to enforce article 6 of LBS Protocol, as amended in 1996, where an authorization process is foreseen. In conjunction with article 5, the authorization process prescribes the elimination – through 'technology forcing' - of pollution deriving from land-based sources and activities. In our applications/examples therefore one may interpret the resulting regional allocation of burdens in order to achieve the 50% overall reduction target as referring only to existing (old) installations.

Rule 1: Sovereignty

When burdens are allocated according to acquired rights (principle of sovereignty), all countries will be discharging at the final year (D_i^T) the same percentage of wastewater that they were discharging in the base year according to the formula: $D_i^T = D^T (D_i^o / D^o)$. Table 7.7 shows the application of this rule for Mediterranean with countries ranked in descending order of welfare losses.

Since the rule respects the relative discharge levels among the countries, all countries will have to reduce discharges by the same percentage (50%). The outcome thus of applying the sovereignty rule is tantamount to the result of the uniform (flat rate) rule. It is of no surprise that, as the rule clearly assumes and Table 7.7 reveals, no correlation exists between the allocated burden (measured either in tonnes per year or as welfare loss) and individual country characteristics such as standard of living, capacity, needs etc.

***Table 7.7** - Application of sovereignty rule*

Countries	GDP (2000, $ mill)	BOD discharges at hot spots (tons/year)	Discharges under 50% rule	Discharges under sover rule	Clean up cost mill (sover)	Welfare losses (% of GDP)
Egypt	98,700	213,160	106,580	106,580	40,946.7	0.4149
Algeria	53,300	113,590	56,795	56,795	11,807.4	0.2215
Bosnia H.	6,200	4,710	2,355	2,355	117.8	0.0190
Malta	3,600	8,430	4,215	4,215	66.0	0.0183
Croatia	19,000	4,100	2,050	2,050	91.8	0.0048
Greece	112,600	8,960	4,480	4,480	436.6	0.0039
Italy	1,074,000	27,140	13,570	13,570	3,962.7	0.0037
Tunisia	19,500	7,250	3,625	3,625	45.2	0.0023
Albania	3,800	540	270	270	5.6	0.0015
Libya	11,700	2,160	1,080	1,080	13.4	0.0011
Lebanon	16,500	4,090	2,045	2,045	12.8	0.0008
Morocco	33,300	5,180	2,590	2,590	24.3	0.0007
Slovenia	18,100	450	225	225	7.5	0.0004
Cyprus	8,700	190	95	95	3.0	0.0003
Israel	110,400	5,150	2,575	2,575	24.0	0.0002
Syria	17,000	580	290	290	1.8	0.0001
Turkey	199,900	3,200	1,600	1,600	10.0	0.0001
France	1,294,300	390	195	195	3.0	0.0000
Spain	558,600	*	0	0	0.0	0.0000
TOTAL	**3,659,200**	**409,270**	**204,635**	**204,635**	**57,579.6**	**0.6937**

* Data not provided it is considered 0 in the calculation

Rule 2: Egalitarian

When burdens are allocated according to the egalitarian rule, countries are allowed to discharge in proportion (and only in proportion!) to their share in total population of the region: $D_i^T = D^T (P_i / P)$. Table 7.8 shows the application of this rule for Mediterranean countries.

The first thing to notice is the fact that countries are divided now into those that undertake reductions (Algeria, Bosnia, Croatia, Egypt, Greece, Israel, Lebanon, Malta, and Tunisia) and those that are allowed to raise their discharges (Albania, Cyprus, France, Italy, Libya, Morocco, Slovenia, Spain, Syria, and Turkey). Since the rule respects the relative position of countries with regard to total population of the region, populous countries will have to reduce discharges proportionally less than less populous ones. Nevertheless, advantages due to a high population may be cancelled out because of a very bad starting point, as the case of Egypt illustrates. In Figure 7.1 the relative welfare losses of those countries committed to discharge reduction are shown.

Table 7.8 *- Application of egalitarian rule*

Countries	Population (2000, mill)	BOD discharges at hot spots (tons/year)	Discharges under egali rule	% Change in discharges	Clean up cost (mill)	Welfare loss	Equity claim
Albania	3.1	540	1,520	181	-	-	1,250
Algeria	30.3	113,590	14,855	-87	425.7	0.00799	-41,940
Bosnia H.	3.9	4,710	1,912	-59	29.9	0.00483	-443
Croatia	4.7	4,100	2,304	-44	19.6	0.00103	254
Cyprus	0.8	190	392	106	-	-	297
Egypt	67.9	213,160	33,289	-84	769.4	0.00780	-73,291
France	59.2	390	29,023	7,342	-	-	28,828
Greece	10.6	8,960	5,197	-42	41.0	0.00036	717
Israel	6.0	5,150	2,942	-43	9.4	0.00009	367
Italy	57.5	27,140	28,190	4	-	-	14,620
Lebanon	3.5	4,090	1,716	-58	9.8	0.00059	-329
Libya	5.3	2,160	2,598	20	-	-	1,518
Malta	0.4	8,430	196	-98	35.6	0.00988	-4,019
Morocco	29.9	5,180	14,659	183	-	-	12,069
Slovenia	2.0	450	981	118	-	-	756
Spain	39.9	*	19,561		0.0	-	19,561
Syria	16.2	580	7,942	1,269	-	-	7,652
Tunisia	9.5	7,250	4,657	-36	10.9	0.00056	1,032
Turkey	66.7	3,200	32,700	922	-	-	31,100
TOTAL	**417.4**	**409,270**	**204,635**		**1,351.4**	**0.03312**	**0**

* Data not provided it is considered 0 in the calculation

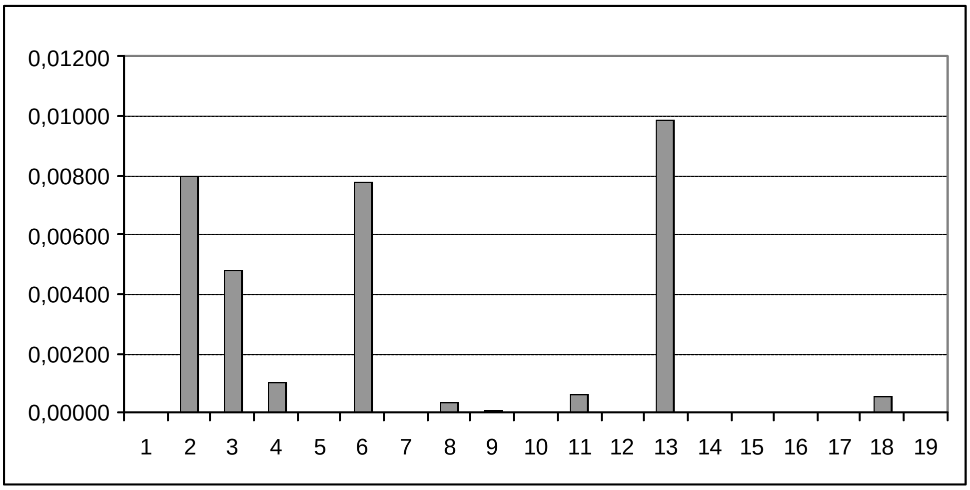

Figure 7.1 *- Welfare losses of egalitarian rule (%of GDP)*

Rule 3: Responsibility

When burdens are allocated according to each party' responsibility, countries will participate in the overall reduction target in relation to their discharges in the base year. Among the variants of this rule we choose to apply here two versions: One that bases responsibility on aggregated current discharges: $D_i^T = D_i^0 - [(D_i^0 / D^0)(D^o - D^T)]$ and one that bases responsibility on per capita current discharges: $D_i^T = D_i^0 - [(d_i / Sd_i)(D^o - D^T)]$.

Tables 7.9 and 7.10 show the application of this rule for Mediterranean countries.

Table 7.9 *- Application of responsibility rule: aggregated version*

Countries	BOD discharges at hot spots (tons/year)	Discharges under aggregated responsibility	Changes compared to base year (in %)
Albania	540	270	50
Algeria	113,590	56,795	50
Bosnia H.	4,710	2,355	50
Croatia	4,100	2,050	50
Cyprus	190	95	50
Egypt	213,160	106,580	50
France	390	195	50
Greece	8,960	4,480	50
Israel	5,150	2,575	50
Italy	27,140	13,570	50
Lebanon	4,090	2,045	50
Libya	2,160	1,080	50
Malta	8,430	4,215	50
Morocco	5,180	2,590	50
Slovenia	450	225	50
Spain	*		
Syria	580	290	50
Tunisia	7,250	3,625	50
Turkey	3,200	1,600	50
TOTAL	**409,270**	**204,635.00**	

* Data not provided it is considered 0 in the calculation

Surprisingly enough, discharges under the aggregated responsibility rule are uniformly reduced at the rate of overall reduction (50%). To understand why this happens, let us rearrange the terms of the formula: $D_i^0 [(D^o - D^T)/ D^0] = D_i^0 - D_i^T$. Since the term in brackets is constant and equal to the overall abatement target, the formula fixes the reduction burden of country i (the right hand term) as a constant percentage (=50% in our case) of individual discharges in the base year. The outcome thus of applying the (aggregated) responsibility is tantamount to applying both the uniform reduction and the sovereignty rules!

In the per capita version of responsibility things look different: A group of countries (the 'receptors': Algeria, Egypt, France, Greece, Israel, Italy, Morocco, Syria, Tunisia and Turkey) reduce their discharges by an average of 5,796 tonnes but taken together they continue to discharge to the Mediterranean a total of 326,366 tonnes, that is 121,731 tonnes over and above the agreed overall reduction target (=204,635 tonnes). The other group of countries (the 'donors': Albania, Bosnia, Croatia, Cyprus, Lebanon, Libya, Malta, and Slovenia) is obliged under the rule not only to abate 100% their own discharges but also to contribute to the abatement of the surplus of 121,731 tonnes. In other words, a number of (financial and/or technological) transfers have to take place from countries to countries in order to achieve the overall target of 50% reduction. Though the modalities of such transfers cannot be detailed here, it is obvious that the overall cost of achieving the 50% reduction is crucially depended on the allocation of transfers. In Table 7.10, the cost of the clean up for countries with transfer obligation is calculated by adding together the (domestic) cost of 100% abatement and the average cost of the transfer cost. [13]

***Table 7.10** - Application of responsibility rule: per capita version*

Countries	GDP (2000, $ mill)	Annual BOD discharges p.c. (ton/year/mill)	Discharges under per capita responsibility	% Change in discharges	Clean up cost (mills)	Welfare loss	Equity claim
Albania	3,800	174	-465	-186.17	14.4	0.0038	-735
Algeria	53,300	3,749	91,955	-19.05	93.3	0.0018	35,160
Bosnia H.	6,200	1,208	-2,260	-147.98	67.9	0.0110	-4,615
Croatia	19,000	872	-934	-122.79	52.1	0.0027	-2,984
Cyprus	8,700	238	-1,181	-721.39	17.2	0.0020	-1,276
Egypt	98,700	3,139	195,043	-8.50	77.5	0.0008	88,463
France	1,294,300	7	352	-9.75	0.8	0.0000	157
Greece	112,600	845	4,082	-54.44	53.1	0.0005	-398
Israel	110,400	858	196	-96.19	21.2	0.0002	-2,379
Italy	1,074,000	472	24,416	-10.04	29.4	0.0000	10,846
Lebanon	16,500	1,169	-2,654	-164.89	37.4	0.0023	-4,699
Libya	11,700	408	-192	-108.89	18.9	0.0016	-1,272
Malta	3,600	21,075	-113,197	-1,442.78	915.0	0.2542	-117,412
Morocco	33,300	173	4,180	-19.30	4.3	0.0001	1,590
Slovenia	18,100	225	-849	-288.56	19.6	0.0011	-1,074
Spain	558,600	*	0		0.0	0.0000	0
Syria	17,000	36	373	-35.62	2.0	0.0001	83
Tunisia	19,500	763	2,846	-60.75	18.6	0.0010	-779
Turkey	199,900	48	2,923	-8.66	1.2	0.0000	1,323
TOTAL	**3,659,200**	**35,458**	**204,635**		**1,443.8**	**0.2830**	**0**

* Data not provided it is considered 0 in the calculation

In Figure 7.2 the relative welfare losses of countries undertaking discharge reductions are shown.

[13] Average cost of transfer for 'donors' = Discharge abatement to be achieved abroad times the average cost of abating a tonne of BOD in the 'receptors'

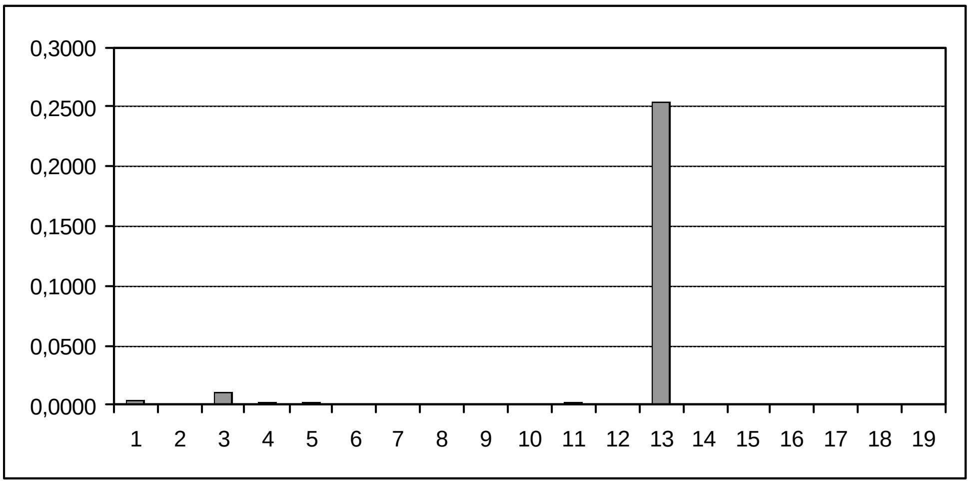

Figure 7.2 - *Welfare losses: per capita responsibility (%of GDP)*

Rule 4: Capacity (ability to pay)

When burdens are allocated according to each party' ability to pay, countries will participate in the overall reduction target in relation to their per capita GDP:

$D_i^T = D_i^0 – [(GDP_i*/ SGDP_i*) (D^0 – D^T)]$. Table 7.11 summarises the results.

Table 7.11 - *Application of ability to pay*

* Data not provided it is considered 0 in the calculation

Countries	**GDP p.c. (2000, $)**	**BOD discharges at hot spots (tons/year)**	**Reduction**	**Discharges under ability to pay**	**%Change in discharges**	**Clean up cost**	**Welfare loss**	**Equity claim**
Albania	863	540	1,144	-604	-211.8	14.8	0.0039	-874
Algeria	1,564	113,590	2,072	111,518	-1.8	8.9	0.0002	54,723
Bosnia H.	1,594	4,710	2,112	2,598	-44.8	22.6	0.0036	243
Croatia	4,102	4,100	5,436	-1,336	-132.6	53.7	0.0028	-3,386
Cyprus	13,247	190	17,554	-17,364	-9,238.7	123.8	0.0142	-17,459
Egypt	1,191	213,160	1,578	211,582	-0.7	6.8	0.0001	105,002
France	28,959	390	38,374	-37,984	-9,839.4	261.2	0.0002	-38,179
Greece	12,652	8,960	16,765	-7,805	-187.1	97.6	0.0009	-12,285
Israel	16,438	5,150	21,782	-16,632	-423.0	22.0	0.0002	-19,207
Italy	20,174	27,140	26,733	407	-98.5	289.0	0.0003	-13,163
Lebanon	8,577	4,090	11,365	-7,275	-277.9	65.3	0.0040	-9,320
Libya		2,160	0	2,160	0.0	0.0	0.0000	1,080
Malta	9,000	8,430	11,926	-3,496	-141.5	59.7	0.0166	-7,711
Morocco	1,359	5,180	1,801	3,379	-34.8	7.7	0.0002	789
Slovenia	11,128	450	14,746	-14,296	-3,276.8	108.3	0.0060	-14,521
Spain	16,989	*	22,512	-22,512		150.1	0.0003	-22,512
Syria	1,238	580	1,640	-1,060	-282.8	12.7	0.0007	-1,350
Tunisia	2,390	7,250	3,167	4,083	-43.7	13.4	0.0007	458
Turkey	2,965	3,200	3,929	-729	-122.8	18.9	0.0001	-2,329
TOTAL	**154,430**	**409,270**	**204,635**	**204,635**		**1336.3**	**0.0549**	**0**

Here again, a group of countries (the 'receptors': Algeria, Bosnia, Egypt, Italy, Libya, Morocco, and Tunisia) reduce their discharges by an average of 6,244 tonnes but taken together they continue to discharge to the Mediterranean a total of 335,727 tonnes, that is, 131,092 tonnes over and above the agreed overall reduction target (=204,635 tonnes). The other group of countries (the 'donors': Albania, Croatia, Cyprus, France, Greece, Israel, Lebanon, Malta, Slovenia, Spain, Syria and Turkey) is obliged under the rule not only to abate 100% their own discharges but also to contribute to the abatement of the surplus of 131,092 tonnes. The necessary transfers and the total cost of achieving the 50% reduction target obey the same logic as in the previous rule. In Figure 7.3 the allocation of welfare losses is presented.

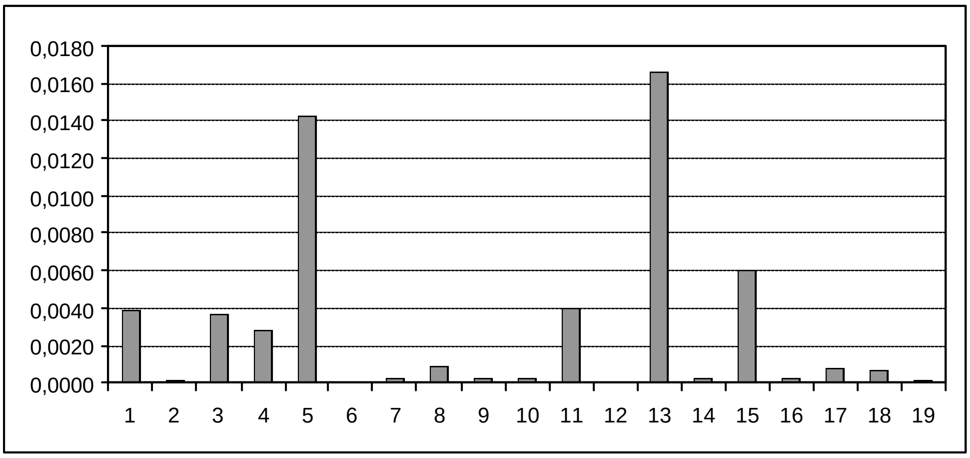

Figure 7.3 *- Welfare losses: capacity to pay (%of GDP)*

Rule 5: Need (Rights)

Based on the principle of (developmental) 'need', a burden-sharing rule becomes quite versatile, since it can be linked to a number of indicators such as: population growth, GDP, per capita discharges etc. We choose here to illustrate two versions: one that bases need on the rate of population growth: $D_i^T = (dP_i / SdP)\ D^T$ and another one that bases need on GDP per capital: $D_i^T = D_i^0 - [(GDP_i^*/ SGDP^*)\ (D^0 - D^T)]$.

In Table 7.12 the results of applying the principle of 'need', based on the rate of population growth, is presented. In this case three groups of countries are formed: A group of countries (the 'privileged': Albania, Cyprus, France, Israel, Lebanon, Libya, Morocco, Syria, Tunisia and Turkey) are allowed to raise their discharges by 138,265 tonnes (from 28,730 tonnes to 166,995 tonnes) or 481%. Four countries (the 'receptors': Algeria, Bosnia, Egypt and Malta) undertake the reduction of 291,064 tonnes or 85% of their own discharges. In order to achieve the desired level of 204,635 tonnes, the third group of countries (the 'donors': Croatia, Greece, Italy, Slovenia and Spain) are obliged to reduce their own discharges to zero and, additionally, to finance the abatement of 11,186 tonnes of discharges at the 'receptors'. In Figure 7.4 the allocation of welfare losses is presented.

Table 7.12 *- Application of need based on population growth*

Countries	Annual population growth (2000-15)	BOD discharges at hot spots (tons/year)	Discharges under need1	% Change in discharges	Clean up cost	Welfare loss	Equity claim
Albania	0.600	540	7,952	1,372.6	-		7,682
Algeria	1.500	113,590	19,880	-82.5	404.08	0.0076	-36,915
Bosnia H.	0.284	4,710	3,764	-20.1	10.12	0.0016	1,409

Countries	Annual population growth (2000-15)	BOD discharges at hot spots (tons/year)	Discharges under need1	% Change in discharges	Clean up cost	Welfare loss	Equity claim
Croatia	-0.044	4,100	-583	-114.2	50.85	0.0027	-2,633
Cyprus	0.700	190	9,277	4,782.9	-		9,182
Egypt	1.500	213,160	19,880	-90.7	826.76	0.0084	-86,700
France	0.300	390	3,976	919.5	-		3,781
Greece	-0.100	8,960	-1,325	-114.8	111.35	0.0010	-5,805
Israel	1.600	5,150	21,206	311.8	-		18,631
Italy	-0.300	27,140	-3,976	-114.7	334.64	0.0003	-17,546
Lebanon	1.300	4,090	17,230	321.3	-		15,185
Libya	1.900	2,160	25,182	1,065.8	-		24,102
Malta	0.400	8,430	5,301	-37.1	13.51	0.0038	1,086
Morocco	1.500	5,180	19,880	283.8	-		17,290
Slovenia	-0.200	450	-2,651	-689.0	40.49	0.0022	-2,876
Spain	-0.200	*	-2,651		-		-2,651
Syria	2.400	580	31,809	5,384.2	-		31,519
Tunisia	1.200	7,250	15,904	119.4	-		12,279
Turkey	1.100	3,200	14,579	355.6	-		12,979
TOTAL	**15.440**	**409,270**	**204,635**		**1,791.79**	**0.0276**	**0**

* Data not provided it is considered 0 in the calculation

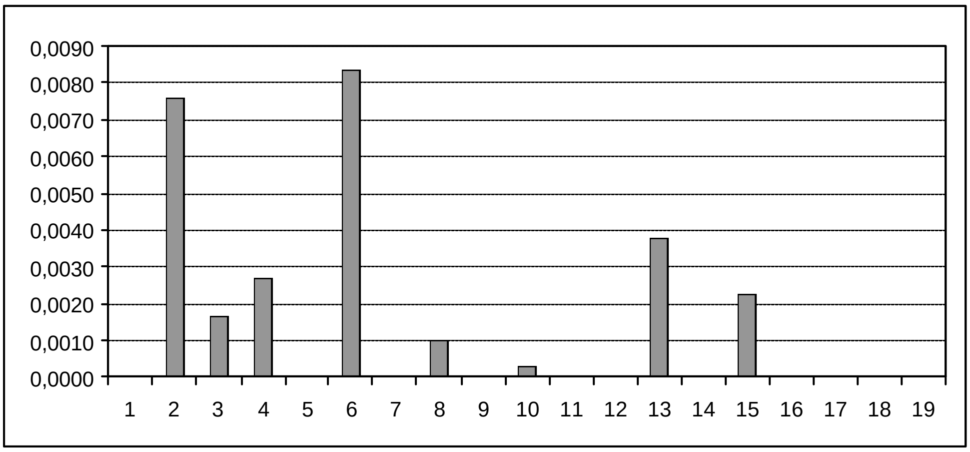

Figure 7.4 *- Welfare losses: Need based on rate of population growth*

A straightforward version of ‘need’ is based on the participation of countries in the overall target in proportion to their relative GDP per capita. The results are shown in Table 7.13. We note that the same results are produced by the application of the vertical equity rule, with the formation of three groups again: A group of countries (the ‘receptors’: Algeria, Bosnia, Egypt, Italy, Morocco and Tunisia) undertake the reduction of 37,463 tonnes or 90% of their own discharges. In order to achieve the desired level of 204,635 tonnes, the second group of countries (the ‘donors’: Albania, Croatia, Cyprus, France, Greece, Israel, Lebanon, Malta, Slovenia, Spain, Syria and Turkey) are obliged to reduce their own discharges to zero and, additionally, to finance the abatement of 131,092 tonnes of discharges at the ‘receptors’. The third group consists solely by Libya who neither reduces nor augments its discharges.

Table 7.13 *- Application of need based on per capita GDP*

Countries	GDP p.c. (2000, $)	BOD discharges at hot spots (tons/year)	Discharges under need2	% Change in discharges	Clean up cost	Welfare loss	Equity claim
Albania	863	540	-604	-212	14.68	0.0039	-874
Algeria	1,564	113,590	111,518	-2	8.94	0.0002	54,723
Bosnia H.	1,594	4,710	2,598	-45	22.60	0.0036	243
Croatia	4,102	4,100	-1,336	-133	53.39	0.0028	-3,386
Cyprus	13,247	190	-17,364	-9239	119.73	0.0138	-17,459
Egypt	1,191	213,160	211,582	-1	6.75	0.0001	105,002
France	28,959	390	-37,984	-9839	252.41	0.0002	-38,179
Greece	12,652	8,960	-7,805	-187	147.82	0.0013	-12,285
Israel	16,438	5,150	-16,632	-423	129.02	0.0012	-19,207
Italy	20,174	27,140	407	-98	289.00	0.0003	-13,163
Lebanon	8,577	4,090	-7,275	-278	63.61	0.0039	-9,320
Libya		2,160	2,160	0	3.50	0.0003	1,080
Malta	9,000	8,430	-3,496	-141	58.89	0.0164	-7,711
Morocco	1,359	5,180	3,379	-35	7.72	0.0002	789
Slovenia	11,128	450	-14,296	-3277	104.99	0.0058	-14,521
Spain	16,989	*	-22,512		144.85	0.0003	-22,512
Syria	1,238	580	-1,060	-283	12.42	0.0007	-1,350
Tunisia	2,390	7,250	4,083	-44	13.37	0.0007	458
Turkey	2,965	3,200	-729	-123	18.69	0.0001	-2,329
TOTAL	**154,430**	**409,270**	**204,635**		**1,472.38**	**0.0556**	**0**

* Data not provided it is considered 0 in the calculation

In Figure 7.5 the allocation of welfare losses is presented.

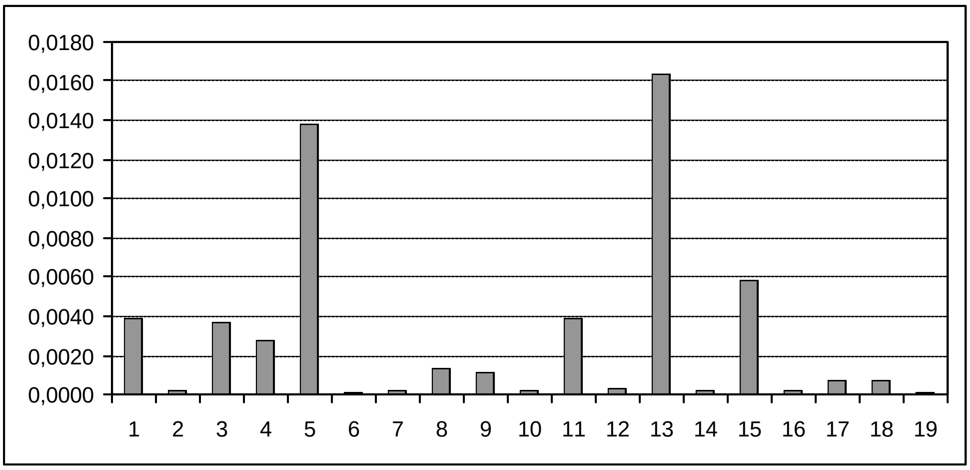

Figure 7.5 *- Welfare losses: Need based on per capita GDP*

Rule 6: Opportunities

Sharing the burden on the base of opportunities is one more rule with a wide range of specific versions. Out of the four versions presented in Table 7.4 we choose to develop here one based on discharges per GDP. The rule: $D_i^T = D_i^0 – [(d_i^*/ Sd_i^*) (D^0 - D^T)]$ considers high discharges per GDP as an indicator for inefficient use of resources and accordingly as a proxy for wide margins of cost-effective wastewater reduction. The results are shown in Table 7.14 below.

Table 7.14 *- Application of opportunities rule*

Countries	GDP (2000, $ mill)	Discharges per GDP (ton/yr/bill $)	Hot-spots BOD discharges (tons/yr)	Discharges under opportunities	& Change in discharges	Clean up cost	Welfare loss	Equity claim
Albania	3,800	142	540	-2,706	-601	87,477	23.0204	-2,976
Algeria	53,300	2,131	113,590	64,909	-43	210	0.0039	8,114
Bosnia H.	6,200	760	4,710	-12,643	-368	50	0.0081	-14,998
Croatia	19,000	216	4,100	-829	-120	45	0.0024	-2,879
Cyprus	8,700	22	190	-309	-263	8	0.0009	-404
Egypt	98,700	2,160	213,160	163,828	-23	211	0.0021	57,248
France	1,294,300	0	390	383	-2	0	0.0000	188
Greece	112,600	80	8,960	7,142	-20	20	0.0002	2,662
Israel	110,400	47	5,150	4,084	-21	5	0.0000	1,509
Italy	1,074,000	25	27,140	26,563	-2	6	0.0000	12,993
Lebanon	16,500	248	4,090	-1,572	-138	17	0.0010	-3,617
Libya	11,700	185	2,160	-2,057	-195	17	0.0015	-3,137
Malta	3,600	2,342	8,430	-45,059	-635	36	0.0101	-49,274
Morocco	33,300	156	5,180	1,627	-69	15	0.0005	-963
Slovenia	18,100	25	450	-118	-126	13	0.0007	-343
Spain	558,600	*	*	0		0	0.0000	0
Syria	17,000	34	580	-199	-134	6	0.0003	-489
Tunisia	19,500	372	7,250	-1,243	-117	31	0.0016	-4,868
Turkey	199,900	16	3,200	2,834	-11	2	0.0000	1,234
TOTAL		**8,959**	**409,270**	**204,635**		**88,169**	**23.0538**	**0**

* Data not provided it is considered 0 in the calculation

Once more we notice the grouping of countries into 'donors' and 'receptors' in a similar pattern as before. Welfare losses are presented in Figure 7.6.

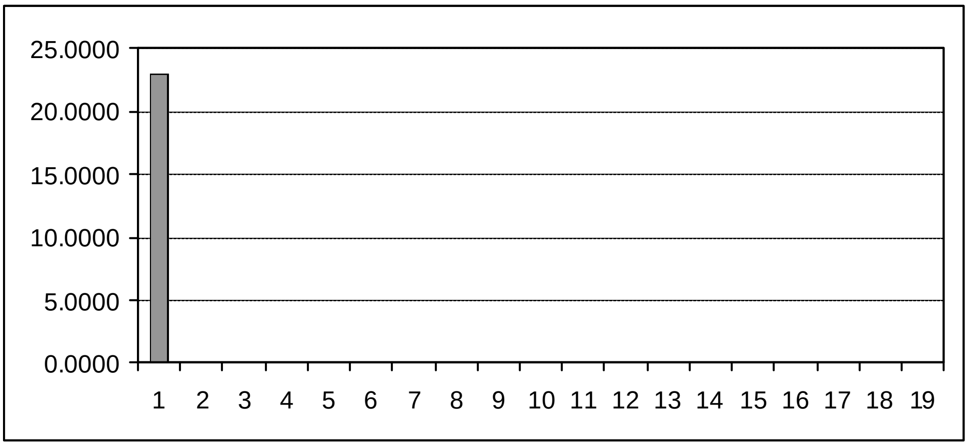

***Figure 7.6** - Welfare losses: Opportunities*

Rule 7: Need, responsibility and capacity

After six simple rules, we apply here a synthetic one, combined by the principles of need (linked to population growth), responsibility (linked to discharges per capita) and capacity (linked to GDP per capita). The relative formula is:

$D_i^T = D_i^o - [x(dP_i/SdP_i)+y(d_i/Sd_i)+z(GDP_i*/SGDP_i*)]\ (D^o - D^T)$

with x, y, z, weights adding to 1. For expository purposes we set x=0.5, y=0.25 and z=0.25.

***Table 7.15** - Application of need, responsibility and capacity combined*

* Data not provided it is considered 0 in the calculation

Countries	Hotspots BOD discharges (tons/year)	Discharges under N+R+C	Change in discharges	Clean up cost	Welfare loss	Equity claim
Albania	540	-3,973	-4,513	45.18	0.0119	-4,243
Algeria	113,590	97,723	-15,867	68.42	0.0013	40,928
Bosnia H.	4,710	558	-4,152	44.43	0.0072	-1,797
Croatia	4,100	1,774	-2,326	25.41	0.0013	-276
Cyprus	190	-9,180	-9,370	87.44	0.0101	-9,275
Egypt	213,160	198,296	-14,864	63.58	0.0006	91,716
France	390	-11,201	-11,591	104.93	0.0001	-11,396
Greece	8,960	4,212	-4,748	51.72	0.0005	-268
Israel	5,150	-12,137	-17,287	127.02	0.0012	-14,712
Italy	27,140	21,764	-5,376	58.12	0.0001	8,194
Lebanon	4,090	-9,052	-13,142	95.13	0.0058	-11,097
Libya	2,160	-11,019	-13,179	112.75	0.0096	-12,099
Malta	8,430	-27,609	-36,039	275.31	0.0765	-31,824
Morocco	5,180	-5,460	-10,640	69.45	0.0021	-8,050
Slovenia	450	-2,236	-2,686	32.35	0.0018	-2,461
Spain	*	-4,303	-4,303	37.23	0.0001	-4,303
Syria	580	-15,786	-16,366	142.20	0.0084	-16,076
Tunisia	7,250	-2,595	-9,845	53.06	0.0027	-6,220
Turkey	3,200	-5,141	-8,341	58.49	0.0003	-6,741
TOTAL	**409,270**	**204,635**		**1,552.23**	**0.1413**	**0**

Again, we note once more the grouping of countries into 'donors' and 'receptors' in a similar pattern as before. Welfare losses are presented in Figure 7.7.

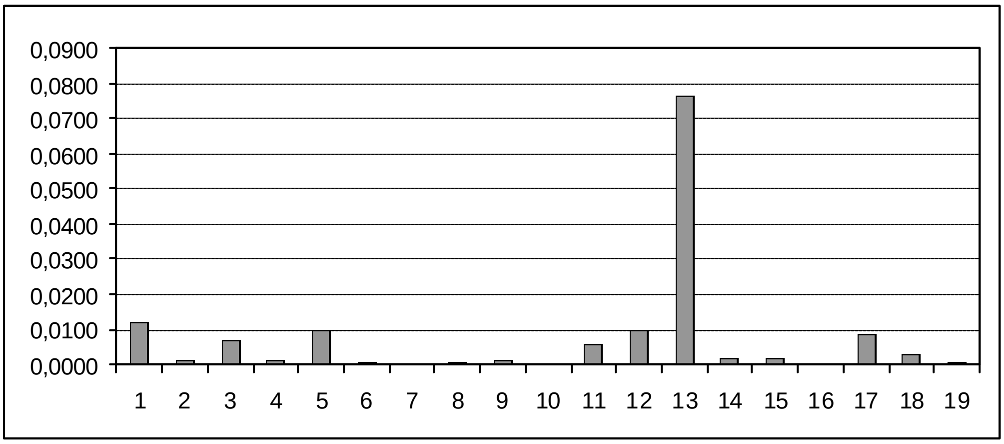

Figure 7.7 *- Welfare losses: Need, responsibility and capacity*

- *Discussion of the applied fairness rules*

The results from our 'exercise' must now be evaluated and assessed. In order to evaluate, one needs a benchmark and a number of criteria. Since the perspective of a differentiated burden sharing among the Mediterranean countries has not yet, at least to the knowledge of the author, been discussed formally within the framework of the Barcelona Convention, our discussion is bound to be speculative. Some important insights can be gained though at this stage, as far as the feasibility and appropriateness of the examined rules are concerned.

Are the rules politically acceptable?

We start by inquiring into the chances that the examined differentiation rules might have to become politically acceptable at the regional and national level. The question posed is: Does a differentiated burden sharing regime promises an improvement (that is, cost savings) to the individual members of the Convention in relation to their existing obligations? We use as benchmark the results obtained under the uniform reduction rule in order to quantify the notion of differentiation implied in our examples. For each case the results are compared to those of the uniform reduction rule and presented as 'equity claim'. Due to lack of data it is not possible to calculate the 'efficiency claim' as well. The column of equity claims shows countries that, in relation to the uniform rule allotments, benefit from the adoption of a differentiated burden sharing rule (positive claims) and countries that are disadvantaged by the rule (negative claims).

Table 7.16 reveals the fact that on the basis of the number of countries benefiting from a burden sharing policy shift within the Barcelona Convention, the egalitarian rule is the most preferred one followed by the (aggregated) 'need' rule. The combined application of need, responsibility and capacity is on the contrary the less favoured rule in this respect. If decisions were taken on the basis of majority voting, the egalitarian rule could be accordingly the strongest candidate for a future policy shift. Would all countries follow this direction? As it can be seen from the last column of Table 7.16, Croatia, Malta and Slovenia, the countries with a disproportional majority of negative equity claims, would be logically most unwilling to enter a negotiation on the relative merits of burden sharing rules.

The political attractiveness and feasibility of the proposed rules can been seen also from a different perspective: Rules that imply financial transfers, such as per capita responsibility, ability, both versions of need, opportunities, and N+R+C, can be proved too complicated and problematic to be implemented. [14] On the other hand, since both the sovereignty and the aggregated responsibility rules produce practically the same results as the uniform rule, the realistic options reduce to only one rule, the egalitarian!

***Table 7.16** - Equity claims under the examined fairness rules*

Countries	Sovereignty	Egalitarian	Responsibility		Ability	Need total	Need p.c.	Opportunity	N+R+C	Number of positive (+) and negative (-) claims
			total	p.c.						
Albania	0	1,250	0	-735	-874	7,682	-874	-2,976	-4,243	3+ 5 -
Algeria	0	-41,940	0	35,160	54,723	-36,915	54,723	8,114	40,928	5 + 2 -
Bosnia H.	0	-443	0	-4,615	243	1,409	243	-14,998	-1,797	3 + 4 -
Croatia	0	254	0	-2,984	-3,386	-2,633	-3,386	-2,879	-276	1 + 6 -
Cyprus	0	297	0	-1,276	-17,459	9,182	-17,459	-404	-9,275	2 + 5 -
Egypt	0	-73,291	0	88,463	105,002	-86,700	105,002	57,248	91,716	5 + 2 -
France	0	28,828	0	157	-38,179	3,781	-38,179	188	-11,396	4 + 3 -
Greece	0	717	0	-398	-12,285	-5,805	-12,285	2,662	-268	2 + 5 -
Israel	0	367	0	-2,379	-19,207	18,631	-19,207	1,509	-14,712	3 + 4 -
Italy	0	14,620	0	10,846	-13,163	-17,546	-13,163	12,993	8,194	4 + 3 -
Lebanon	0	-329	0	-4,699	-9,320	15,185	-9,320	-3,617	-11,097	1 + 6 -
Libya	0	1,518	0	-1,272	1,080	24,102	1,080	-3,137	-12,099	4 + 3 -
Malta	0	-4,019	0	- 117,412	-7,711	1,086	-7,711	-49,274	-31,824	1 + 6 -
Morocco	0	12,069	0	1,590	789	17,290	789	-963	-8,050	5 + 2 -
Slovenia	0	756	0	-1,074	-14,521	-2,876	-14,521	-343	-2,461	1 + 6 -
Spain	0	19,561	0	0	-22,512	-2,651	-22,512	0	-4,303	1 + 5 -
Syria	0	7,652	0	83	-1,350	31,519	-1,350	-489	-16,076	3 + 4 -
Tunisia	0	1,032	0	-779	458	12,279	458	-4,868	-6,220	4 + 3 -
Turkey	0	31,100	0	1,323	-2,329	12,979	-2,329	1,234	-6,741	4 + 3 -
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Number of positive (+) and negative (-) claims		**14 + 5 -**		**7 + 11 -**	**6 + 13 -**	**12 + 7 -**	**6 + 13 -**	**7 + 11 -**	**3 + 16 -**	

Are the rules costly to implement?

The (direct) cost aspect of the examined fairness rules is presented in Table 7.17. Costs to the Mediterranean countries of implementing the rules are calculated as welfare losses, that is, as percentages of total cost to the relative GDP. Here, only direct, that is capita and operating costs of abatement are considered leaving for the next section the question of wider, indirect or ‘transaction’ costs.

[14] They are the analogous to the application of Hicks-Kaldor compensation criterion within a country.

Table 7.17 *- Welfare losses under the examined fairness rules (as % of GDP)*

Countries	Sovereignty	Egalitarian	Responsibility		Ability	Need total	Need p.c.	Opportunity	N+R+C
			total	p.c.					
Albania	0.4149		1.4211	0.0038	0.0039		0.0039	23.0204	0.0119
Algeria	0.2215	0.0080	4.5947	0.0018	0.0002	0.0076	0.0002	0.0039	0.0013
Bosnia H.	0.0190	0.0048	4.0645	0.0110	0.0036	0.0016	0.0036	0.0081	0.0072
Croatia	0.0183	0.0010	1.1789	0.0027	0.0028	0.0027	0.0028	0.0024	0.0013
Cyprus	0.0048		0.4598	0.0020	0.0142		0.0138	0.0009	0.0101
Egypt	0.0039	0.0078	4.6190	0.0008	0.0001	0.0084	0.0001	0.0021	0.0006
France	0.0037		0.0031	0.0000	0.0002		0.0002	0.0000	0.0001
Greece	0.0023	0.0004	0.4334	0.0005	0.0009	0.0010	0.0013	0.0002	0.0005
Israel	0.0015	0.0001	0.0996	0.0002	0.0002		0.0012	0.0000	0.0012
Italy	0.0011		0.1366	0.0000	0.0003	0.0003	0.0003	0.0000	0.0001
Lebanon	0.0008	0.0006	0.5091	0.0023	0.0040		0.0039	0.0010	0.0058
Libya	0.0007		0.7436	0.0016	0.0000		0.0003	0.0015	0.0096
Malta	0.0004	0.0099	5.0556	0.2542	0.0166	0.0038	0.0164	0.0101	0.0765
Morocco	0.0003		0.3333	0.0001	0.0002		0.0002	0.0005	0.0021
Slovenia	0.0002		0.3591	0.0011	0.0060	0.0022	0.0058	0.0007	0.0018
Spain	0.0001		0.0000	0.0000	0.0003		0.0003	0.0000	0.0001
Syria	0.0001		0.1647	0.0001	0.0007		0.0007	0.0003	0.0084
Tunisia	0.0000	0.0006	0.7846	0.0010	0.0007		0.0007	0.0016	0.0027
Turkey	0.0000		0.0350	0.0000	0.0001		0.0001	0.0000	0.0003
TOTAL	**0.6937**	**0.0331**	**24.9958**	**0.2830**	**0.0549**	**0.0276**	**0.0556**	**23.0538**	**0.1413**

Table 7.17 reveals two important insights: Among the examined fairness rules, the egalitarian rule is the least cost option while the aggregated responsibility rule represents the highest cost option. The implementation of the former requires 0.0331% of the total Mediterranean GDP while the implementation of the latter raises this amount to almost 25%! We remind here the reader that the latter rule produces the same results with the 'status quo' of a uniform rate of abatement. Therefore, the shift from the uniform rule to the egalitarian one promises a clear cost saving of considerable proportion.

Are the rules easy to implement?

Widening the cost problematic in order to include all kinds of 'transactions costs' in designing and implementing the examined rules, we have to ask questions about:

- Availability of data / cost of new data collection and harmonization.
- Flexibility of the rules in the face of changes in national circumstances.
- Easiness of accommodating ceilings and other allowances in specific countries

Answers to the above questions are not easy to provide at this stage. The availability of data on discharge loads into the Mediterranean is far from been satisfactory. We already mentioned the expected change of this situation when national Baseline Budgets are in place. National cost data on abatement are almost non-existent. Pollution and cost data aside, all other data requirements can be collected relatively easy from international sources.

Easiness of accommodating ceilings and other allowances is another form of flexibility. Common sense predicts that the simpler a rule is, the more rigid it may turn out to be in the face of changes. In this respect, the N+R+C promises more flexibility in the face of changes in the economic growth rates and/or the developmental needs of a country relatively to, for example, the egalitarian rule. The latter rule could only accommodate changes in the population and/or discharge rates.

o *Conclusions and prospects for future research*

Multilateral environmental agreements have acknowledgeably contributed to the protection of global commons. The Barcelona Convention, and specifically its LBS Protocol stand up to this tradition by contributing to the technological and institutional capacity building of the Mediterranean countries. A pertinent aspect of this effort is the ability of the Convention to accommodate the divergent equity and fairness perceptions of the signatories into a realistic burden-sharing rule. The paper at hand has set as a target the discussion of the impacts of implementing a differentiated burden-sharing rule for the Mediterranean counties.

The rationale of applying a differentiated burden-sharing rule in the Mediterranean can only be understood from the background of the corresponding debate within the Framework Convention on Climate Change. As this debate continuously teaches us, ideas on fairness and equity are powerful drivers and indispensable elements of a successful multilateral environmental agreement. They will, sooner or later, find their explicit role within the negotiations of the Barcelona Convention as well.

A tentative application of seven fairness rules in the framework of the Mediterranean Convention has shown that by a majority of standards and criteria the egalitarian rule is the most preferred one. For this possibility to be further investigated, better data with a wider coverage are needed. The data problem aside, research should be undertaken in order to highlight crucial aspects of a future Mediterranean burden-sharing rule:

- Explore the possibilities of more synthetic rules on the base of multicriteria analysis
- Explore the effects of differentiated rules on trade.
- Investigate the reactions of state officials and national experts on a number of possible differentiation schemes.

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• Conclusions and recommendations

o *Gaps of knowledge*

The definition of the transboundary problems in terms of the relevant data needed is a prerequisite to find the proper management solutions. In this respect, as already has been pointed out in previous sections, the Mediterranean region exhibits important gaps of knowledge regarding levels and loads of pollutants, statistics of elements of transboundary concern (e.g. maritime transport) , inventories of specific ecosystems and hot spots and regional cooperation.

▪ Data on levels and loads

Several transboundary compartments, namely atmosphere and coastal waters, are not well covered yet regarding pollutant loads, and the spatial coverage of the data is also very heterogeneous. For example, in the North-western Mediterranean, metal and nutrient data in aerosols and rainwater exist since late 80's. However, the aerosol and rainwater composition in the south-west Mediterranean is unknown when it can be significantly different, as the north-west basin is very close to emission sources in Europe. Data for organic pollutants is almost unexistent.

The same spatial coverage problem also exists in the Eastern Mediterranean. Assessments on aerosol and rainwater composition in the eastern Mediterranean are based on data generated on the Turkish coast, Crete Island and coast of Israel and no data exists on the southern coast. Obviously, data on the south coast is needed in both Eastern and Western Mediterranean.

Data on riverine discharges is also very scarce. Most rivers are not adequately monitored for organic and inorganic pollutants in order to assess loads, even though they are very important. High concentrations have been found in some specific studies and are believed to occur in many small rivers which are affected by intensive agriculture or urban discharges.

During MEDPOL Phase I (1975–1980), it was attempted to estimate the quantity and nature of riverine inputs in the region. The tentative met with considerable difficulties. Country responses were geographically almost restricted to the northern Mediterranean. Sampling frequency, sample pretreatment, analytical methods and reporting formats varied widely. Some pollutants were rarely analysed (e.g. metals and specific organics). Field measurements of domestic sewage and industrial wastewaters were very limited. No field measurements on agricultural run-off were available. Among 68 rivers registered, only 30 were adequately monitored but not for organic pollutants.

In view of the limitations and difficulties encountered, assessments of the pollution loads from all land based source (LBS) categories have been carried out, largely, by indirect computations and extrapolations. They have been worked out taking into account demographic statistics, the GNP of the countries, industrial production and manpower, and agricultural data.

Due to the difficulties and the uncertainties involved in the complex computations and extrapolations carried out, the results could not be better than rough estimates reliable within an error margin of one order of magnitude.

As far as the urban-industrial discharges is concerned, the information so far collected indicates two main things, in one hand there is a limited amount of information provided by the national authorities. On the other hand, from the information collected we can conclude that there are still critical sources of pollution not well characterised and budgeted, like industrial waste waters directly discharging into the rivers and sea; dumping of industrial solid wastes in coastal zones without any containment, and pollution coming from the mismanagement of the production, transformation and transport of hydrocarbons. It should be mentioned that the preparation of National Baseline Budget of releases from LBS point sources could fill the gaps in data on loads.

There are also some problems with temporal coverage of existing data as well. Although there are fair amount of data as pointed out earlier, most of them are generated in few month long campaigns and data covering few years are scarce. Short term extensive measurements are useful to understand processes that bring pollutants to the Mediterranean Sea, but when they are used in annual assessments they may increase the uncertainty. Consequently, increase in the long term measurements of atmospheric composition and deposition of pollutants and of urban-industrial-riverine discharges can be useful in basin wide assessment.

Domestic and regional monitoring efforts should continue to study multi-media transport across air, rivers and seas, and the resultant environmental concentration levels. Regional co-operation may successfully stimulate the production and dissemination of technical and scientific knowledge, and also expand and sustain regional environmental assessment capacities. Such assessment work will be instrumental as a basis for prioritising issues and formulating joint policies.

For comparative reasons, further standardisation (or, at least, increased data compatibility) of research and assessment methodologies and reporting requirements is needed. This would both facilitate the compilation of reliable regional state of the environment assessments, and cross-country comparisons. However, the efforts carried out until now in quality control/quality assurance (QC/QA) in monitoring programs at regional level are not reflected in the existence of adequate data banks.

Lack of measurement data is a very serious drawback for environmental assessments but also for modelling transfer processes of pollutants and, particularly, transboundary transport within the region. Therefore, any attempt to increase data base measurements through comprehensive monitroing networks should be welcome.

- *Marine Traffic Statistics*

Pollution prevention and contingency planning in Mediterranean ports, coastal zones and deep-sea areas as well as salvage tug stations and places of refuge should be defined and, eventually, modified, after a careful analysis of the corresponding risks.

Such analysis requires, in order to be seriously prepared, a precise knowledge of ships and cargoes movements during a certain past period, in order to take into account the seasonal variations and to identify the commercial and technical development trends. The present situation of the published Word-Wide Maritime Statistics is far from satisfactory specially as regards the flows of sea-borne trade, the ship's movements and the combination of both data.

In matter of reluctant dissemination of maritime trade data, the Mediterranean area is no exception and the drawback of such dearth of statistical information as regards the regional shipments of hazardous substances and the ship's wastes generation has been already underlined in several parts of the present chapter.

It is also unlikely that published statistics will ever provide the distribution by cargo categories of loaded and unloaded goods, with the degree of detail required to usefully monitor at the regional level the flows of the multifarious products, crossing the Mediterranean Sea under the general label of "chemicals".

To address this clearly identified issue, it will be worth to create a Mediterranean Maritime Statistics Observatory within the existing framework of REMPEC, the UNEP/MAP Co-ordinating Unit or Mediterranean BLUE PLAN regional Activity Centre. The first task of this Observatory should be to prepare an inventory of existing relevant shipping and sea-borne trade published basic data sources, mainly Mediterranean ports and riverine countries customs statistics but also oil and chemical industries ones.

Ultimately, it could prove necessary to institute a compulsory notification to this Regional Observatory, for each shipment of polluting noxious and/or dangerous goods, mentioning a precise description of the product, its volume, physical condition, form of packaging, ports of origin and destination, name, type and size of the carrying ship.

Ideally, these Mediterranean maritime statistics should cover the following items:

- detailed and coherent data on loaded and unloaded cargoes, specially pollutants, distributed by destination and origins;
- ships' movements, mentioning their respective cargoes and the last port of call for the arrivals or the next one for the departures;
- combination of the above information in order to ascertain the links between types of ship and categories of cargoes.

The Mediterranean Maritime Statistics Observatory should also cover the usual field of the regional merchant fleets analysis by types, age and tonnage groups as well as newbuilding scrapping and losses figures. In these matters, the Observatory shall just process the existing World Merchant fleet yearly statistical tables published by the Lloyd's Register of Shipping. Other systematic electronic connections should also be considered with other relevant global maritime and international trade and ship data bases, either public, such as the ones of UNO, UNCTAD or EU statistical offices, the Paris MoU previously mentioned EQUASIS, or private as the ones of LRS-FAIRPLAY or LMIU (Lloyd's Maritime Intelligence Service).

- *Inventories and monitoring of ecosystems*

Inventories are the third category of background information which need to be enforced. Besides inventories of species like the current one carried out by CIESM on allochthonous species in the Mediterranean, there is an urgent need of inventories of habitats. More particularly, since it has been defined as a key sustainable development indicator, there is an urgent need to make a thorough inventory of the state, for example, of wetlands and seagrass beds all around the Mediterranean basin which, given the hugeness of the task, supposes the settling of a well-defined and coordinated mapping strategy based on a common methodology.

Within an ecosystem, there are many hierarchical levels of organization that are linked to one another (i.e., nutrient cycling, trophic levels, water flow, etc.). To adequately ensure that the best management decisions are being made with the best available scientific data, changes in the functional processes of an ecosystem must be measured on the physical, biological, and chemical levels using various indicator parameters. For example, much attention should be paid to linking biodiversity issues to ecosystem level indicators such as NPP (Net Primary Production). Similar to NPP, nutrient and carbon cycle models (e.g. the Thau lagoon, the Ionian Sea) are also in the early stages of development, especially for management purposes. Yet it seems clear that NPP estimates are an essential component of ecosystem management and that biodiversity by itself is an insufficient tool. To overcome this knowledge gap, greater attention should be placed on measuring NPP in ecosystems. Productive capacity will have to overcome its obvious public relations and comprehension disadvantage to biodiversity.

Following this approach of ecosystem management, monitoring should be considered crucial and for that there is a need for the development of long-term monitoring programmes at the national level, developing as much as possible standardised methods so as to allow the coordination of such programmes at the regional level when necessary.

In that regard, increased attention should be devoted to the concept of ecoregions as proposed by recent studies like the World Wildlife Fund (cf. Sensitive areas in the Mediterranean Sea), provided that higher-risk ecoregions will usually require more conservation attention (protected areas being only one of the tool) in order to maintain their biodiversity. In that sense, scientists and managers should take advantage of the methodology and results from international programmes applied in sub-regions (e.g. the Nile) like IGBP/LOICZ (Land Ocean Interactions in the Coastal Zone) which is devoted to the identification of coastal change and river catchment-based forcing of change by considering coastal geomorphology, coastal habitats/biodiversity, climatic conditions, people relationships (forcing drivers like demography), catchment size and seasonal runoff, land-use and cover. This effort of integration from a network of interdisciplinary scientific groups should be an excellent opportunity for “good science” input in the management process.

- *Monitoring capacity*

The definition of the problem in terms of the relevant data needed is a prerequisite to find the proper management solutions. As already has been pointed out, the Mediterranean region exhibits important data gaps regarding hazardous substances. A more comprehensive understanding of how and where hazardous substances are used and released, and in what quantities, and the situation regarding disposal and/or storage of existing stockpiles and major sources of hazardous by-products will need attending to in the region. Domestic and regional monitoring efforts should continue to study multi-media transport across air, rivers, seas, and soil, and the resultant environmental and human concentration levels. Furthermore, research on environmental and human health effects needs to try and improve our understanding of the short-term and long-term effects of exposure to hazardous substances to wildlife and humans.

It is arguable that the two main difficulties facing the development of an environmental regional policy are the lack of funds and reporting obligations. Much valuable work has been carried out but is underused in terms of practical risk reduction impact due to the difficulties in establishing and maintaining a regional network of active integrated assessment that works in an iterative manner relating monitoring, modelling, policy making and compliance. Such processes have been established at a national and European scale and it should be a priority to extend them to the Mediterranean region. The existence of such long term regular reporting practices increases the value of the effort of all components and monitoring data are more valuable if they are useful for modellers and models are more valuable if they are liked with users such as policy makers the public or scientist doing the monitoring.

It should be underlined, at the end, that Information Technologies have a great potential for improving access of users of different profiles (public, scientist, industry, policy, compliance monitors) to large amounts of dispersed and diverse available information. A much more intense and effective relation between experts and models, simulating different environmental components (such as chemical toxicological and epidemiological/ecological/geophysical and transport models) or activity sectors (industry/transport/agriculture), will be needed and such communication can be simplified with Machine Learning and Evolutionary Computing tools. Similar current efforts should be spent to harness the information processing resources available in order to extract “expert common sense” from available models and data for a particular problem or application.

o *Reduction of pressures*

Pollution effects is only one of the problems threatening the viability of the Mediterranean as an ecosystem. The alteration and destruction of marine and coastal habitats through improper development practices and poor management are also very significant problems. Both problems need to be adequately addressed in establishing a strategy of reduction of pressures of transboundary concern, the first primarily requiring technological interventions and the second improved management practices.

▪ <u>*Technological interventions*</u>

Investments in technology could assist in reducing the pressures on the environment as well as in avoiding specific impacts. A recommended key action in the line of preventing direct urban and industrial coastal discharges should go through the integration of cleaner production and pollution prevention concepts in national environmental policy.

Pollution prevention (P2) should be the strategic option ,it is defined as the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous and non-hazardous materials, energy, water, or other resources as well as those that protect natural resources through conservation or more efficient use. P2 techniques not only resolve or reduce environmental quality issues or problems, but also save money, by reducing expenses, pollution prevention improves the competitiveness of business and industry. It promotes continuous improvement through operational and behavioural changes. P2 is a shared responsibility among governments and individuals, industrial, commercial, institutional, and community sectors.

It focuses on areas such as:

- substances of concern (e.g. POPs, PTS, etc);
- efficient use and conservation of natural resources;
- operating practices;
- clean production processes which create less waste;
- training;
- equipment modifications;
- process changes;
- materials and feedstock substitution;
- product design and reformulation;
- product life-cycle;
- purchasing practices.

The P2 also introduce a more effective and efficient approach to environmental approvals that will streamline and possibly replace the existing command and control approval process. However, detailed community participation programs would be a requirement for any industry requesting exemption from an approval. This would ensure that important public issues would not be lost in any approval exemption process.

The P2 should facilitate agreements with associations that represent small businesses in order to develop codes of practice and certification programs that meet pollution prevention standards. Upon completing codes of practice and certification programs, Governments should act to ensure these programs are implemented throughout the business sector.

The benefits of practicing P2 have long been noted:

- reduced operating costs;
- improved worker safety;

- reduced compliance costs;
- increased productivity;
- increased environmental protection;
- reduced exposure to future liability costs;
- continual improvement;
- resource conservation;
- enhanced public image.

In the Northern side of the Mediterranean region, the most industrialised, and consequently the one bringing more pollutants into the system, there are *a priori* the necessary prevention mechanisms, correction technologies and the appropriated legal framework. However, there is a lack of political willingness from the countries to enforce the environmental regulations. Nevertheless, there is a hope for self-control of the industrial contamination from this part of the region.

The Southern side of the Mediterranean region is, however, growing at a large expense of the environment, since neither the economical conditions not the required technologies are available. In this context, UNEP should play a role in order to make possible the socioeconomical conditions and the technological transfer to prevent further environmental deterioration of the Mediterranean basin at the expense of the industrialisation of the Southern countries.

Promotion of treatment (primary and secondary) of municipal sewage prior to its discharge to estuaries and coastal areas, disinfection of treated sewage effluent to be discharged in the marine environment and reduction of the emissions and discharges of bioaccumulative toxic substances from the industry sector, are important interventions for the aquaculture sector.

The agriculture and mariculture activities, still based on several traditional practices, should also incorporate more rigorous practices regarding the use of fertilisers, pesticides and chemotherapeutants. These preventive measures will improve the quality of the aquaculture environment and restrict the health hazard risks for consumers.

The reduction of inputs of extraneous compounds, like metals (e.g. from antifouling agents) or the replacement of antibiotics by vaccines could contribute to reduce the impacts. Site selection is also an important process for the sustainable development of mariculture with minimum environmental consequences. Geographical information systems and satellite remote sensing could be useful tools for site selection for the development of mariculture.

Finally, improved feed conversion ratios will reduce cost, the level of organic enrichment directly beneath the farms since this is largely the result of the deposition on uneaten feed. The industry should improve also feeding strategies and should also investigate the use of low phosphorus diets, otherwise possible further expansion of certain cultures will create serious ecological problems.

The marine pollution risks generated by maritime transport activities in the Mediterranean waters and ports, has considerably receded, during the last decade, owing specially to the growing implementation of SOLAS and MARPOL regulations by the shipowners whose vessels are operating in the area and by a constant improvement of navigation aids provided in the Region. However, some interventions are still required to reduce the environmental pressure of this activity. Governments of maritime countries should ensure the availability of reception facilities in ports, adequate to meet the needs of ships using their ports.

The port reception facilities generally are constituted by mobile or moveable equipment, with moderate investment and operational cost. Therefore, it is surprising that the provision of such low cost facilities seem to be difficult to implement in many Mediterranean ports.

On the other hand, measures for the proper management of dredging sediments before dumping should be enforced. According to the protocol “for the prevention of pollution of the Mediterranean Sea by dumping from ships and aircraft or incineration at sea” (adopted in

1976 and modified in 1995) dredged material is listed among the substances that could be dumped at sea, after a permit issued by the competent authority. The Parties of the Barcelona Convention have decided to establish “Guidelines for the Management of Dredged Material” in the Mediterranean Sea. A preliminary evaluation of the need for dredging and disposal is required, as well as a study of the composition of the dredged materials, estimation of pollutant loads and proposal of disposal options, before the selection of the dumping site.

Another important issue is the implementation of “Port Emergency Plans” and the improvement of regional availability of salvage capacity and designation of place of refuge for disabled vessels.

Within the MAP framework it would seem advisable to undertake a feasibility study analysing the regional risks of casualties likely to involve all polluting cargo categories. Such a risk analyse should present various scenarios of accidents, and establish their most likely geographical distribution. The conclusion of such a cost/benefit analysis will probably indicate that Salvage availability should be increased in the some areas of the Mediterranean Sea. To reach this objective it appears that, beyond the existing means, several dedicated salvage tugs, should be stationed permanently in most casualty-prone Mediterranean areas. As the cost of such stationing will exceed by far the benefit that a private salvor may expect to get from it, this cost should be supported jointly by the riverine countries, on a regional or sub-regional geographical basis, each one contributing proportionally to the value of hydrocarbons and chemicals loaded and unloaded in its Mediterranean ports. The choice of the areas where these tugs should be kept in station will be difficult as it is impossible to forecast the timing and location of the next tanker casualties involving major spill risks in the Mediterranean. To obtain a good cover of these risks up to five tugs could be required to be stationed near the straits of Gibraltar and Sicily, also in Tyrrhenian, Adriatic and Aegean Sea (the two Suez Canal Authority's tugs offering a suitable cover for this seaway and its Mediterranean approaches). The above mentioned regional navigation safety study shall also result in suggestions concerning the number of required places of refuge, distributed along the sections of the Mediterranean coast bordering the most casualty–prone parts of the Sea.

The stationing of a salvage tug may be coupled with the designation of a place of refuge, in search of a balance between advantage and disadvantage for the involved coastal-state. As previously underlined, the new "Emergency protocol", in the wake of the CASTOR affair have enacted the obligation for the parties to the Barcelona Convention to provide such places for disabled vessels. Nevertheless, the actual selection of suitable location will certainly prove very difficult for such a sensitive problem; therefore it may seem advisable to link it with the emergency towing one that enjoys the favour of the public opinion. It should be clearly stated that an emergency towing to be successful in preventing marine pollution, has to be terminated more often than elsewhere in a place of refuge.

However, the implementation of such an ambitious "Salvage and Refuge" program will have to be spread over some years and priorities should be established. As for a first unit, it seems that a station covering the highly trafficked straits of Sicily, Messina and even Otrante as well as a long part of the dangerous North African Coast, could be an obvious choice for both geographical and political motives. Such a location may also permit to directly place this major regional pollution prevention means under the international aegis of REMPEC in its capacity of joint Agency of IMO and UNEP in charge of organising the regional and sub-regional co-operation for pollution prevention and fighting among the parties to the Barcelona Convention.

- *Proper development practices for the ecosystem*

All around the Mediterranean basin, coastal urbanisation is interrelated with biodiversity losses, stable increase of water demand, as well as of wastes and thus pollution. Wetland losses and environment degradation have imposed a serious threat to many aquatic species.

The creation of marine protected areas for conservation purposes is often not sufficient as an impact-limitation measure, since many of the impacts derive from pressures that are not necessarily locally originated.

The protection of species and habitats in the Mediterranean should not be based on a number of separate measures directed to the protection of certain species on the one hand and certain habitats on the other. The protection of species and habitats needs an integrated ecosystem approach, based on the conviction that an ecological network should be protected and restored when and where necessary.

With reference to what have been said before, the following is recommended :

- In the context of the protection of species and habitats, pollution reduction continues to deserve high priority through national and regional planning going from the reduction of contaminants sources, better knowledge of their fluxes and inputs into the sea, and well coordinated coastal monitoring system allowing a better understanding of their dynamic and thus location through time and within space.

In the further development of a strategy to protect species and habitats, the following policy options should be considered:

- To implement with high priority the provisions of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, i.e. the identification of marine sites (including coastal, estuarine, and open seas area) of national or regional importance, in accordance with the the common criteria adopted.
- To identify an ecological network of habitats in the Mediterranean which could serve as the focal point for the protection of selected species. Seagrass beds could be one of the first selected habitat for such a networking, provided their large spreading in the entire Mediterranean basin and their crucial ecological role in coastal waters. For these qualities but also because of their vulnerability, seagrass beds have been chosen as the main sustainable development indicator for the coastal waters biological quality in the Mediterranean.
- To use the elements (species and habitats) of this network, and the identified marine sites of national or regional importance, for the further elaboration of ecological objectives for the Mediterranean.
- To develop special protection regimes for these habitats (including coastal, estuarine, and open sea areas), inter alia, including measures to reduce particular sea uses and to establish water quality objectives.
- From the definition of ecological and water quality objectives, to develop a common set of meaningful indicators of success, i.e. to demonstrate the benefits and effectiveness of Specially Protected Areas and Biological Diversity in the Mediterranean (SPAMI). These indicators should be based on a compilation of the biological, economic, socio-cultural, and process variables that would be identified and defined by local stakeholders and managers as directly influencing Specially Protected Areas impact.
- From an active and networked application of these indicators, could be unfold an effective “Good Practice Guide” which would facilitate the integration and

application of these indicators at the early stages of Specially Protected Areas management strategy.

- To implement the different Action Plans adopted for the protection and/or recovery of selected species.

On a more broader sense, the improvement of the institutional capabilities of the Mediterranean countries in the sustainable management of their environment and its rational integration in development policies is a major challenge for the region.

Coastal Area Management Programmes, for instance, are practical MAP initiatives lasting an average of 3-4 years aiming at the introduction of integrated coastal area management at local or national levels and institutional strengthening and capacity building in an effort to rehabilitate areas with the heaviest load of environmental problems.

Curbing pollution through marine and maritime monitoring and control, notably with the Strategic Action Programme for Land Based Pollution sources, remains a major MAP activity, whereas safeguarding natural and cultural resources is an increasingly important one.

The establishment of the Mediterranean Commission on Sustainable Development (MCSD) in 1996, demonstrated the commitment of Mediterranean states to working towards integrating the environment and development in the entire region . The MCSD has produced recommendations and proposals for action that encompass ones on water demand management, coastal area management, tourism, industry, urban development, free trade and the environment, public participation and awareness raising and sustainable development indicators. Issues now being examined include agriculture and rural development, urban waste management and consumption patterns, local governance and finance and cooperation for sustainable development.

8.3 Management and regulatory mechanisms

Number one priority in environmental management in the Mediterranean region is to develop the necessary environmental legislation and to enforce it. This will be the only route to a real improvement of the environmental conditions in the region, and should be done at both national and regional levels.

As shown in the previous section, besides the national regulatory structures, the EU directives and the regional Conventions, namely MAP , are the main driving forces for environmental protection in the region. However, the Mediterranean region generally lacks strong national environmental leadership and compliance of regional commitments is, in general, very irregular.

The regulatory status of the Region mimics the socio-economic and political structure. The legislation for hazardous substances management in EU members and the associated countries are regulated by the European directives, although the degree of compliance is varying within the four member States, and their investment in regional hazardous substances issues has been slow. On the other hand, States facing low levels of organisational capacity and weak economies have serious difficulties in increasing environmental protection and fulfilling international commitments.

The control and management of pollution and specially hazardous substances at national levels is quite dispersed among various authorities. Hazardous substances control and regulation in many of the countries of the Region the environmental control and regulation is quite decentralised which implies that many of the responsibilities are transferred to regional, provincial or local authorities.

The state of implementation and compliance of the existing regulations concerning hazardous substances in the Region is quite varying. The available information indicate that countries, which have more effective national environmental law and regulations and capabilities to undertake monitoring and enforcement activities exhibit several positive signs of high compliance of substantive obligations through their commitments to regulationssuch as EU directives and MEAs. In fact, implementation of these commitments could lead directly to implementation of Convention obligations, which takes place via three overlapping mechanisms:

- conventions sponsored implementation efforts,
- state-driven domestic implementation efforts, and
- EU-driven efforts to harmonise national environmental law and regulations.

Other Mediterranean countries exhibit low commitments to relevant national and regional regulations even though they have developed a comprehensive national legal and institutional framework for implementation of national and regional regulations. Furthermore, because these countries have ratified only few of the MEAs, they are not required to submit reports on several important requirements. As such, information about compliance of substantive obligations and implementation of the Protocols and common measures concerning hazardous substances remains extremely scarce and, where it exists, quite uneven in coverage and quality.

Implementation of MEAs commitments in these countries takes place via three main channels which include:

- multilateral assistance programs such as those sponsored by MAP bodies, UNEP, the GEF, and multilateral development banks;
- state-driven domestic implementation efforts; and
- EU-driven efforts for EU candidate states and non European countries through the Euro Mediterranean partnership.

In general these countries are lacking the necessary technical, financial and human resources to comply with national and regional regulations.As an aeample it is considered that the important numbers of stockpiles of PTS existing in the jurisdiction area of these countries as a relevant indicator that would support these facts.

Ratification of protocols remains a challenge for the region. Most of the existing MEAs have low numbers of ratifications. As an example, neither the revised Barcelona Convention, nor any of the most recent Protocols (including the revised ones), has entered into force, despite having been adopted six to seven years ago in 1995 and 1996.

8.4. Identification of needs, in particular for regional co-operation

It is obvious that the development of management structures and the implementation of National Action Plans (NAP) to address Land based sources of pollution cannot take place under the same conditions in all countries. The southern countries of the region are those facing major problems with regards to pollution management capacities and, therefore, those primarily requiring external co-operation. The problem fully remains for the treatment of organohalogen wastes, which have no recycling value and require major investments.

The conclusion, which may be drawn from this point, is that technologies for the management of industrial waste that could be developed are those generating a local economic activity solely based on supply and demand. Treatment technologies involving costs cannot be developed as long as they are not economically integrated in production costs. It is therefore evident that any national action plan should be preceded by the establishment of a pollutant release and transfer register. National and regional action plans should, therefore, consider the following aspects:

- Development of a systemic approach for the global management of pollution.
- Extension of registers to production flows
- The issue of environmentally rational management of hazardous industrial waste

All environmental conventions have raised the problem of the treatment of industrial effluents generated by producers or users of dangerous substances. There are three aspects, which are indivisibly linked to this issue and which are often overlooked during the implementation of conventions: the Technology/Regulation links, the Technology/Financing links and the Financing/Regulation links.

The search for solutions should therefore aim at a global approach, which would integrate these three parameters. Today, however, environmental conventions have been implemented according to a pattern that does not take into consideration the close interrelation between them. It is therefore of primary importance to encourage in each country the creation of working groups bringing together the national operators of the different conventions, in order to integrate all the aspects of the problem in a global manner:

- Financial capacity
- Technological capacity
- Harmonisation of regulations

NAPs should take into account as a key element each country's economic situation. In this respect, the North/South financial responsibilities should be considered for an effective implementation of environmental conventions in the southern countries.

The North/South pattern as it applies to the Mediterranean region

The large debate that has been opened focuses on the historic responsibility of Northern countries, which in the absence of precautionary principles, which did not exist at the time, have released substances on the market without being yet aware of their characteristics of persistent pollutants or the by-products generated by their thermal decomposition. It would be very difficult to convince them of the contrary, in the sense that it is impossible to make them responsible of the absence of the precautionary principle when they purchased these products in a situation of total technological dependence. For this reason, the financial instruments that should be provided in order to allow the countries of the South to meet with their obligations need to take into account the legitimate demands of the private sector in these countries.

In addition to the historic nature of these products, the increasingly more stringent environmental regulations in industrialised countries compel private industries in these countries to relocate their production facilities in the countries of the South and in doing so they also relocate emissions and transfers of pollutants in these countries. And this is taking place within a globalisation context where trade activities are subject to deregulation rather than regulation.

8.5. Needs and future interventions for CZM

In order to mitigate negative trends caused by the previously mentioned transboundary related issues affecting the Mediterranean Sea, proposed interventions should satisfy specific needs/areas for intervention:

- Harmonization and strengthening of CZM implementation at the regional, national and local levels.
- Securing and upgrading the application of CZM when dealing with transboundary issues.
- Upgrading specific components of ICZM (coastal urban – sea level rise).
- Upgrading the human and institutional capacity for the implementation of transboundary related projects.

However, before describing the nature of interventions needed in coastal zone management and planning and before formulating proposals for action, the following must be considered and respected:

- Need for a realistic approach, formulation of viable proposals, applicable and with short and medium term deadlines but providing grounds for further larger/ more extended initiatives.
- Proactive context, including future/ potential transboundary impacts and issues.
- Harmonization with past and on going relevant initiatives at all levels.
- Consistence with global/ regional/ national/ local objectives, strategies and programs.

- Provisions formulated in Agenda 21, MED Agenda 21, MAP, GPA, GEF and EU Demonstration Program.
- Requirement that proposed activities are specific, issue and target oriented, providing for practical outputs and results, intended to mitigate/ control/ prevent present and future transboundary sources and issues.
- Adoption of common framework of policies general or specific to a particular type of a coastal area.
- Building political support