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REPORT ON THE STATE OF POLLUTION OF THE MEDITERRANEAN SEA

June 1985

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I. INTRODUCTION

On the occasion of the 10th anniversary of the adoption of the Mediterranean Action Plan, UNEP commissioned this report, announced by its Executive Director at the Extraordinary Meeting of the Contracting Parties held in Athens 9-13 April 1984, both as a recognition of past achievements in improving the quality of the environment and as a warning of the threats to the Mediterranean region that still persist and will continue to endanger its future unless stricter control and more energetic action is undertaken.

Although the Mediterranean Sea is small compared with the oceans, the size of its basin exceeds the spatial scales of many physical, chemical and biological processes occurring in it. As Desfontaines puts it, "The Mediterranean Sea appears as an oceanic basin, in fact a miniature ocean" (Henry, 1977). However, the large ratio of coastline relative to the surface area, the large number of inhabitants dwelling on its shores (more than 100 million permanent residents) and the high degree of agricultural, industrial and maritime development makes the Mediterranean Sea one of the regions most susceptible to pollution.

The Mediterranean Sea has indeed lived with pollution ever since large cities developed along its banks, but only in recent decades have the wastes from these flourishing communities, become a significant threat, because of their greatly increased amounts and toxicity.

If the overall threat of pollutants to the Mediterranean Sea were to be assessed, the following order of significance could probably be agreed upon (Osterberg and Keckes, 1977; Fowler, 1985):

a) Sewage and solid refuse from cities and urban aggregates.

b) Oil from land-based sources, tanker operations and bilge pumping.

c) Organic matter, heavy metals and other toxic substances contained in industrial wastes.

d) Nutrients and pesticides used in agriculture.

e) Coastal engineering and construction, and damming of the rivers flowing into the basin.

The routes through which the pollutants reach the Mediterranean Sea, could be ranked as follows:

a) Land-based point sources, mainly urban and industrial discharges.

b) River run-off which collects urban, industrial and agricultural wastes, sometimes from large watersheds.

c) Maritime sources in normal operation, and through dumping and emergency situations.

d) Atmospheric transport from remote as well as nearby land-based sources.

With regard to the impacts of pollution in the Mediterranean Sea, three major areas of concern may be identified:

a) Human health, both through the consumption of contaminated seafood and sea-side recreation.

b) Living resources, particularly fisheries. Additionally, the development of aquaculture may be severely limited by increasing pollution of those areas traditionally used for such a purpose, and by indiscriminate urbanization of coastal areas untouched until recent times.

c) Aesthetic considerations, especially in view of the economic importance of tourism to many Mediterranean countries, and the high value placed on sea-side recreation by Mediterranean inhabitants.

Most of the topics discussed in this report are substantiated by scientific research carried out in recent years by hundreds of Mediterranean and other scientists. Though all available sources of information have been taken into consideration, the present assessment has been mainly prepared on the basis of reports and documents published by UNEP and the cooperating agencies responsible for the implementation of the Long-term programme for pollution monitoring and research in the Mediterranean Sea (MED POL -PHASE II).

Since this report is addressed mainly to readers who may not be acquainted with scientific terminology, the use of scientific jargon and cumbersome lists of numbers has been avoided as far as possible. Only a few tables from previous publications have been retained. However, because of the large gaps which exist in the scientific and technical information available, a number of statements made should be regarded as representing informed scientific judgements or estimates, rather than as established facts.

Pyrenees (Ebro) and Alps (Rhone and Po), or by the abundant rains of tropical Africa (Nile). The latter however, particularly after the construction of the Aswan High Dam, could be considered in the group of typical Mediterranean rivers.

The continental runoff estimated in the framework of the MED POL project on Pollution from Land-based Sources (UNEP 1984), gave a value for total runoff of about 14000 m^3 s^{-1}. There is a large imbalance between runoff from the northern shore, draining 92 per cent of the water that flows into the Mediterranean Sea, and the southern shore, draining only the remaining 8 per cent. This difference arises mainly from differences in yearly precipitation since the size of the areas drained is quite similar. The area of the Mediterranean that receives the largest input through river runoff is the Adriatic Sea, followed by the northwest Mediterranean, receiving between them nearly 70 per cent of all the river discharges. These two areas are followed by the Aegean, the Tyrrhenian and the Ionian Seas (20 per cent). The north African coast, including runoff from the Nile, receives less than 10 per cent.

These estimates are rather imprecise, but accurate assessment of the rate of evaporation, being in itself the result of various complex interacting mechanisms, is impossible. Most of the evaporation takes place during the first half of the year and is linked to the process of deep-water formation. The strong and dry continental winds rapidly evaporate surface water causing an increase in salinity and a lowering of its temperature. The consequent increase in density of the water causes it to sink to varying depths.

<u>Water masses</u>

The Mediterranean Sea, with its negative water balance, is a typical example of reverse estuarine dynamics. The process by which the incoming surface North Atlantic water is transformed into the outgoing deep Mediterranean water requires large horizontal movements, covering the entire basin, and the general net gain in density generates unusual vertical movements seldom found in other regions of the world's oceans.

The temperature of the Mediterranean water is subject to strong seasonal changes that affect the upper layers down to depths of about 50 to 75 m. Sea surface temperatures may range between 12 and 29 °C the lowest being in winter in the northwest basin and in the north Adriatic Sea and the highest in summer in the north east Levant Sea. The temperature of the water below the thermocline is characterised by an outstanding homogeneity. It varies around 13 °C in the western Mediterranean; while in the eastern Mediterranean, a wider range of variation occurs, between 13 and 16 °C. Changes in salinity of the subsurface and deep waters range from 38.35 ppt to 39.10 ppt (Miller and Stanley, 1965) with only 2 per cent of the water being fresher than 38 ppt and 0.1 per cent saltier than 39 ppt. The freshest waters are found in the western Mediterranean and in the Adriatic Sea, and the saltiest in the Levant Sea.

Of the various water masses that have been identified, the North Atlantic Water mass is perhaps the most conspicuous. It is found in the surface layers of both the western and eastern basins. It is formed by mixture of the relatively fresh water entering through the Straits of Gibraltar as a surface layer 150 to 250 m thick and the saltier Mediterranean water filling the largest part of the basin. The salinity values at the salinity minimum, encountered in the surface layer, increase eastwards rapidly in the Alboran Sea as a consequence of intense recirculation. Later they increase more slowly, as the water mass approach the Sicilian and Balearic channels (Cruzado, 1983), with salinities around 37 ppt, indicating a mixture of roughly 70 per cent North Atlantic water and 30 per cent Mediterranean intermediate and deep waters. In parts of the Levant Sea, a remnant of the North Atlantic Water may also be detected as a subsurface layer of minimum salinity (Lacombe and Tchernia, 1960; Oren, 1971).

The intermediate water masses are generated within the Mediterranean Sea by winter convection processes and show characteristics close to those of the deep waters. Intermediate waters produced in the northwest Mediterranean, often referred to as "winter waters", show lower temperature and salinity than deep waters (Furnestin, 1960). They are relatively short lived as a consequence of vertical mixing.

Intermediate waters produced in the eastern basin, on the other hand, have quite a different behaviour as a consequence of their higher density. They play a very important role in maintaining the salt balance of the two basins and of the Mediterranean Sea as a whole. They are formed by the winter cooling of the highly saline surface water (up to 39.5 ppt) and mixing with the remains of the subsurface North Atlantic Water. After crossing the sill at the Sicilian Channel they constitute another water mass normally identified as Levantine Intermediate Water that has been tracked in the various regions of the Mediterranean Sea. As this water mass progresses away from its source in the Levant Sea, it is diluted with the deep water of the corresponding basin with no significant change in density. Just after crossing the sills of the Sicilian Channel, the Levantine Intermediate Water seems to spread to the north and west covering large areas of the western basin. In the eastern Alboran Sea, the Levantine Intermediate Water is thoroughly mixed with the deep water. This mixture, flowing over the Gibraltar sills along their northern channel, is strongly exposed to admixture with the North Atlantic surface water since the sills are exterior to the Mediterranean Sea (Hopkins, 1978).

The deep water mass that occupies depths greater than about 500 m in the western basin and 700 m in the eastern basin, should be considered as formed from a number of different water types filling the various basins of the Mediterranean Sea. Due to the relative isolation caused by the existence of a shallow sill across the Sicilian Channel and of a layer of warmer and saltier intermediate water that acts as a lid in the eastern basin, relatively important differences exist between the temperature and salinity of the deep water in the eastern and western basins. The deep water of the western Mediterranean has a mean temperature of 12.7 °C and a mean salinity of 38.4 ppt, while that of the eastern Mediterranean, only slightly heavier,(more dense) has a mean temperature of 13.6 °C and a mean salinity of 38.7 ppt (Hopkins, 1978).

The process by which surface water cooled by strong continental winter winds, (mainly the Mistral), is transformed into deep water has been studied in great detail in the northwest Mediterranean by a number of authors (Hopkins, 1985). Three phases may be identified:

i) The first phase occurs when the heat loss into the atmosphere from the surface water in areas located at the centre of cyclonic gyres is not balanced by the weak solar energy input of the winter. Because of the divergence associated with this type of circulation, this water tends to upwell thus facilitating the onset of the second phase.

ii) The second phase has been described as very pronounced, requiring the action of strong winds. Under their effect the water underneath the core of the gyre becomes vertically homogeneous to depths of more than 500 m, disrupting the intermediate layer (where it exists) and penetrating into the core of the deep water. When this happens, the entire water column is filled with "winter water" or deep water, and strong upward and downward vertical motions develop, with velocities up to 2.5 cm S^{-1}.

iii) The third phase, normally taking place in March, begins after abatement of the winds. The surface layer, warmed by the increasingly strong solar radiation, regains some of its former stratification and the column of dense water spreads laterally. This gives rise to deep water, intermediate "winter water" and surface water that is in fact warmed winter water with the high salinity typical of the deep and intermediate waters.

Although deep-water formation is known to take place only in a few locations with peculiar meteorological and hydrographic conditions, strong evaporation takes place during winter all over the basin due to the strong and dry continental winds prevailing. Mistral in the Rhone valley, Bora in the northern Adriatic Sea and Vardarac in the northern Aegean Sea are the most outstanding cold winds: warm winds such as the Sirocco originating in the Sahara desert and the Meltemi in the northern Aegean Sea, also contribute substantially to the evaporation of the surface sea water and the formation of Intermediate Levantine Water (Unluata et al., 1983).

Circulation

The forces that drive the flow of the surface North Atlantic Water into the Mediterranean Sea seem basically to be produced by a lower sea level in the Mediterranean, owing to the predominance of evaporation over precipitation and river runoff; and by a lower mean atmospheric pressure on the eastern Mediterranean compared with the Atlantic Ocean, creating a permanent "sucking" effect towards the east. Due to the weakness of the tidal forces in the Mediterranean Sea, tidal circulation is in general negligible except in the neighbourhood of the various straits, of areas like the Sicilian Channel and Sea of Crete, and of the north Adriatic. Motions caused by wind stress and atmospheric pressure distribution may be important components of the velocity field but the temperature/salinity forces created by the hydrographic structure already described seem to play the most important role in determining the general circulation in the Mediterranean Sea at all levels. The spatial distribution of density suggests that surface North Atlantic water flows through the Mediterranean Sea eastwards and intermediate and deep waters do the opposite before they both, well mixed, exit through the Straits of Gibraltar.

Nielsen (1912) proposed a surface circulation pattern for the entire Mediterranean Sea which is still widely referred to. Ovchinikov (1966) also produced a somewhat more realistic composite chart of the Mediterranean surface currents. However, the large number of straits and sills, especially in the eastern Mediterranean, complicates the actual circulation pattern not only of the surface layer, but also of the deep and intermediate water layers.

If the circulation of the surface layer is only known with a large degree of uncertainty, even less is known about the circulation of the intermediate and deep waters in both the eastern and western basins. The general displacement of these waters is from east to west and with the very few measurements of velocity that have been carried out, no more than a rough estimate of 5 to 10 cm s^{-1} may be given as the maximum velocities for the more important veins of intermediate water (Lacombe and Tchernia, 1974) that are presumed to follow a generally cyclonic circulation. The corresponding velocities are much higher in the Alboran Sea, the Straits of Gibraltar and the Sicilian Channel, where speeds up to 40 cm s^{-1} have been measured (Morel, 1971).

Basic knowledge of the circulation in most coastal areas of the Mediterranean Sea is severely limited and fragmented. Many direct current measurements have not been published either because they are made by private companies for specific purposes or because the full scientific analysis of the large data bases is too cumbersome.

Velocities in the coastal zone are mostly due to the transient disturbances caused by successive gusts of wind. Small scale eddies, often trapped in the inner shelf, are caused by the existence of topographical features such as islands, capes or embayments, further complicating local coastal circulation patterns. The longshore component of velocity generally predominates over the onshore-offshore component (Unluata et al., 1979) although point observations may often indicate the existence of important cross-shelf motions. Measurements of this kind should always be looked upon critically since a number of high-frequency elements are normally included in the coastal velocity field without much effect on the transport of water. At any rate, coastal circulation is a local phenomenon likely to vary from hour to hour and from place to place, following local meteorological conditions.

Chemistry

The Mediterranean Sea, although of a semi-enclosed nature, does not have a chemistry of its own. However, some distinctive features do exist in the Mediterranean Sea when compared to other oceans. In addition to its high salinity, comparable only to the Red Sea and other completely enclosed seas, the most outstanding characteristic of the Mediterranean Sea is the relatively low concentrations, even in the deeper waters, of some biologically important chemical consituents. This is caused by the continuous wash-out of the Mediterranean basin which receives through the Strait of Gibraltar poor surface North Atlantic water and exports the relatively rich deep Mediterranean water. Land runoff and sewage, although creating important enrichments in certain areas, cannot balance such a nutrient loss.

Of particular interest are the high oxygen concentrations observed in the deep Mediterranean waters. The oxygen distribution in the Mediterranean Sea is not substantially different from that of the major oceans, except that deep Mediterranean waters are oxygen-rich and often nearly at saturation. This is due to the relatively low concentrations of organic matter sinking to the deepest waters, especially in the eastern basin; to its extreme oligotrophic character; and to the short residence time of the waters in the basin (Cruzado, 1985). Thus deep-sea sediments are very poor in organic matter, and sustain a relatively poor deep-sea fauna.

Another peculiarity of the chemistry of the Mediterranean is the relatively high level of some trace elements, particularly mercury, selenium, arsenic, and cadmium of natural origin. This is apparently due to the existence of minerals rich in such elements in various areas around the Mediterranean Sea, and to the atmospheric emissions by volcanoes of the central Mediterranean Sea. However, this topic remains to be properly investigated.

Biology

The oligotrophic character of the Mediterranean Sea has led many authors to consider this as an impoverished sea. However, the productivity in terms of sustained fish yeld is comparable to other areas of the oceans, apart from the richest eastern boundary current upwelling regions. Various factors contribute to it:

1. In winter, when vertical mixing develops, nutrient-rich waters occupy an important section of the productive zone giving rise to a sustained primary production.

2. In spring and autumn, phytoplankton blooms develop as a consequence of the increased availability of sunlight while nutrient enrichment still persists.

3. In summer, a transfer of nutrients from the reserve in deeper waters to the shallower depths below the thermocline enables the existence of a deep phytoplankton crop commensurate with other regions having a larger reserve of nutrients but a reduced rate of supply.

4. Some areas around the larger rivers (Ebro, Rhone, Po, Nile, etc.) are highly productive due to the year-round nutrient discharges.

The Mediterranean ecosystem is a well characterized subprovince of the Atlanto-Mediterranean province, with a high number of endemic species and a considerable diversity of environmental conditions allowing the occurrence, though in different areas, of both temperate and subtropical benthic populations. In addition to the natural environmental and biotic factor which influence the structure and dynamics of communities, it is possible that anthropogenic influences have had a significant effect on Mediterranean biogeography (Sara, 1985).

The Mediterranean fisheries are governned by the low nutrient levels, leading to restricted productivity, and by the narrow continental shelf found in most of its shores. The total fish catch is estimated at 0.6 million metric tonnes approximating a standing crop of 0.24 $tm/km^2/y$ of fish for the Mediterranean. The estimated world fish catch is about 60 million metric tonnes, thus ranging between 0.16 and 0.28 $tm/km^2/y$ or 0.5 $tm/km^2/y$, if under-exploited stocks are included. The continental shelves in the Mediterranean are capable of producing nearly 0.96 $tm/km^2/y$ of fish, compared to a world average estimate of 3.44 $tm/km^2/y$ of fish. Total possible fish yield estimated for waters over the continental shelf is 1.9 $tm/km^2/y$. Ecological efficiency for the transformation of the primary production into fish, is assumed to be nearly 0.1 per cent for the Mediterranean Sea (Murdoch and Onuf, 1972).

The Mediterranean countries account for 8 per cent of the world's population, but consume 10 per cent of the world catch. Many of these countries must import fish to supplement their limited harvest. Except for the more developed fishing fleets of Spain, France and Italy, their resources are limited by the traditional gear often used by fishermen. Only the shallow inshore areas of the shelf can thus be harvested. Limited exploitation of for mid-water, bottom or migratory fish stocks, such as tuna, has occured.

III. ASSESSMENT OF THE STATE OF POLLUTION

The state of pollution of the Mediterranean Sea has been the subject of a number of scientific meetings sponsored by various international organisations (FAO/GFCM,ICSEM,UNESCO/IOC, UNEP, WHO, etc) during the last 20 years. Generally it can be said that manifest pollution problems, particularly as regards coastal waters of the Mediterranean, are caused mainly by the indiscriminate introduction of untreated domestic sewage and industrial waste waters, and by the largely uncontrolled discharges from rivers, agricultural runoff and atmospheric fallout, components whose contribution to the overall pollutant load of the Mediterranean Sea remains largely unknown.

As anywhere else on the world's oceans, pollution may not have changed greatly in the last two decades or so but man's perception of the matter has changed markedly. As public awareness grew, alarming voices were raised from environmentalists, scientists and politicians which led the coastal states to adopt the Mediterranean Action Plan in 1975.

In spite of the efforts made by participating laboratories in the Mediterranean Pollution Monitoring and Research Programme (MED POL) both during the pilot phase and since the long-term phase began in 1981, relevant information for the Mediterranean Sea, is still very limited. A proper assessment of the state of pollution of the Mediterranean Sea, along the lines proposed by the GESAMP Working Group on the Health of the Oceans (UNEP, 1982) would require information on:

a) The sources of substances and energy, existing and predicted quantities of pollutants and their distribution in the environment.

b) The processes leading to dispersion in the marine environment, the ultimate location of substances from a particular source, and the targets which may be affected.

c) The effects of pollution on various targets, and the ecological and public health significance of these effects.

The Mediterranean environmental data base, should still be considered as patchy and fragmentary.

Information on concentration levels in various compartments of the environment has been gathered, mostly through the various MED POL projects during its pilot phase (UNEP 1983):

MED POL I — Baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters.

MED POL II — Baseline studies and monitoring of metals particularly mercury and cadmium, in marine organisms.

MED POL III — Baseline studies and monitoring of DDT, PCBs and other chlorinated hydrocarbons in marine organisms.

MED POL IV — Research on the effects of pollutants on marine organisms and their populations.

MED POL V	Research on the effects of pollutants on marine communities and ecosystems.
MED POL VI	Problems of coastal transport of pollutants.
MED POL VII	Coastal water quality control.
MED POL VIII	Biogeochemical studies of selected pollutants in the open waters of the mediterranean.
MED POL IX	Role of sedimentation in the pollution of the mediterranean sea.
MED POL X	Pollutants from Land-based Sources in the Mediterranean.

Most of the information used for the present assessment has already been the subject of various sectorial assessments (WHO/UNEP, 1983; FAO/WHO/UNEP, 1983, 1985a, 1985b; IOC/IMO/UNEP, 1985).

However, in spite of a common methodology adopted by most scientists, sampling and analytical difficulties as well as patchy distribution of the results obtained, make comparison rather difficult.

<u>Assessment of pollutant inputs</u>

The most important sources of marine pollution are land based. Whether they are point or diffuse sources, coastal outfalls or rivers, they have always been considered as the major contributors to the pollution load entering the marine environment. Because they are concentrated along the coastline, their effect tends to be greater in coastal waters than that of other sources of pollution known also to make important contributions, such as atmospheric transport and maritime activities.

Pollutants may also be introduced by dumping, shipping, from structures such as oil drilling rigs built on the continental shelf, by incinerating vessels and by other human activities such as construction, land reclamation or river damming. Below is an assessment of the importance of each of these groups of pollutant sources for the Mediterranean Sea.

Land-based sources

The chief sources of marine pollution in the Mediterranean Sea, as in other oceans, are land-based. Pollutants may reach the sea through direct coastal outfalls, urban, industrial and agricultural runoff, rivers, and the deposition of airborne substances. The contribution of land-based sources to the pollution load of the Mediterranean Sea was assessed in the early stages after the adoption of the Mediterranean Action Plan, through the MED POL X pilot project on Pollutants from land-based sources in the Mediterranean (Helmer, 1977). From the results obtained during the project, Table 2 was prepared on the basis of country by country inventories as well as computational factors that were developed for the region (UNEP, 1983). Even so, the accuracy of the estimates cannot be considered better than an "order-of-magnitude" approximation. More accurate results obtained through the relevant monitoring activities in the MED POL - PHASE II programme will only be available after a number of years if the Mediterranean Governments undertake a serious effort.

Table 2 shows that the volume of water contributed by all the land-based sources is practically that of the river discharges. Natural runoff and direct municipal and industrial discharges constitute a minor contribution. Suspended substances from anthropogenic sources are of comparatively minor significance when compared to natural inputs, although a drastic increase in anthropogenic input has been observed in recent times.

Coastal sources and rivers both contribute, in approximately equal proportions, organic matter, (expressed as biological oxygen demand, BOD and chemical oxygen demand, COD). Phosphorous and nitrogen loads are mostly due to rivers, agricultural runoff and municipalities equally sharing the remainder. On the other hand, most detergents derive from coastal municipalities, while phenols and mineral oil discharges are almost entirely due to industrial activities with minor contribution from coastal refineries and oil terminals.

Discharges of heavy metals, largely of natural origin, are often due to river inputs although some metals may be equally contributed by rivers and coastal sources.

Persistent organohalogen compounds are mostly discharged through rivers and to a lesser extent from coastal industry discharges. The major compounds were found to be polychlorinated hydrocarbons (PCB).

The pilot project did not make any attempt to assess the inputs of radioactive substances. Another study, carried out under the sponsorship of UNEP's IRPTC programme (Woodhead, 1978), did assess the potential problems created by the inputs of radionuclides, particularly those derived from existing and planned nuclear power plants and nuclear fuel reprocessing installations. Such installations are largely concentrated in Spain, France and Italy, the three countries located in the northwest Mediterranean region (see section on Radionuclides below).

The following sections constitute an assessment of the various categories of pollutant sources that were identified:

Municipal inputs

According to the results of the MED POL X project (UNEP, 1984), domestic waste sources, (defined as cities of 10,000 or more inhabitants) are largely concentrated in a few areas:

- the northwest Mediterranean between Valencia (Spain) and La Spezia (Italy).
- The Tyrrhenian Sea between Rome and Naples and the coast of Sicily.
- The Italian coasts of the Adriatic and Ionian Seas.
- Other highly populated areas around large cities, such as Split, Rijeka, Athens, Thessaloniki, Izmir, Beirut, Alexandria, Tripoli, Tunis and Algiers.

Most of the urban sewage discharges are untreated, and often are not equipped with even the simplest mechanisms to facilitate the dispersion of the discharged, wastewater.

According to a survey carried out by the municipality of Barcelona (as the secretariat of the Union of Mediterranean Towns) which covered 75 coastal cities (from eight Mediterranean states), sewage treatment facilities existed in 1980, or were planned, in approximately 50 per cent of the towns surveyed. This accounted for not more than 30 per cent of the total sewage discharged (Tables 3 and 4). However, only 33 per cent of the towns had, at that time, an underwater outfall for disposal of the raw or treated sewage. Of the others, 13 per cent discharged their sewage along coastlines devoted to recreational activities. This is indeed a common practice in many countries around the Mediterranean (Barcelona, 1985).

Industrial inputs

Industrial waste sources are mainly concentrated in the northwestern Mediterranean. By sector, the main contributing industries are:

- leather tanning and finishing;
- iron and steel basic industries;
- production of chemicals (organic and inorganic), and
- petroleum and petrochemical industries.

Many of the greatest polluters discharge their wastes untreated or only partially treated, into urban sewers. Others use direct coastal discharges to avoid damage to the public sewers. A few do have treatment facilities, but their operation, largely uncontrolled, is often far from achieving any degree of protection for the environment. The discharges of "red muds" from the titanium oxide industries, highly acidic and loaded with a host of other toxic elements, have also been of special importance.

Agricultural inputs

Agricultural runoff is rare on the southern shores, except perhaps for limited areas such as the Nile delta and the Gulf of Tunis. This is an important route for nutrients, pesticides and sediments originating from land erosion, and is greatly enhanced by forest fires and other factors. Its greatest impact, particularly with regard to chlorinated hydrocarbons, has been in areas of intensive agriculture such as in cultures of flowers, rice and citrus, all of them taking place in the warmer coastal areas of southern European and Levantine countries.

Riverine inputs

River discharges are uneven both in flow rate and in pollutant loads. The rivers draining the highly populated areas of western Europe and the Nile contribute important loads, while those from the Balkans and Anatolia peninsula seem to be relatively free from pollution. Among those rivers identified as major sources of pollution are the Ebro, the Rhone, the Po and the Nile.

The first three of these rivers drain highly industrialized basins, including most of the nuclear power and fuel reprocessing plants. The Nile is heavily loaded with agricultural products. Data on the hydrology of the rivers draining into the Mediterranean basin are scarce. The International Hydrological Programme fostered a relatively thorough assessment of the water flowing into the sea, but failed to evaluate the pollutant load of the dissolved and particulate phases, particularly during the flood periods often experienced by Mediterranean rivers.

Atmospheric Inputs

There is no doubt that pollutants are transported via the atmosphere to the Mediterranean Sea. Both local sources near the basin, and source areas up to thousands of kilometers away contribute to the pollution of the atmosphere and the sea. At certain times, natural materials such as the Saharan dust and volcanic emissions can be important sources for some trace substances to the Mediterranean region. With the realization that atmospheric transport may be a major pathway for many marine pollutants, it has become extremely important for the countries that ring the Mediterranean, as well as for other regions around the world, to understand the possible seriousness of the problem.

To this end, a Working Group was established at the request of UNEP, by GESAMP, to review current knowledge in the field of atmospheric transport, with special emphasis on the Mediterranean area (WMO/UNEP, 1985b). The data available so far on atmospheric concentrations of pollutants over the Mediterranean derive from a few recent oceanographic cruises. The most - studied pollutants to date have been the heavy metals and metalloids, such as vanadium, chromium, manganese, copper, zinc, arsenic, selenium, silver, cadmium, antimony, mercury, gold and lead. Very limited data exist for other pollutants such as chlorinated hydrocarbons (PCBs) and artificial radionuclides (e.g. Plutonium - 237 and 240).

The assessment made by the GESAMP Working Group focused on the two best studied elements (lead and cadmium) which originate largely from anthropogenic sources. Table 5 presents a summary of atmospheric lead and cadmium concentrations over various regions of the Mediterranean. Atmospheric concentrations span two orders of magnitude, with extreme variability noted over very short time periods (hours to days). Within the Mediterranean, it is apparent that Pb and Cd concentrations in the atmosphere are 5 to 10 times higher in densely populated coastal regions than over open waters. The range of mean atmospheric and rainwater concentrations of lead and cadmium over the Mediterranean are comparable with those over other regions such as the Baltic and North Sea (Table 6). These concentrations are an order of magnitude greater than concentrations in remote regions of the South Pacific. Direct assessments of total atmospheric deposition (wet and dry) of pollutants into the Mediterranean are not possible, as there have been very few reliable measurements of pollutant levels in rain. The estimate of total atmospheric deposition into the Mediterranean presented in Table 6 is based on a total deposition velocity of 1 cm s^{-1}. It does not differ appreciably from those estimated for other regions around Europe, while Atlantic and Pacific depositions are lower. As demonstrated in other oceanic regions, rain can be expected to account for most of the atmospheric deposition into the Mediterranean. Thus, seasonal variation in the flux of pollutants into the Mediterranean should occur, with greater deposition occurring during rainy periods.

The few measurements of organic pollutants in the Mediterranean atmosphere which have been made, suggest that PCB (chlorinated hydrocarbons) concentrations are lower than in North Sea air and comparable to open ocean regions of the Atlantic and Pacific (Table 7). By contrast, concentrations of n-alkanes, both in particulate and vapour phases, are substantially higher than over the Pacific. No measurements of organic pollutants in rain over the Mediterranean seem to exist.

In comparing total atmospheric input of metals into the Mediterranean with riverine input, it is clear that both are significant and comparable sources of pollutants (Table 8). Similar conclusions are drawn from studies in other regions. It is noteworthy that deposition of the transuranic elements derived from nuclear weapons tests in the atmosphere of the Pacific is detectable over the Mediterranean. Thus, very long range atmospheric transport of pollutants clearly occurs over the Mediterranean. The association of metals and other pollutants with very fine aerosol particles (<1 um) clearly indicates that these pollutants have been transported over very long distances.

Air over coastal regions has greater pollutant concentrations than open-ocean air (Table 5), suggesting the possibility of enhanced atmospheric deposition of these pollutants in coastal areas. There have been few studies of this problem in the Mediterranean. Clerici (in press) calculated deposition of cadmium around some large industrial centres in Italy. Palumbo and Iannibelli (1985) showed that atmospheric deposition of iron, copper, zinc, cadmium and lead was a major factor in pollution in the Bay of Naples. Other studies on the offshore transport of heavy metals are currently being undertaken as part of the MED POL programme.

Indirect estimates of metal emissions (based on consumption data, evaluation of metal content of raw materials, the physical/chemical properties of the metals, technology of production and the efficiency of emission control devices) are available for European countries since 1979 (Pacyna et al., 1984) but no data for any kind of pollutant exist for the North African region. Organic pollutant emissions from European sources are also unknown. The most accurate estimates are probably for lead, cadmium and arsenic, while data for other metals warrant much further study. In the context of modelling long-range atmospheric transport of these pollutants, there is almost no available information on single large sources. The estimated atmospheric deposition of lead, zinc and chromium over the Mediterranean represents approximately 5 to 20 per cent of total European emissions of these metals.

Natural sources of trace elements are volcanic activity, soil erosion, and the ocean itself. Studies of emissions from Mt. Etna indicate that volcanic activity may be an important source of selenium, mercury, arsenic and cadmium for the central and eastern basins of the Mediterranean (Buat-Menard and Arnold, 1978; Martin et al., 1984).

Soil erosion can be a major source of metals in the atmosphere, but is very episodic in nature. The annual input from soil erosion, including the periodic but pronounced storms bringing in Saharan dust, has not yet been quantified.

Aerosol production from the ocean surface may result in the recycling of certain pollutants (heavy metals, radionuclides, bacteria, organic compounds). The importance of this phenomenon has not been assessed for the Mediterranean. It should be pointed out than in coastal areas this phenomenon might significantly contribute to the atmospheric concentrations of these pollutants under sea-breeze conditions.

The subject of atmospheric inputs can be summarized as follows:

It has been shown that the concentrations and depositions of certain atmospheric pollutants (eg. lead and cadmium) over the Mediterranean are comparable to those over the Baltic and the North seas. For lead, zinc, copper and mercury the atmospheric input to the Mediterranean appears to be of the same order of magnitude as the input from rivers. Though many more pollutants must be measured, the initial evaluation leads to the conclusion that the Mediterranean basin may be substantially polluted by atmospheric input.

The overall pollution sources are poorly known, especially in the North African area. The unknown relative importance of local and remote sources complicates their evaluation. Determination of the type, magnitude, and location of the sources is a critical aspect in evaluating the impact of airborne pollution on the Mediterranean.

The Mediterranean region has a very complex weather regime. Based on the prevailing trajectory climatology, however, the following can be stated:

- Long-term pollutant flow to the western Mediterranean takes place from the north at least 30 per cent of the time, with no detectable seasonal variation.

- Transport to the eastern Mediterranean is mainly from the north and north west, where industrial sources could contribute to pollution loadings.

- Flow patterns and therefore pollutant transport vary significantly from year to year.

Considerable research is still needed to better understand atmospheric pollutant transport to the Mediterranean basin.

Maritime sources

The maritime sources are second in importance to the land-based sources of pollution. No attempt has ever been made to assess the overall inputs of pollutants into the Mediterranean Sea from ships and other platforms in normal operations, dumping emergencies and accidents; nor has the flux of pollutants in the sea water flowing through the Straits of Gibraltar and the Dardanelles been quantified.

Below is an attempt to assess the pollutant loads contributed by the various types of maritime sources:

Adjacent seas

Although the flux of water from the Atlantic Ocean and Black Sea is known with some degree of certainty, no figures exist for the flow of pollutants through the Straits of Gibraltar and the Dardanelles. The situation is basically different in each case. The flow through the Dardanelles allows the Black Sea and Sea of Marmara to flush out into the Mediterranean while the opposite holds true at the Straits of Gibraltar.

The Black Sea receives several of the largest rivers in Europe, receiving heavy pollution loads from the highly industrialized central European countries and from agricultural runoff of vast areas of central and eastern Europe. The Sea of Marmara receives, in addition, important domestic and industrial wastes from the Istanbul metropolitan area.

On the other hand, the North Atlantic Ocean water is often quoted as being relatively free from pollution. Influence can be expected from the shores of northwestern Europe, north and western Spain and Portugal. However, the large mass of water involved in the Iberian/Canary current and the divergent circulation in the area tends to cause coastal pollution to be driven away from the Straits of Gibraltar.

On the whole, while the Dardanelles might be considered as contributing to the overall pollutant load of the Mediterranean, the Straits of Gibraltar can be considered as tending to reduce it.

However, further oceanographic research is needed since until recently, very little has been achieved through ICSEM and IOC sponsored efforts. Only recently have Mediterranean and other states undertaken investigations into the water balance of the basins and the mechanisms by which transport of substances may take place.

Shipping and fishing

Shipping is an important source of marine pollution. In addition to the wastes generated by the crews and passengers, other wastes are caused by the operation of the ships: bilge waters, oily residues, nets, cables and all kinds of solid and liquid refuses are normally discharged overboard. Oil tankers add to all these wastes the oily ballast pumped out just before calling at oil-loading terminals. The short duration and high frequency of Mediterranean voyages, and the absence of ballast-receiving facilities at oil terminals makes it almost impossible for tankers to operate without heavy oil pollution. This happens mostly on the southern shores, namely Libya and Algeria, the main producers of oil in the Mediterranean region (see section on Persistent solids below).

Dumping

This type of pollution source has never been previously assessed. Although a great effort was made in the framework of the Mediterranean Action Plan, to develop legislation to control dumping, no parallel effort was made to assess its contribution to the overall pollutant load. However it is probable that dumping of wastes makes a limited contribution to the total discharge of industries and municipal wastes to the Mediterranean.

According to the formal reports made by the Mediterranean Governments under the provisions of the Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft (UNEP, 1985a), only minor amounts of pollutants reach the sea through this route. Only dredging of polluted harbours may represent a real threat to the environment in the dumping grounds. However, as more sewage treatment plants are built, dumping may be an attractive alternative method to land-disposal of sludge.

Dumping of radioactive wastes into the Mediterranean Sea was forbidden by a resolution of the Contracting Parties to the Barcelona Convention at their second meeting (Cannes, 1981).

Emergencies

The major cause of concern relating to emergencies has been discharges of oil, either from ships or from loading and unloading terminals. The Regional Oil Combating Centre keeps records of those oil spills requiring a certain degree of combating activities (Table 9). However, many emergencies do not concern oil spillage, or are not recorded. Shipwrecking in various areas of the Mediterranean Sea, particularly in the central part, occurs with amazingly high frequency. The sunken cargoes, often posing a certain risk for the environment may be suddenly or slowly released.

One example is the Yugoslav cargo CAVTAT, loaded with drums of highly toxic tetraethyl lead which was sunk in the Adriatic Sea, off the Italian coast, close to Straits of Otranto. The risk posed by such an accident was so large that a very costly rescue operation had to be mounted and was successfully completed. Other emergency situations have been recorded but less well documented, such as the case of the US B-52 strategic bomber releasing various nuclear bombs over the southeast coast of Spain after an in-flight refuelling accident, which could result in the release of toxic and highly radioactive material into the environment.

Purposeful sinking of distressed ships has also been used to avoid greater risks. Such was the case of the Cavo Cambanos, a Greek tanker which after being set on fire off the coasts of Spain drifted towards the coasts of Corsica and Sardinia where it was blown up by the French Navy after a well planned exercise which was followed by a detailed monitoring of the area.

Offshore platforms and deep-sea mining

Offshore drilling and oil-extracting platforms are known to contribute substantial amounts of pollutants. Not only oil can leak out in normal operations and accidents but other pollutants such as PCBs , detergents and other wastes are released into the environment. No information has been obtained as to the amounts of pollutants discharged from offshore platforms but oil spills caused by minor accidents have generated concern in various areas of the western Mediterranean and in the Aegean Sea.

Experience with similar installations in the North Sea has shown that unacceptable amounts of polluted muds are often released by oil exploration drilling platforms. There is no reason to believe that those in the Mediterranean Sea would do otherwise.

Fortunately, no deep-sea mining has yet been undertaken in the Mediterranean Sea. However, pipeline laying and sonic prospecting have caused wide concern to Mediterranean fishermen, who claim that fish kills have occurred. More serious, however, may be the practices of dynamite fishing and coral dredging, which still occur in some areas of the Mediterranean.

Incineration

Shipboard incineration of highly toxic organic substances is current practice by some of the more developed countries. Strict regulations have been established to control the efficiency of incinerating plants, thus minimizing the flow of pollutants into the atmosphere and the sea in the vicinity of the incinerating vessel. Fortunately, there are no incinerating vessels operating in the Mediterranean Sea and the effect of those operating elsewhere contribute only remotely to the long range pollution transported through the atmosphere from remote sources.

Assessment of pollutant levels

An assessment of the present levels of pollution in the Mediterranean Sea, with regard to the categories of pollutants which may have a greater impact on the marine and coastal environment, is summaried in the following sections.

Microbial pollution

The threat to public health from microbial pollution of the marine environment stems from two different uses of it, from recreation and through consumption of seafood (Pavanello, 1978). Organic matter and suspended solids, which usually are present in large quantitities in waste waters can greatly enhance the survival of pathogenic micro-organisms.

Biological agents present in the marine environment which are likely to be of public health importance include those pathogenic organisms present in sewage, discharged without treatment or with partial treatment, into rivers and coastal waters. Other sources of pathogens are wastes from animal farms, slaughter house waste waters, and rodents living in sewers.

Microbial pollution in most cases results from direct discharge of untreated or partially treated wastes. The importance of ensuring adequate water quality is obvious in view of the popularity of the Mediterranean coastal resorts and the demand for high quality seafood. In this respect one must note that in the Mediterranean over 70 per cent of municipal wastes are discharged into the sea untreated, causing nuisances and potential health hazards. Ecological considerations, such as relatively high temperatures, serve to highlight the importance of remedial action.

Consumption of shellfish grown in polluted water has long been recognised as an important cause of typhoid fever and other enteric diseases. Evidence is also available that cholera and infectious hepatitis can be transmitted in this way. In the Mediterranean basin, because of the large consumption of shellfish, epidemics of enteric diseases from this cause still occur.

The most important factor determining the suitability of water for bathing and swimming is of course the presence of pathogenic organisms and it is obvious that such recreational water must be reasonably free from bacteria or other organisms indicating possible sewage pollution.

Many epidemiological studies have been conducted in several parts of the world including the Mediterranean region. The diseases that are most relevant are those known to spread by the faecal/oral route, partly because the causal agents are present in sewage and partly because of their capacity for natural dispersion in this manner, as is testified to by the very history of water-borne diseases. Other infectious conditions may be caused by microorganisms that are often, if not always, present in man but which give rise to disease only when, for one reason or another the resistance of the individual harbouring them is lowered. Such microorganisms may be found in polluted water. Another common route for diseases is infection of skin, eyes and mucoses by bacteria, fungi and yeast which are often found in polluted water and sand.

It is generally recognised that health hazards associated with the presence of microbiological agents in coastal waters are dependent on a large number of factors and conditions which vary widely geographically and climatically. They also depend on the presence, and degree of endemicity, of various diseases, as well as on the habits of populations living in coastal and inland areas. The enormous increase of the number of tourists and non-resident persons concentrating in certain periods of the year on Mediterranean beaches and coasta areas has created new problems (WHO/DANIDA, 1976).

Some scientists speak of the phenomena of self-purification and antibiotic power of sea water. Factors acting upon microbes discharged with sewage into the sea, include light (different kinds of solar radiation), temperature, chemical composition, pressure and others. It has been demonstrated that bactericidal radiation penetrates to a depth of a few centimeters. Bacteria and viruses do exist which have a very low resistance to a range of environmental conditions outside their normal ones, and this may be the cause for their rather rapid disappearance.

One of the most important physical factors which must be considered is adsorption. Floating living and non-living particles such as plankton, organic particles and colloids, always present in polluted water, tend to absorb microbes thus giving them a means of support and a favourable micro-environment for survival and development. Microorganisms fixed on particulate matter in the marine environment follow the fate of the particles themselves and will flocculate, disperse or sediment with them, ultimately settling to the bottom.

Salt has little or no effect on many bacteria, fungi, yeast and viruses altough it might be responsible for a slight reduction of their number. The marine environment, apart from heavily polluted waters, is well known for its deficiency in absorbable organic matter. If microorganisms discharged with sewage become diluted by sea water and find themselves in a milieu which is poor in organic nutrients they will have a lower resistance and this may lead to their disappearance. Pathogenic microrganisms do live for a certain time after their discharge in the marine environment. Some disappear sooner than others, but it has to be taken into account that their discharge with sewage is massive and continuous , especially in high endemicity areas, thus compensating for their disappearance through dispersion.

A general picture of the microbial water quality for the Mediterranean has emerged from the work spanning the past decade within the jointly coordinated Mediterranean Pollution Monitoring and Research Programme (MED POL) adopted by the Mediterranean Governments in 1975 as the scientific component of the Mediterranean Action Plan. This awareness resulted in a concerted action for obtaining information necessary for an assessment of the situation.

In order to assess the state of microbial pollution in the Mediterranean a pilot project on Coastal Water quality Control (MED POL VII) was carried out during MED POL PHASE I. As a result, a full assessment of the sanitary quality of recreational and shellfish-growing areas was carried out by WHO and UNEP (WHO/UNEP, 1985). The selection of sampling stations was not random, and the case of shellfish-growing areas were determined by the location of shellfish. Furthermore, the number of the collaborating institutes was large with a wide spatial distribution. Thus, the conclusions derived can be considered as representing the general situation around the Mediterranean. Based on 12500 analyses from 864 stations throughout the Mediterranean basin, the microbiological quality of recreational waters was analysed according to WHO/UNEP interim criteria, and the results are presented in Table 10. It is evident that 76 per cent of the sampling stations complied with the WHO/UNEP interim criteria for microbiological quality of recreational waters.

On the other hand, results obtained from the monitoring of shellfish and of shellfish-growing water, when compared to the WHO/UNEP quality criteria, showed that only 3 to 4 per cent of the monitored stations were suitable for direct consumption of shellfish. Of course, the accepted practice of keeping shellfish in clean waters prior to their sale reduces their danger to some extent. All these criteria were a direct result of scientific collaboration within the MED POL Programme.

A direct offshoot of the field studies carried out was the acceptance by a number of Mediterranean Governments of the methods and criteria proposed into their public health protection schemes. In addition, scientific knowledge of the different survival patterns of the three microbial indicators was obtained. While total coliforms and faecal coliforms seem to be inactivated in sea water rather quickly under natural conditions, faecal streptococci show a lower inactivation rate, outnumbering the other two indicators in the marine environment in contrast to what is normally observed in raw effluents. This supports the argument for the inclusion of faecal streptococci in routine monitoring programmes.

Bacterial pollution is often associated with eutrophication in enclosed sections of coastal areas or brackish lagoons. Eutrophication, infection of shellfish by heterotrophic bacteria, and general damage to ecosystems, render impossible the exploitation of zones with great potential for aquaculture.

As a result of occasional pollution of the sea, some recreational activity has shifted into artificial swimming pools creating its own characteristic health problems. Furthermore, not enough studies have been undertaken of transmission of infections through sand or shower zones, which may be relevant in epidemiological studies.

National monitoring programmes have been established in the framework of the long term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MED POL - PHASE II), and are being carried out in order to improve and safeguard the quality of Mediterranean recreational waters and shellfish growing areas. There is little doubt that such programmes are slowly changing earlier practices about indiscriminate use of the coastal zone for both recreational and shellfish-growing purposes and as a medium for sewage disposal. More and more, Mediterranean Governments are becoming concerned about environmental health problems, and regulation are being established to limit the exposure of bathers and shellfish consumers to contamination. At the same time, the number of sewage treatment schemes is growing, though probably not at the required pace.

Metals

Pollution by metals arises from various land-based operations such as mining, milling and smelting activities, metal plating and assorted manufacturing processes. Some of the metals may enter the sea through the aquatic route, while a certain proportion reaches the oceans via the atmosphere, mostly when it is washed out by rain. The amount of iron, manganese, copper, zinc, lead, tin and antimony entering the sea through river discharges is an order of magnitude higher than the amount produced by natural geological processes. Smelter emissions may transmit substantial quantities of metals into the atmosphere. The same holds true for coal-burning thermal plants and metallurgical industries (see section on atmospheric inputs above).

Nevertheless, sea water concentrations of metals in oceanic areas are still regarded essentially as at "background" levels; however, some compartments of the marine environment show important anthropogenic increases in the concentration of some elements.

Lead is a good example of a major element whose natural geochemical cycle has been clearly altered by man, leading to concentrations of lead in the surface waters of some parts of the oceans at above background levels. The use of tetraethyl-lead as an anti-knock agent in gasoline and, the emissions from steel plants have increased the flux of lead to the atmosphere by an order of magnitude over the natural flux. Other metals may exhibit comparatively high local concentrations in nearshore waters, where there may be industrial or urban sources of these metals, but their global budget has not been significantly altered.

The Bureau of the Contracting parties to the Mediterranean Action Plan, at its very first meeting in 1979 pointed out the necessity of developing quality criteria for heavy metals. Among these, mercury was the most prominent contaminant due to its high toxicity, which had been well documented. Earlier studies on Mediterranean fish had already shown abnormally high concentrations in certain fish. Man, who is at the upper end of the food chain, is liable to take up mercury from contaminated seafood.

A full assessment of the levels of pollution of the Mediterranean Sea by Mercury was carried out by FAO, WHO and UNEP (1985). Table 12 gives an approximate picture of mercury concentrations in sea water and sediments. These values must be regarded with caution due to sampling and analytical problems. Furthermore, available data are not amenable to statistical treatment. Therefore, it cannot be concluded that Mediterranean waters and sediments have significantly higher concentrations of mercury than other open ocean areas (FAO/WHO/UNEP, 1985). There is, however, considerable data on the concentration of mercury in marine organisms. Most of it was gathered through MED POL II, IV and V pilot projects. Table 13 compares values reported for various species of Mediterranean fish, molluscs and crustaceans. As yet the available information from the Mediterranean and neighbouring seas does not give a plausible explanation of the higher mercury levels reported in Mediterranean tuna and several other pelagic species. Observed mercury levels in water and sediments are not sufficient to account, according to existing models for mercury accumulation for the high levels observed in some Mediterranean organisms. This enigma (Fowler, 1985) will need further attention in view of the hazardous nature of mercury and in view of the commercial importance of meny pelagic fish to the region in general.

Even though the risk for the population at large has been estimated to be negligible (FAO/WHO/UNEP, 1985), at the present time an accurate evaluation of health hazards through consumption of mercury in sea food by high-risk groups such as fishermen, children or pregnant women is difficult due to the limited amount of available dietary information. This is particularly true as regards levels of methylmercury intake (FAO/WHO/UNEP, 1985). Hence there is a need to carry out further study taking into account levels of mercury in the consumers, the seafood and the environment, its mechanisms of accumulation and the synergistic or antagonistic effects of its toxicity in relation to other hazardous substances. It is fortunate that, as yet, there have been no health problems as far as coastal communities are concerned but urgent study of high-risk population groups is important.

Although there is a paucity of data in comparison with mercury, the same general conclusions apply to other metals such as cadmium, copper, zinc and lead. Generally higher values are found in estuarine sediments and near "hot spots", with values decreasing towards the open sea (Bernhard 1978). Inputs of other hazardous metals have not been properly evaluated. The input of metals has not had proper evaluation and assessment. The input of these metals is expected to rise as a result of anthropogenic activity such as agriculture, mining and industrial processing of ores and metals. Rivers appear to be the most important source of lead, chromium and zinc in the Mediterranean, followed by atmospheric inputs of lead and zinc (FAO/WHO/UNEP, in preparation). The values available usually refer to the Mediterranean coastal sediments only, and no definitive information exists for estimating their levels in the Mediterranean as a whole.

Table 14 gives a summary of the concentration of several metals in open waters, in coastal waters and in sediments. Table 15 gives the levels for nine different metals found in *Mytilus* in different regions of the Mediterranean. Comparisons with the open seas are difficult, although studies conducted on mussels (Tables 14 and 15) do not show increased concentrations (except for lead) when compared with North Sea or Arctic mussels. A close inspection of Tables 12 to 15, however, reveals the wide range and geographical variation in the concentration of the studied metals reported

Chlorinated hydrocarbons

The chlorinated hydrocarbons are but a few of the synthetic compounds that are known to enter the marine environment. They originate largely from terrestrial application, including pesticides used in agriculture and forestry. These synthetic chemicals may reach the sea through agricultural runoff and rivers, but a comparatively large proportion is transported seaward in the atmoshpere by winds and is ultimately washed out by rain. In addition, industrial chemicals, such as polychlorinated biphenyls (PCBs), used in various industries leak into the environment and eventually reach the sea through direct discharges, rivers, urban and industrial runoff, as well as from the atmosphere.

After entering the marine environment these hazardous substances may accumulate in marine organisms. They may affect the food chain by their adverse effects on the phytoplankton, bringing about undersirable changes in the ecosystem. One possible result of their bio-accumulation and long persistence is that, in the absence of concerted action, their concentrations may reach unmanageable proportions. The damage to the environment as well as the high costs of abatement may reach a stage beyond the capabilities of many states.

In the northern hemisphere, at least at middle latitudes, the use of such halogenated hydrocarbons as DDTs and PCBs was curtailed around 1972 (although other pesticides, e.g. toxaphene, have taken the place of DDTs) and they have thus generally shown decreased concentrations in estuaries and coastal waters along the North Atlantic and Pacific during the last decade. Their application in tropical and subtropical areas has, however, not been substantially abated, and in the southern hemisphere has increased. Generally speaking, their use in the less developed countries is expected to rise (Barney, 1980). Substituting such compounds by "safe" and biodegradable chemicals could bring about some improvement.

Abundant literature is available on the toxicity of organochlorine pesticides such as DDTs and PCBs (Geyer et al., 1984). Apart from the controversial nature of certain health problems: (their carcinogenic nature, toxicity, persistence and bio-accumulation), their relatively slow elimination and degradation have brought these hazardous substances to the attention of Mediterranean scientists and administrators.

Unfortunately, no reliable data exist on the overall impact of chlorinated hydrocarbons in the Mediterranean. Available information from a few industrialized countries does not suggest any decrease in levels, although general measurements of PCBs in aerosols and sea water indicate a slight reduction.

Table 16 summarizes data available on levels of chlorinated hydrocarbons, obtained through the MED POL III IV and V pilot projects. Table 17 gives data on chlorinated hydrocarbon residues in euphousids (crustacea) from different regions of the open Mediterranean, while Table 18 gives values for PCBs in marine samples from the Mediterranean Sea as compiled by Fowler (1985). The apparent difference in levels for the various sub-regions of the Mediterranean, e.g. Tyrrhenian and Algero-Provencal basins, is attributable to industrialization and/or proximity to major point sources such as rivers.

Transfer of relevant technology for analytical methodology has not been as efficient and successful as for heavy metal analysis, partly due to the complexity of the instrumentation and methodologies required. A serious effort must be made to monitor and collect reliable data from all regions of the Mediterranean; more Mediterranean laboratories need assistance in upgrading their analytical capabilities for the determination of these contaminants in marine organisms, sea water and sediments, enabling fuller coverage of the Mediterranean region. Parallel to this approach, the national science funding agencies in all Contracting Parties should increase support to scientists allowing for a better fulfillment of their role in the respective national monitoring programmes.

Petroleum hydrocarbons

It is unfortunate in relation to oil pollution problems that more attention is given to major accidents involving huge oil spills than to the presence of unmanageable amounts of tar balls deposited along coastal stretches used for recreation. Though accidental oil spills from large tankers are most dramatic, only a small part of the total petroleum hydrocarbons arises thus. Various routes have been identified as having an important contribution. According to the assessment made by the IOC, IMO and UNEP (1985), the amount of oil introduced into the world's oceans annually has been estimated to lie somewhere between 1.8 and 8.6 million tonnes, of which between 1.0 and 2.6 million tonnes come from various sources related to transportation of oil by sea, but only about 0.35 - 0.43 million tonnes of that is attributable to tanker accidents. In addition, production platforms with 0.04 - 0.07, atmospheric input with 0.05 - 0.50, municipal industrial wastes and run-off with 0.70 - 2.80 and natural steps/erosion with 0.03 - 2.60 million tons annually are estimated to contribute to the overall pollution by petroleum hydrocarbons.

Oil pollution is not a new phenomenon in the Mediterranean. Natural seeps have existed over geological times in the northeastern part. However, oil pollution of anthropogenic origin is a relatively new phenomenon. The sources of oil in the Mediterranean are numerous: terrestrial runoffs, natural seeps and large accidental or deliberate releases. However, there is a consensus that chronic hydrocarbon pollution is far more important than accidental pollution. Also the amounts of tar balls floating or deposited along the shorelines, together with oil films on water are substantial. The R/V Atlantis II, during a Mediterranean cruise in 1970, reported considerable amounts of floating tar balls and oil, up to 500 litre/km^2. In fact, the Mediterranean is considered to be more polluted by oil than any other sea for which data are available (IOC/IMO/UNEP, 1985).

Estimates of total amount of oil released into the Mediterranean range between 0.1 and 1.0 million tonnes per year, with a most probable figure being 0.8 million tonnes per year, compared to 4 million tonnes per year worldwide (IOC/IMO/UNEP, 1985). Also, about 350 million tonnes of oil cross or land within the Mediterranean each year, which is accounted for by 35 per cent of the world's tanker fleet using Mediterranean routes. Oil and natural gas play a key role in the Mediterranean basin for consumption and production. Oil covers about 64 per cent (1980 figures) of the energy consumption within Mediterranean countries. Available forecasts indicate that between 1985 and 1995 the world's oil production will reach its maximum between 5 and 6 billion tonnes per year and then will decline to the level of the 1970s (IOC/IMO/UNEP, 1985).

With 60 refineries located along its coasts and with some of the most congested shipping lanes, the Mediterranean has nevertheless been spared from major oil spills. The topographic, ecological and hydrometeorological conditions of the Mediterranean make it vulnerable to pollution by hydrocarbons. Tar balls, for example , are left within the confines of this system as a result of surface water circulation, to be deposited eventually along the shores. The touristic and economic implications of such a situation are all too evident.

World-wide a major effort has been made to assess the consequences of oil pollution. The extent of damage to the marine ecosystem and the time required for recovery of affected zones depend on a number of parameters: time of year when an accident occurs, sea state, meteorological conditions, type of environment and type of oil spilled. However in the case of the Mediterranean with its particular characteristics, little has been done to study and assess, the potential hazards of oil pollution.

As part of the MED POL I pilot project, visual observations of oil slicks were systematically made. Surface slicks were present in more than 10 per cent of the observations throughout the region. Similarly, considerable amounts of tar balls deposited along Mediterranean shores, particularly in the North African countries, were continually reported (IOC/IMO/UNEP, 1985), evidence of this area's extensive surface pollution as compared to other regions.

An assessment of the petroleum found in the Mediterranean has been recently prepared by the IOC, IMO and UNEP (1985). Generally, the concentration of dissolved and dispersed petroleum hydrocarbons were less than 5 ug/l in the region. However, heavily contaminated areas were frequently observed outside industrialized zones along the coast. Similarly, along the shipping lanes in the eastern regions, where discharges of oil from ships were until recently permitted, higher values of up to 50 ug/l were reported.

Less information is available for the concentration of petroleum hydrocarbons in sediments. Results indicate high values near oil terminals and river months. Similarly, there is a paucity of data for the concentration in organisms. However, in the absence of systematic and comparable results, higher concentrations among fishes are found near major rivers and industrial sources. The effect of these substances on the smell and taste of fish elicits adverse consumer reaction (see section on Tainting below).

The figures given in Table 9 for oil spills in the Mediterranean show a noticeable and virtually continuous decrease in the total number of oil spills recorded, particularly of larger spills. However, these positive trend should not leave the Mediterranean states with a false sense of security. The risk is always there.

Radionuclides

The capacity of marine water masses to disperse, dilute and render harmless those noxious substances introduced as a consequence of human activities can be legitimately regarded as a resource open to rational exploitation. However, this is only one of the many properties of the seas and it cannot be exploited to the extent of damaging other, equally useful, aspects of the marine environment without careful accounting of the relative benefits and costs of alternative courses of action. Such an approach depends on the ability to identify and quantify those pathways which lead from the point of introduction of the noxious substances to the point at which damage may occur (Woodhead, 1978).

In the case of the disposal of radioactive wastes into the marine environment, the prime requirement has been and continues to be the restriction of the radiation exposure to members of the general public within internationally recommended limits, and generally as far below these limits as is readily achievable, with all relevant economic and social factors being taken into account (ICRP, 1977). The exposure of humans may be internal, through ingestion of contaminated seafood or water derived from the sea, or external, due to leisure or commercial activities in contaminated waters or beaches. A pathway which has attracted recent attention concerns the possibility of internal exposure following the inhalation of contaminated particles derived from sea spray or wind-suspended, dried, beach sediments.

Radioactivity has always been a property of the marine environment due to the presence of long-lived radionuclides generated during the primordial synthesis of the elements making up the Earth, and also to the presence of radionuclides produced via the interaction of particulate cosmic radiation with the consituents of the atmosphere.

The ionizing radiations emitted as a consequence of the decay of these natural radionuclides are of the same kind and quality as those arising from radioactivity generated by human activities. Table 19 summarises the concentrations in Mediterranean seawater of the most abundant natural radionuclides together with the type and energy of the emitted radiation and an estimate of the corresponding total radioactivity present in surface water up to a depth of 100 m.

Potassium, carbon and hydrogen are essential elements in biological tissue and their radioisotopes are therefore invevitably incorporated into plants and animals. The remaining elements have no known biological function but are nevertheless accumulated by absorption onto the surface of biota or by absorption from ingested water and food. In certain organs of some aquatic animals ^{210}Pb is accumulated to such an extent that it becomes the predominant source of radiation dose despite having an external water concentration which is 3 - 4 orders of magnitude lower than that of ^{40}K.

Up to now, more than 500 nuclear devices have been tested in a variety of environments. Of these, perhaps a quarter have been underground explosions in conditions in which the majority of the radioactivity generated has been contained. For the remainder, a substantial proportion of the radioactivity entered the marine environment directly (underwater tests or surface tests on small coral islands) or indirectly as fallout. Clearly then, the whole range of fission product radionuclides and a variety of activation product radionuclides could, in principle, have been detected in marine environments. However, short half-lives or low fission yields or a combination of both have meant that the concentrations of many of the radionuclides in the water have been below the limits of detection.

As no tests have taken place in the Mediterranean basin (the nearest being the French series in the Sahara) the input from this source derives entirely from tropospheric and stratospheric fallout and data have been obtained mainly for the longer-lived radionuclides. Some measured values of the concentrations of certain fallout radionuclides are given in Table 20, together with very approximate estimates of the corresponding inventory in the surface waters of the Mediterranean Sea. Because of radioactive decay and the action of biological, hydraulic and geochemical processes these concentrations are lower than those which were attained during the period following the last extensive series of atmospheric weapon tests in 1961-62. For example, a peak value of 0.74 pCi l^{-1} of strontium-90 was recorded in the Adriatic Sea in 1962, although observations made in subsequent years showed rapidly declining values in this and other regions of the Mediterranean (Volchok <u>et al.</u>, 1971). Meaningful comparisons of the concentration data given in Tables 19 and 20 are strictly possible only for tritium and carbon-14.

From these tables it can be seen that weapons tests had increased the tritium concentration of Mediterranean surface waters by an order of magnitude over background in 1974 and that of carbon-14 by 40 per cent over background in 1975. Thus to the extent that fractions of the human radiation exposure are due to tritium and carbon-14 in marine products, these fractions of the radiation exposure would be increased by like factors. Since the annual whole body exposures from natural tritium and carbon-14 from all sources, inluding marine products, are 0.001 mrad and 1.3 mrad respectively out of a total of the order of 100 mrad it can be seen that the increment due to fallout tritium and carbon-14 in marine products has relatively little significance.

A survey of the estimated inputs into the Mediterranean Sea from nuclear power programmes was made (Woodhead, 1978), taking into account power reactors, fuel reprocessing plants, research establishments and the medical uses of radionuclides, all of which consitute effective point inputs into the Mediterranean sea either from coastal sites or from inland sites on rivers (up to 700 km from the estuary). For each type of plant, standard discharge values were selected individually for tritium and for all other radionuclides as a single group.

In the case of radionuclides other than tritium arising at inland sites and being discharged into rivers, rather arbitrary reduction factors depending on the distance of the release point from estuary, were applied to correct for the removal of the radioactivity from the river water by interaction with sediment and biota. While it is clear that accurate assessment of the inputs requires a detailed site-specific analysis, the approach adopted provides estimates of the inputs within an order of magnitude, which provide a basis for a preliminary assessment. The estimated total annual inputs to the Mediterranean Sea are given in Table 21, together with a projection of approximate values for the cumulative quantities of radioactivity discharged up to the year 1987.

Thus, on the basis of past experience, the concentrations of radioactivity in the water in the vicinity of the primary input into the Mediterranean Sea, either from a coastal pipeline or a river estuary, are likely to be relatively low.

The greatest risk of exposure will continue to arise in the vicinity of the individual discharge points where the greatest degree of control should be exercised, particularly since reactor malfunctions and accidents may lead to unpredictable high releases. However, there is insufficient detailed information available for the individual discharges into the Mediterranean Sea to make valid estimates of the dose rates likely to be received by biota.

Low level radioactive wastes, dumped in other areas of the world oceans, were banned in the Mediterranean Sea by agreement of the Contracting Parties to the Barcelona Convention in 1981. Ocean dumping of low-level and intermediate-level radioactive wastes is awaiting the IAEA's definition of the "de minimis" levels.

Therefore, all the inputs being coastal, the control system mentioned above should ensure that the major part of the surface water mass will not become significantly contaminated even in the case of a relatively long-lived and relatively conservative radionuclide like Caesium-137. All the available evidence supports the contention that when radioactive waste disposals to the sea are controlled so as to safeguard human health, there is no significant hazard for populations of marine organisms (Woodhead, 1978).

As plans for new nuclear power reactors are implemented in many countries to supplement existing energy sources, it is expected that the entry of radioactive materials into the sea will increase. Reprocessing of nuclear fuel from nuclear power reactors may also add radioactive materials to the sea.

Eutrophicants

Many pollutants have adverse effects on the processes that control the oxygen balance. One of the most important kinds of pollution, as far as oxygen is concerned, is eutrophication.

Introduction of foreign organic matter, or enhancement of primary production by the introduction of plant nutrients, results in a higher consumption of oxygen at depth which is not balanced by the extra amount of oxygen produced at the surface layers which is lost in the atmosphere. The final result of eutrophication is always an overall reduction of oxygen in the deep layers and in the sediments. This is often irreversible in enclosed areas, and even in open coastal areas subjected to large discharges, at least on the human time scale.

The self-purifying capacity of marine waters is directly related to the processes that control the oxygen balance. This balance is easily upset and, when sewage is continuously discharged into a coastal zone with restricted circulation, in excess of the capacity of self-purification , the zone rapidly becomes a nuisance, turbid and foul-smelling and devoid of natural life. Such a nuisance can be prevented by limiting the quantity of organic matter and nutrients discharged well below the capacity of self-purification of the water body receiving the discharge (Cruzado, 1978).

Oxygen deficiency develops from the increased respiratory demand of the saprobic microorganisms digesting the excess organic matter discharged into the sea in crude or partially-treated sewage effluents. The oxygen cycle may then be broken into an oxygen-producing surface layer and an oxygen-consuming bottom layer, with transport of this element in the downwards direction severely limited by restricted diffusion due to strong temperature and salinity gradients. Once the cycle is broken, the oxidation of organic matter proceeds through anaerobic pathways producing foul-smelling compounds and toxic gases (hydrogen sulphide, methane).

Mediterranean sediments have in general a low organic carbon content due to the presence of high oxygen concentrations in the deeper waters and to the low biological production of the overlying waters, except perhaps in the neighbourhood of the large rivers. Local oxygen deficiencies are always connected with eutrophicating zones due to the discharge of raw or treated effluents.

In the sediments of polluted waters, a lowering of their oxygen content occurs due to the high biological and chemical oxygen consumption rates. If the waters above are highly polluted, sediments may become completely anoxic. Even unpolluted waters, if they are eutrophic, can produce local deficiencies in the sediments by the decomposition of the decaying organic matter. Production of toxic hydrogen sulphide in the sediments may lead to lethal conditions for the fauna and flora in the overlying water. It also combines with the oxides of iron to form sulphides, which blacken the anaerobic layer.

Sources of eutrophicants in the Mediterranean Sea have been identified and their effect estimated by UNEP (1984). Their distribution around the region is uneven but is found in the areas receiving the sewage from the large cities and in the major rivers and river estuaries. Owing to the strong stratification of the surface waters, eutrophication is more acute in summer, when the oxygen transport through the thermocline is strongly reduced and the natural nutrient concentrations are low outside the eutrophic areas.

Both organic matter and nutrients have approximately the same effects on the oxygen balance since increased organic matter, either directly discharged or through photosynthesis, is always the end-product. The deeper waters and the sediments are most affected, since the mixed surface layer is always at or near saturation.

The reduction of the compensation depth by increased turbidity created by the suspended inorganic material or by the organic matter and planktonic organisms should not be of great concern, as it would leave some unused nutrients at the base of the euphotic zone which would still be used at somewhat greater distances from the source.

Large scale effects should not be expected in the Mediterranean Sea as a whole even if the natural increase in the human population is taken into account. However, anoxic sediments with abnormally high organic carbon content are nowadays common in previously oxygenated areas, and important changes have already occurred, due to eutrophication, in beaches and rocky shores along the highly-populated areas and in the neighbourhood of tourist resorts. This fact may already be acting as a feed-back mechanism to reverse previously high trends of seaside urban development in some critical areas and therefore should be taken into account if we aim at maintaining the Mediterranean Sea, as far as possible, in the condition in which it was received from our parents.

The abnormal plankton blooms, known as "red tides", are closely related to eutrophication. Overgrowing planktonic populations have been reported in recent years in many areas around the Mediterranean Sea, particularly in parts of the north Adriatic Sea. Decaying blooms have caused in these areas a marked decrease of oxygen concentrations in the deeper waters and, in some cases, anoxia has caused major fish kills. When taken up by filter-feeding shellfish (mussels, oysters, etc) the planktonic organisms may produce various kinds of toxic syndromes in humans consuming the shellfish, though the problem does not seem to be serious in the Mediterranean.

Another effect of eutrophication may have been the blooming of jellyfish that has threatened tourism, the major economic resource of many coastal areas, although so far no conclusive relationship has been found(UNEP, 1985b.)

Persistent solids

Persistent solids, such as plastics, may have undesirable ecological effects in the sea and hinder maritime operations. In general, much of the persistent plastics and other litter entering the sea from land-based sources comes from garbage disposal and ordinary human refuse. Solid wastes, of which persistent plastics form only a part, are at present being introduced into the oceans in ever-increasing amounts. Approximately 6.4 x 10^6 tonnes of shipboard litter are discarded annually into the world's oceans. At present the production is doubling every 12 years, so that the amount of plastic litter can be expected to increase substantially unless controls are applied (Carpenter, 1978).

Plastic litter has been observed floating ubiquitously on the world oceans and most of it is polyethylene. Foamed polystyrene is perhaps the second most abundant litter on the sea surface. Other than plastic, the commonest types of surface litter are wood, metal (cans, floats, etc) and glass. There is virtually no information available on densities of these latter objects on the sea surface. In the water column the major type of plastic observed is polystyrene in the shape of spherules about 0.5 to 1.0 mm in diameter. The next most abundant plastic litter in the water column is polyethylene sheeting, which is typically observed in the upper 10 m. Water motion, combined with the large surface area of the sheets is enough to prevent the sheets from floating so they are usually observed drifting in near-surface waters. There is evidence that, even in warm shallow water, domestic refuse decomposes slowly. Thus some litter on the bottom may be persistent. However, relatively little is known about the quantities and types of litter on the sea bed.

Most of the litter on Mediterranean beaches originates from beach visitors. However, some lonely beaches contain large amounts of shipping-derived litter, mainly plastic bottles and sheeting. In some areas, nylon fish netting is a common beach problem.

The U.S. National Academy of Sciences has estimated the refuse generated by passenger cruise ships leaving U.S. ports and sailing in the Mediterranean Sea. To estimate this, the mean value for trash generation on shore (1.6 kg litter/person/day) was applied to people on board ships. The total number of man-days on passenger ships serving U.S. ports and sailing the Mediterranean is 1.5 million per year. Thus the estimated refuse generation is 2.4 million kg per year. This is obviously an underestimate, since only a few passenger ships sailing the Mediterranean make port in the United States (Carpenter, 1978).

As regards merchant shipping, the same study revealed that about 1035 ships per day sail in the Mediterranean with 41400 crew present per day (mean of 40 crew per ship). The estimated amount of refuse generated is thus 12.1 million kg per year. This is based on a mean refuse generation of 0.8 kg per crewperson per day. In addition, cargo wastes (pallets, wires, plastic, covers, dunnage etc) are estimated at 285 metric tons per ship per year. This results in 295 million kg per year as cargo waste, assuming that there are 1035 ships present in the Mediterranean year round.

In the Mediterranean, the study had no values for refuse generated by recreational boaters. The fishing industry in the Mediterranean is calculated to generate 5 million kg per year. However, this is an understimate since only ships from Greece and Italy were used in the calculations. Military activity involves about 12.8 million person-days per year. Assuming 0.8 kg refuse per person per day, this amounts to about 10 million kg per year. Offshore oil producting wells and rigs are assumed to have an average litter generation of 0.3 million kg produced per year.

The total estimated litter generation by shipping and oil drilling activities is thus calculated to be about 325 million kg per year. This average yearly generation factor is an underestimate as it does not include all passenger liners, fishing or recreational vessels. In addition, there are no data available on land-generated litter entering the Mediterranean Sea. Refuse disposal at the shoreline for land reclamation and on dry river beds is a general practice in many Mediterranean countries.

Birds, fish and marine mammals are all affected by litter. Economically, a large loss to fishermen occurs from the entanglement of trawl nets on bottom material. However, it is practically impossible to quantify this loss. As regards floating debris, a considerable economic loss occurs from the fouling of screws and water-intake pipes of ships. However, here also there is little quantification of the economic loss to shippers from floating debris. On beaches, the annual cost of removing the litter is high but many Mediterranean countries have undertaken cleaning programmes at least at the most frequented beaches.

Litter is obviously not homogeneously distributed throughout the Mediterranean. This is because ship and land-generated refuse volumes differ from one area to another. In addition, water currents may be such that litter may be concentrated on specific beaches. In the case of tar lumps, several studies have been done on distribution in the Mediterranean Sea and greatest concentrations of pelagic tar were found in the southern Ionian Sea and southern Alboran Sea. Low concentrations were noted in the Balearic and Tyrrhenian Seas. Similar distribution patterns sould not be expected for pelagic litter since it originates in a different way. However, there is virtually no information available on litter concentrations in the Mediterranean.

Tainting of seafood

Taints are usually caused by the presence in edible tissues of low concentrations of chemical components which are highly flavorous. The substances, often lipid-soluble, may be present in the water in soluble or solubilized form and absorbed into tissues across the respiratory, digestive or body surfaces. They may be present in food ingested or in particulate matter, and also ingested along with food or drinking water or deposited on the respiratory surfaces. Perhaps the most common and most widely reported taints in marine species are petroleum-derived. Virtually all fractions of oil from gasoline to heavy boiler fuel or crude oil are potential sources of taint.

Differences in conditions of exposure, species, types of oil or oil fractions, acuity of assessors and preparation of sample for taint assessment clearly play a part in explaining the variable results which have been reported. Broadly speaking, the pattern of taint effectiveness seems to follow the ranking of oils and oil products by odour threshold, accepting that the highly volatile light fractions are very quickly lost by evaporation when spilt. It is the more polar components which have been implicated, such as the aromatic hydrocarbons, substituted benzenes and naphthalenes. Naphthenic acids, organo-sulphur compounds and olefins, if cracked products, are also involved (Whittle, 1978).

Phenols and related compounds are another group of substances implicated in tainting problems related to refinery, petrochemical plant and pulp and paper mill waste water. Availability of phenols to organisms will be affected quite markedly by pH, since the partition coefficient between lipoidal and aqueous phases will change depending on the degree of dissociation. Such effects probably would be more important in estuaries than in the sea. The minor contituents of phenolic wastes are thought to be responsible for causing taints and a variety of compounds have been tested for effects on flavour related to fish and shellfish.

Kraft mill and sulphite-base mill effluent discharges from pulp and paper manufacture can taint resident fish stocks but experimentally the latter are less potent and biological treatment reduces the potency of the former. The dilution required to reach the taint threshold varies from situation to situation, and some discharges still give strong taints after dilution 100 times.

Petroleum-derived and phenolic substances, entirely from industrial activities, together with products from the pulp and paper industries seem to account for the majority of tainting incidents mentioned earlier. The intertidal area in the Mediterranean is often littered with stranded oil and tar. Fishing gear and nets may get fouled and commercial species such as spiny lobster, mussels, mullet and occasionally tuna are often reported tainted by one means of another.

The economic impact of tainting in fisheries has never been assessed adequately. The problem is compounded by the very subjective nature of taint to the consumer and the level at which it can be tolerated.

Although it has not been possible to review Mediterranean experience in detail because of the paucity or non-availability of published work, there is no doubt that serious tainting incidents occur. Pelagic species, bivalve molluscs and crustaceans make up a large proportion of the Mediterranean catch. All the pelagic fish concerned have high muscle fat contents and hence their flesh is more susceptible to the uptake of lipid-soluble tainting substances. The value of Mediterranean fish, particularly demersal fish, is high compared to world values and, since fishing remains charcteristically artisanal, its social as well as economic significance is important.

Other pollutants

Nearshore marine pollution problems can also arise from a host of other agents that are not included in the above categories. While having perhaps little impact globally, they can have serious consequences in local areas. Some of these agents are:

a) Soil and other debris.

b) Thermal discharges.

c) Coastal constructions.

While thermal discharges do not seem to endanger the ecosystem in any way, side effects may be caused by chlorine or other antifouling mixed to the discharged waters. However, such discharges would then fall into some of the categories described in other sections.

Changes in shoreline by land reclamation, coastal and offshore dumps of dredge and other materials and constructions have been common practice around the Mediterranean Sea for centuries. The coastal landscape has been profoundly altered through such actions. Probably thousands of kilometers of coastline do not maintain any of the original forms and structures. However, an assessment of such changes in the light of the GESAMP definition of marine pollution cannot be made.

IV. CONCLUSIONS

An approximate estimation of pollution loads entering the Mediterranean Sea, directly or indirectly from land-based sources, was given priority within the context of the Mediterranean Pollution Monitoring and Research Programme (MED POL) during its pilot phase. Restrictions of budget and time and the limitations of the available information, did not allow a more accurate assessment to be made. The results obtained were based on guidelines agreed among collaborating scientists. They are also an example of concerted and coordinated efforts, which have set a precedent within the Regional Seas Programme of UNEP. The overall outcome, however, has been more an assessment of present waste disposal and management problems than a real quantitative evaluation of the contribution of the land-based sources to the overall pollutant loads.

On the other hand, in the framework of the MED POL programme, the monitoring of the levels of pollutants mainly along the coastal zones was a major effort carried out by all states and within them by numerous scientists and scientific institutions. A large number of analyses following agreed methodologies on standard matrices (water, sediments and organisms) were carried out and the results reported to the relevant coordinating agencies. Today we know more about nutrients, suspended matter, microorganisms, pesticides, heavy metals, radionuclides and oil than previously. As a result, the assessment of various categories of pollutants were prepared by UNEP and the Cooperating Agencies (FAO, WHO, UNESCO, IOC, WMO, and IAEA) and presented to the Contracting Parties at various meetings with proposed remedial actions.

The overall state of pollution of the Mediterranean Sea is not as bad as some voices had claimed it to be in the 1970s. The open sea waters and sediments have a relatively acceptable quality (except for floating materials and oil), comparable to the open ocean and there are no signs of damage to the physical, chemical and biological equilibria of the basin as a whole.

However, some of the coastal zones are in a poor condition, especially in the neighbourhood of the sewers of the large cities (Barcelona, Marseilles, Genoa, Rome, Venice, Split, Athens, Izmir, Beirut, Alexandria, Tripoli, Tunis and Algiers). Attempts to treat their sewage have been initiated very slowly. Tar accumulates on the shores of the north African countries and some of the Middle East in amounts that may be the highest in the world, and without any sign of decrease. Floating litter at the surface of the sea is a common and distressing sight.

As far as the impact of such pollutant levels on the critical targets (human and living resources) is concerned, no serious widespread risk of damage appears to have been reported, though mild diseases are common among bathers and outbreaks of serious epidemic diseases may happen at any time due largely to uncontrolled shellfish harvesting from areas too close to domestic sewage discharges to be safe.

Regrettably most states have failed to comply with the philosophy which made the existence of the Barcelona Convention and its protocols possible. So far, none of the measures proposed have been adopted at the regional level. Some Mediterranean Governments have adopted the proposed measures at the national level but no actions have been taken for the assessment of their effectiveness.

One may therefore conclude that in the years to come, it will be crucial that urgent measures be adopted to abate the present pollutant sources and prevent any new ones being established without a proper assessment of the environmental impact they may produce. The social costs of pollution are becoming greater and affect mankind and nature in unexpected ways (Benford, 1980).

V. PROSPECTIVES

If our present knowledge of the state of pollution of the Mediterranean Sea is limited in scope, it is even more difficult to understand how this basin will evolve in the coming years and the picture it will present at the turn of the century. Based on global projections (Barney, 1980) and a synthesis of relevant information available at present, one could attempt to forecast future trends in order to propose preventive actions.

It is today accepted that the marine environment has a finite capacity to receive contaminants. This capacity is determined by a number of factors, including the characteristics of the contaminants as well as the uses made of the environment, these factors varying widely among the various locations. The "health" of the Mediterranean Sea depends on whether this capacity is being approached or even exceeded.

While the open-sea water and sediments of the Mediterranean are far from showing any signs of having serious pollutant impacts, (apart from oil residues and solid wastes floating at the surface), the receiving capacity at some areas along the coasts has been clearly exceeded. Knowledge of the biogeochemical processes which may lead to the accumulation of pollutants in parts of the marine environment, or their removal from it, is required to make any projection. Yet such information is at best scanty.

Indeed, it is extremely difficult to assess trends. Overall changes in the basin take place at such slow rates that local and seasonal variability make such an assessment practically impossible for most substances. The rate at which pollutant levels evolve, a very difficult parameter to determine, is made up of two counteracting factors:

a) rate of increase in population, industrial and agricultural development as well as maritime activities, and

b) rate of implementation of technical and other measures aiming at reducing pollutant inputs.

As population increases and the gross national product rises, the impact of generated wastes and their consequence will increase. Global projections point to increasing destruction of our ecosystem, a resource on which many human activities (from tourism to fisheries) depend.

It thus appears that, if such trends continue unabated one might find that the least stable ecological environments in the Mediterranean will be subject to disruption and destruction. This is especially so for those areas that are already showing sign of potentially irreversible ecological changes, such as those near large cities and rivers.

It is worthwhile to note that the general awareness of the authorities has substantially contributed to reverse the past trend, through good management and legislation. Examples from some Mediterranean countries as well as from other regions are tangible evidence of the benefits of timely remedial actions.

It is highly significant that this awareness within the Mediterranean community has often stimulated less developed countries of the region to seek technical assistance and to negotiate loans through international financing agencies for the construction of treatment plants with more willingness than some of the better developed countries.

Only if corrective measures are adopted in a concerted way and applied energetically by all Mediterranean Governments, and if development is carried out with respect for the environment, can the situation improve and the levels of pollutants in the Mediterranean Sea become more acceptable.

However, the reluctance of some of these Governments to agree on concerted actions such as the establishment of pollution abatement programmes and of common environmental quality criteria, in the way that other groups of countries are doing in various regions of the world (Oslo/Paris commissions), is making the situation worse and the possible remedies less effective. Any delay in implementing the legal instruments already existing within the framework of the Mediterranean Action Plan makes them less and less sufficient.

VI. RECOMMENDATIONS

The following are general recommendations that might assist the Contracting Parties in their future policy making. The Parties should actively undertake:

1. Definition of programmes for the reduction of pollutant levels, as called for by the Protocol on the Protection of the Mediterranean Sea from Pollution from land-based Sources.

2. Establishment of common emission standards and environmental quality criteria for the protection of human health and the marine environment.

3. Establishment of a system to monitor the effectiveness of the actions taken in the implementation of pollution abatement programmes.

4. Strengthening of the MED POL National Monitoring programmes, particularly with regard to the assessment of the pollutant loads entering the marine environment, and especially those inputs, never evaluated before, that require such an assessment to be made (atmospheric, riverine, maritime inputs).

5. Improvement of the quality of data both through technology transfer and by rigorous intercalibration exercises in which all national participants as to be involved.

6. Improvement of the timing and quality of reporting procedures, data processing and evaluation, making the results of the monitoring and research available through international data bases.

7. Increase of the contacts among scientists and experts in pollution control through personal exchange, visits, seminars, workshops, etc.

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Table 1
Water budget for the Mediterranean Sea*
(in $m^3 s^{-1} \times 10^{-3}$)

Process	McGill 1969	Tixeront 1970	Morel (+) 1971	Lacombe et Tchernia 1974	Béthoux 1977
Evaporation	-92 (2)	-95 (1)	-70 (1)	-	-122
Precipitation	33 (2)	28 (3)	13 (3)	-	25
Run-off (++)	14 (2)	16 (4)	9 (4)	-	16 (4)
Net Inflow Through:					
Dardanelles	6 (5)	6 (5)	6 (5)	6 (5)	6 (5)
Sicilian channel	-	-	42 (6)	-	52
Gibraltar	40 (7)	45 (6)		54.4 (8)	75
Total Inflow Through:					
Dardenelles	-	-	-	12.5	-
Sicilian channel	-	-	1000	-	-
Gibraltar	-	-	-	1187.5	-

* From UNEP/WG.11/Inf.4

(+) Only for the eastern basin

(++) MED X estimate for total run-off is 13.250 for the whole Mediterranean and 8.663 for the eastern basin

(1) Estimated from studies made in Tunisia (Berkaloff, 1952)

(2) Based on Carter (1956)

(3) Estimated from pluviometric charts and sailors' accounts

(4) Direct measurements on some rivers and from pluviometric charts and area of all other river basins

(5) Based on Merz and Moeller (1928)

(6) Estimated by balance

(7) Based on Schink (1967)

(8) Estimated by salinity difference between incoming and outgoing waters and mean flow

Table 2. Estimated annual pollution loads of the Mediterranean from land-based sources 1/

(detailed explanations are provided in the report § 81 to § 91)

Pollutant	Pollution loads originating in the coastal zone				Loads carried by rivers into the Mediterranean				Total Mediterranean Loads		
	Domestic t/a	Industrial t/a	Agricultural t/a	Sub-total t/a	Pollution t/a	Background t/a	Sub-total t/a	Sub-total (range)	Pollution	Total (including background) t/a	Total (including background) (range)
1. Volume:											
Total discharge $x10^9$	2	6	-*	(8)	(-)	420	420	(400-500)	(-)	430	(400-500)
2. Organic matter:											
BOD $x10^3$	500	900	100	1 500	1 000	(800)	1 800	(1200-2300)	2 500	3 300	(2700-3800)
COD $x10^3$	1 100	2 400	1 600	5 100	2 700	800	3 500	(2300-4700)	7 800	8 600	(7400-9800)
3. Nutrients:											
Phosphorus $x10^3$	22	5	30	57	260	40	300	(200-400)	320	360	(260-460)
Nitrogen $x10^3$	110	25	65	200	600	200	800	(600-1000)	800	1 000	(800-1200)
4. Specific organics:											
Detergents $x10^3$	18	-	-	18	42	0	42	(9-75)	60	60	(30-90)
Phenols $x10^3$	-	11	-	11	1	0	1	(0.5-1.8)	12	12	(6-18)
Mineral oil $x10^3$	-	120	-	120	(-)	0	(-)		(120)	(-)	
5. Metals:											
Mercury	0.8	(7)	-	(8)	90	30	120	(40-200)	100	130	(50-200)
Lead	200	1 400	-	1 600	2 200	1 000	3 200	(2700-3800)	3 800	4 800	(4300-5400)
Chromium	250	950	-	1 200	1 200	400	1 600	(500-2700)	2 400	2 800	(1700-3900)
Zinc	1 900	5 000	-	6 900	14 000	4 000	18 000	(14000-22000)	21 000	25 000	(21000-29000)
6. Suspended matter:											
TSS $x10^6$	0.6	2.8	50	53	-	300	300	(100-500)	-	350	(100-600)
7. Pesticides:											
Organochlorines	-	-	-*	-	90	0	90	(50-200)	90	90	(50-200)
8. Radioactivity:											
Tritium Ci/a	-	400	-	400	2 100	(-)	2 100	(1600-3100)	2 500	(-)	
Other radio-nuclides Ci/a	-	25	(-)	25	15	(-)	15	(10-25)	40	(-)	

Legend:
- \- contributions from this source negligible
- (-) insufficient data base for estimate
- -* included in river assessment

1/ From UNEP Regional Seas Reports and Studies No. 32

Table 3

Present situation and projections relating to sewage treatment in the Mediterranean towns participating in the survey produced by the Barcelona Intermunicipal Conference1/

State	Towns under consideration	Towns with treatment installations functioning	under construction	projected	Towns without treatment facilities	Towns with at least one emissary
Cyprus	1	1	1	0	0	0
Spain	26	13	3	18	10	10
France	15	10	4	7	5	7
Greece	5	0	0	3	5	2
Italy	17	11	10	7	2	5
Tunisia	4	2	0	1	2	0
Turkey	4	1	1	1	2	0
Yugoslavia	1	0	1	0	0	1
Total	74	51 %	27 %	37 (50%)	26 (35%)	34 %

1/From Informe technic del Secretariat per a la Proteccio de la Mediterrania,nn°1.

Table 4

Type and capacity of the installations for treating sewage in the Mediterranean towns participating in the survey produced by the Barcelona Intermunicipal Conference

State	Towns with installations functioning or under construction	Capacity of treatment plants as a percentage of the resident population. Pretreatment	Primary	Secondary	Tertiary
Cyprus	1	-	-	32	-
Spain	10	-	12-100	33-125	89-107
France	10	-	100-155	72-2500	100-754
Greece	0	-	-	-	-
Italy	13	-	100-413	38-1400	77-2950
Tunisia	2	-	-	29-42	-
Turkey	0	-	-	-	-
Yugoslavia	1	77	-	-	-

1/ From Informe tecnic del Secretariat per a la Proteccio de la Mediterrania n° 1.

Table 5

Atmospheric concentrations of lead and cadmium over the Mediterranean basin 1/ (ng m^{-3})

	Lead		Cadmium		number of samples	References
	range	mean	range	mean		
- Eastern and Central (1979)	2-25	14	--	--	5	Chester *et al.*, (1981)
- Tyrrhenian Sea (1979)	3-16	10	0.07-1.6	0.40	9	Chester *et al.*, (1984)
- Central and Tyrrhenian Sea						
(1980) -	10-98	50	0.2-6.0	2.10	19	Seghaier (1984)
(1982) -	3-39	15	0.2-2.4	0.9	16	Buat-Menard *et al.*, unpubl. data
- Western Basin						
Phycemed 1 Cruise (1981)	3-58	33	0.1-5.5	1.4	13	Seghaier (1984)
Phycemed 2 Cruise (1983)	4-54	27	0.4-3.2	1.6	15	Buat-Menard *et al.*, unpubl. data
- Alboran Sea (1981)	5-78	49	0.3-7	1.5	7	Seghaier (1984)
- Coastal Regions						
Marseille (1977-1979)		305		5.9	200	Viala *et al.*, (1979)
Monaco (1978)		171		4.5	30	Seghaier (1984)

1/ From Report of the Expert Consultation on the Atmospheric Transport of Pollutants into the Mediterranean Region (GESAMP), Athens, 21-25 January 1985.

Table 6

Atmospheric and rainwater concentrations of, and flux data for, lead and cadmium in different regions 1/

	Lead	Cadmium	Reference
AIR		ng m^{-3}	
Samoa area			
Tropical South Pacific	0.02	0.005	Duce, unpublished data
Enewetak			
Tropical North Pacific	0.12	0.003	Duce *et al.*, (1983)
Hawaii	2	0.02	Settle and Patterson (1982) and Hoffman *et al.*, (1982)
North Atlantic	10	0.13	Buat-Menard (1983)
Bermuda Area	3	0.2	Duce *et al.*, (1976)
Baltic Sea	10-60	0.1-0.5	Rodhe *et al.*, (1983)
North Sea	20-200	0.5-2.5	Van Aalst *et al.*, (1983) Chester *et al.*, (1981, 1984)
Mediterranean Sea	10-60	0.4-2.1	Arnold *et al.*, (1982) Seghaier (1984) Buat-Menard *et al.*, unpub.
PRECIPITATION		ug.l^{-1}	
Samoa	0.007	0.002	Duce *et al.*, unpub. data Settle *et al.*, (1982)
Enewetak	0.023	0.0041	Arimoto *et al.*, (1985) Settle *et al.*, (1982)
Bermuda	0.77	0.006	Juckells *et al.*, (1984)
Baltic Sea	10-30	0.3	Rodhe *et al.*, (1980)
North Sea	10-35	0.3-1.2	Van Aalst *et al.*, (1983)
Mediterranean Sea	6-12	--	Buat-Menard *et al.*, unpub.
TOTAL DEPOSITION		ng.$cm^{-2}yr^{-1}$	
Enewetak	7	0.35	Arimoto *et al.*, (1983) and
North Atlantic	310	5	Buat-Menard (1983)
Baltic Sea	400-1750	13-20	Rodhe *et al.*, (1980)
North Sea	700-2600	20-85	Van Aalst *et al.*, (1983)
Mediterranean Sea	300-1800	10-50	Calculated from Chester *et al.*, (1981, 1984), Arnold *et al.*, (1982), Buat-Menard *et al.*, unpub. data.

1/ From Report of the Expert Consultation on the Atmospheric Transfer of Pollutants into the Mediterranean Region (GESAMP), Athens, 21-25 June 1985

Table 7
Concentration in Air ($ng\ m^{-3}$) of organic compounds in different regions 1/

Region	PCB	n-Alkanes (Vapour)	n-Alkanes (Particulate)
Mediterranean	0.04-0.3 (Villeneuve, in press)	65-147 (Ho et al., 1982)*	10.8-43.7 (Ho et al., 1982)*
North Sea	0.96 (Diederen et al., 1981)	-	-
Central Pacific	0.19-0.32 (Tanabe et al., 1982)	-	-
N. Pacific Trades	0.049 (Giam & Atlas, 1982)	2.6** (Duce & Gagosian, 1982)	0.044*** (Duce & Gagosian, 1982)
S. Pacific Trades	0.012 (Giam & Atland, 1982)	1.4 - 3.9+ (Giam & Atlas, 1982)	-
W. Ireland	-	253++ (Eichmann et al., 1979)	3.3+ (Eichmann et al., 1979)
Equatorial Atlantic	-	30-281* (Marty & Saliot, 1982)	1.5 - 14* (Marty, 1981)
Tropical N. Atlantic	0.21-0.65 (Bidleman & Olney, 1974)		4-50* (Marty, 1981)
N. Atlantic		66** (Duce & Gagosian, 1982)	3.3+ (Duce & Gagosian, 1982)

* C_{14} - ?
** C_{13} - C_{30}
*** C_{21} - C_{30}
\+ C_{15} - C_{28}
\++ C_{10} - C_{26}

1/ From Report of the Expert Consultation on the Atmospheric Transfer of Pollutants into the Mediterranean Region (GESAMP), Athens, 21-25 June 1985

Table 8

Comparison of atmospheric and riverine inputs of heavy metals and radionuclides into the Mediterranean sea 1/

	Atmospheric input y^{-1}	Riverine input y^{-1}
Pb	5000-30000 tons*	2200- 3100 tons***
Zn	4000-25000 tons*	11000-17000 tons***
Cr	200- 1000 tons*	350- 1900 tons***
Hg	20- 100 tons*	30- 150 tons***
^{137}Cs	980 Ci**	32 Ci**
^{238}Pu	0.45 Ci**	0.12 Ci**
$^{239+240}Pu$	20 Ci**	0.46 Ci**
^{241}Am	1.5 Ci**	0.19 Ci**

1/ From Report of the Expert Consultation on the Atmospheric Transfer of Pollutants into the Mediterranean Region (GESAMP), Athens, 21-25 June 1985

* Based on data from Arnold et al., (1982); Buat-Menard et al., (unpub. data); Chester et al., (1981, 1984)

** Fukai et al., (1981)

*** UNEP Regional Seas Reports and Studies No. 32 (1984)

Table 9. Spills reported to Regional Oil Combating Centre, Malta 1/

Year	Total spills reported	Cause of identified spills: Collision ding	Wreck or groud- Explo-	Fire and/or sion	Other spills	Un-identified Tonnes	No. of Spillage Tonnes Reported	Size of Spill: Under 1,000 Tonnes	1,000 to 5,000 Tonnes	5,000 to 10,000	Over 10,000	No. of cases in which dispersants used	Remarks
1977 (July/ Dec)	6	1	-	-	3(a)	2	2	1	1	2	-	4	(a) Two accidental discharges during pumping one tank overflow
1978	11	1	5	1	3	9	2	-	-	-	-	2	(b) Wrong manoeuvres in terminal
1979	10	5	2	-	-	3	4	2	1	2	1	5	
1980	12	3	2	2	1	4	7	3	-	-	2	4	
1981	22	1	3	6	4(c)	8	16	5	-	-	1	-	(c) Two pipeline ruptures; two leakages while discharging
1982	11	-	4	4	-	3	10	1	-	-	-	2	
1983	13	3	3	2	2(d)	7	14	3	-	-	-	1	(d) One pipeline rupture; one technical failure
TOTAL	89	14	19	15	11	30	62	17	2	4	4		

1/ From UNEP/WG.118/Inf.10

Table 10

Summary assessment of the microbiological quality of recreational waters in the Mediterranean, according to the WHO/UNEP interim criteria (MED POL VII sampling stations with at least 6 samples per year)1/

Year	Number of stations			
	Surveyed	In accordance with FC50	In accordance with FC90	Satisfactory by FC50 & FC90
1976	26	16 (62%)	15 (58%)	14 (54%)
1977	55	50 (91%)	46 (84%)	46 (84%)
1978	193	181 (94%)	164 (85%)	161 (83%)
1979	288	251 (87%)	201 (70%)	200 (69%)
1980	118	110 (93%)	100 (85%)	97 (82%)
1981	25	19 (76%)	20 (80%)	19 (76%)
Overall	705	627 (89%)	546 (77%)	536 (76%)

1/ From UNEP/WG.118/6

Table 11

Summary assessment of the microbiological quality of shellfish and of shellfish-growing waters in the Mediterranean, according to WHO/UNEP interim criteria (MED POL VII sampling stations with at least 6 analyses per year)1/

Year	Stations surveyed	Stations with satisfactory quality		Stations satisfactory according to both criteria
		water	shellfish	
1976	18	12 (67%)	0 (0%)	0 (0%)
1977	13	8 (62%)	0 (0%)	0 (0%)
1978	24	17 (71%)	3 (13%)	2 (8%)
1979	33	17 (52%)	6 (18%)	3 (9%)
1980	21	14 (67%)	0 (0%)	0 (0%)
1981	7	6 (86%)	0 (0%)	0 (0%)
Overall	116	74 (64%)	9 (8%)	5 (4%)

1/ From UNEP/WG.118/6

Table 12

a) Mercury concentrations in open waters of the Mediterranean 1/

Region	Physico-chemical form	Concentration ug/l	Reference
I	Total	0.11 (0.062-0.17)	Robertson *et al.*, 1972
II	Particulate	0.0013	Buat-Menard *et al.*, 1980
	Dissolved	0.020 (0.008-0.032)	
III	Dissolved	0.014 (0.005-0.30)	Huynh-Ngoc & Fukai, 1978
IV	Dissolved	0.026 (0.010-0.040)	" "
VI-VII	Dissolved	0.030 (0.005-0.080)	" "
VIII	Dissolved	0.040 (0.015-0.080)	" "
X	Dissolved	0.016 (0.012-0.020)	" "
	Total	0.12 (0.09-0.14)	Robertson *et al.*, 1972

1/ From UNEP/WG.118/5

Table 12

b) Mercury concentrations in coastal waters of the Mediterranean[1/]

Region	Area	Physico-chemical form	Concentration ug/l	Reference
II	Rhone Delta	Dissolved	0.010-0.19	Martin *et al.*, 1978
	Ligurian Coast	Total	0.012-0.26	Breder *et al.*, 1980
	Coasts of Tuscany and Rosignano (close to chlor-alkali plant)		0.02 0.18	Renzoni *et al.*, 1973
	Cecina	Dissolved Total	0.012-0.031 0.032-0.061	Breder *et al.*, 1980
V	NW Adriatic	Particulate	1-7	Granzini *et al.*, 1975
	Istrian Coast	Total	0.04	Strohal & Dzajo, 1975
	Adriatic	Total	0.07	Kosta *et al.*, 1978
	Gulf of Trieste	Dissolved	0.073-0.17	Majori *et al.*, 1978
VIII	Saronikos Gulf (close to sewage outfall)	Total	0.15-0.60	Zafiropoulos, 1982
X	Israel	Dissolved (Labile)	0.06 (0.01-0.18)	Roth & Hornung, 1975
Mediterranean coasts			0.02-0.55	Aubert, 1980

1/ From UNEP/WG.118/5

Table 12

c) Mercury concentrations in sediments of the Mediterranean[1/]

	Region	Extraction method	Concentration ug/g dry weight	Reference
I	Alboran Sea	Total	0.26 (mean)	Robertson *et al.*, 1972
II	Ligurian coasts	HNO_3,HCI	0.16-5.4	Breder *et al.*, 1980
	Ebro delta	conc. HNO_3	0.065-1.1	Obiols & Peiro, 1980
	Area of Marseille	HNO_3	0.07-21	Arnoux *et al.*, 1980a 1980b, 1980c
	Bay of Cannes	HNO_3,HPO_4 fraction 63 u	0.1-0.4	Ringot, 1982
	Gulf of Nice	HNO_3,$HClO_4$	0.01-0.16	Flatau *et al.*, 1982
	Catalan coasts	conc. HNO_3	0.2-1.0	Peiro *et al.*, 1980
III	Santa Gilla lagoon, Cagliari	HSO_4,HNO_3	0.7-37	Sarritzu *et al.*, 1982
IV	Tyrrhenian Sea	-	0.05-0.24	Selli *et al.*, 1973
	Tuscany Coast	-		
	near Solvay plant		1.1-1.3	Renzoni *et al.*, 1973
	4 km S and N		0.1-0.8	
	10 km S and N		0.04-0.1	
V	Gulf of Trieste (close to cinnabar mine)	-	1.4-14.8 19.4	Majori *et al.*, 1978
	Gulf of Venice	H_2SO_4	0.15-3.0	Donazzolo *et al.*, 1978 Angela *et al.*, 1980
	Kastela Bay Dalmatia (chlor-alkali plant)	Total	8.5	Stegnar *et al.*, 1980
	Adriatic Sea	Total	0.07-0.97	Robertson *et al.*, 1972
VIII	Evoikos Gulf Aegean Sea	0.5 HCl fraction 55 u	0.3-0.8	Angelidis *et al.*, 1980
	Saronikos Gulf, Athens	Total	0.5-1	Grimanis *et al.*, 1976
	Athens outfall	Total	0.5-3	Papakostidis *et al.*, 1975
IX	Coasts of Turkey	HNO_3	0.019-048	Tuncel *et al.*, 1980
X	Region of Alexandria (close to chlor-alkali plant)	conc. HNO_3	0.8 9 - 15	Elsokkary, 1978 El Sayed & Halim, 1978
	Haifa Bay	HNO_3 fraction 250 u	0.008-0.73	Krumgalz & Hornung, 1982
	Hanigra to Hafifa		0.01-0.57	Roth & Hornung, 1977

1/ From UNEP/WG.118/5

Table 13

Mercury concentrations in Mediterranean fish (ug/kg wet weight)1/

Species	Number of Samples	Minimum	Maximum	Mean	Standard Deviation
Boops boops	15	20	432	125	104
Dentex gibbosus	12	99	178	135	19
Engraulis encrasicolus	254	20	580	167	85
Merluccius merluccius	16	31	258	131	77
Mugil auratus	39	1	5600	171	880
Mullus barbatus	1265	2	7900	694	960
Mullus surmuletus	234	0	510	91	57
Pagellus acarne	12	30	337	159	92
Pagellus erythrinus	112	53	805	203	115
Sarda sarda	11	290	2300	1150	644
Sardinella aurita	47	120	390	248	70
Saurida undosquamis	143	42	649	137	93
Scomber scombrus	16	125	510	335	122
Solea vulgaris	10	10	220	71	65
Thunnus alalunga	38	60	399	262	76
Thunnus thynnus thynnus	325	20	6300	1050	760
Trachurus mediterraneus	54	8	955	116	160
Upeneus moluccensis	127	38	1112	426	290

Mercury concentrations in Mediterranean molluscs (ug/kg wet weight)

Species	Number of Samples	Minimum	Maximum	Mean	Standard Deviation
Donax trunculus	42	35	909	210	220
Mytilus galloprovincialis	488	4	7000	232	596
Perna perna	192	20	370	76	50

Mercury concentrations in Mediterranean crustaceans (ug/kg wet weight)

Species	Number of Samples	Minimum	Maximum	Mean	Standard Deviation
Nephrops norvegicus	554	59	3000	917	494
Parapenaeus longirostris	39	110	1195	345	233
Squilla mantis	20	65	455	152	86

1/ From UNEP/WG.118/5

Table 14

a) Cadmium, Copper, Lead and Zinc concentrations in open waters of the Mediterranean (ug/l)1/

REGION	METHOD	Cadmium	Copper	Lead	Zinc	REFERENCE
II	ASV	0.15	0.4	-	2.7	Huynh-Ngoc and Fukai, 1978
III	ASV	0.005-0.010	0.06-0.13	0.025-0.075	-	Laumond et al., 1982
	ASV	0.11	0.10	-	1.2	Huynh-Ngoc and Fukai, 1978
IV	ASV	0.11	0.18	-	0.9	"
	ASV	0.05-0.09	0.13-0.19	0.018-0.09	-	Nürnberg, 1977
VI-VII	ASV	0.15	0.7	-	1.8	Huynh-Ngoc and Fukai, 1978
VIII	ASV	0.07	0.3	-	3	"
X	ASV	0.04	<0.04	-	0.9	"
Recent data						
I-II		0.004	0.11	-	-	Boyle et al., 1984
IV-VI-VII		0.010	0.15	-	-	"
II	Dowex/ Extraction/ AAS	0.06	1.6	-	-	Frache et al., 1980
II		0.008	-	0.05-0.14	-	Copin-Montegut et al., 1984
Oceans	Extraction on Chelex 100/AAS	0.07-0.7	0.3-2.8	-	1-13	De Forest et al., 1978; Spencer and Brewer, 1969; Chester and Stoner, 1974; Alberts et al., 1976; Riley and Taylor, 1972
Background Oceanic values (Recent data)		0.01-0.07 0.01-0.1	0.1-0.3	0.005-0.015	0.01-0.6	Förstner and Wittmann, 1983 ICES, 1982

1/ From Assessment of the present state of pollution by metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation)

Table 14 (cont'd)

b) Chromium and Nickel concentrations in Mediterranean coastal waters (ug/l) 1/.

REGION	METHOD	Chromium	Nickel	REFERENCE
II Ligurian coasts	Dowex A-1/AAS		<0.15-2.9	Frache *et al.*, 1976
	Filtration/Dowex A-1/AAS			
	Dissolved		<0.27-9.0	Baffi *et al.*, 1982
	Particulate		0.15-0.89	
V	?	0.68	1.3	Marijanovic *et al.*, 1982
VIII	Filtration/Chelex 100/AAS			
Evoikos, Gera Gulfs, Greece	Dissolved	6.2-6.7	1.9	Scoullos and Dasenakis, 1982
	Particulate	1.5-2.5	0.5	Scoullos *et al.*, 1982
Northern Greece	APDC-MIBK Extraction/AAS		0.5-1.5	Fytianos and Vasilikiotis, 1982

1/ From Assessment of the present state of pollution by metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation)

Table 14 (cont'd)

c) Chromium, Manganese and Nickel concentrations in Mediterranean sediments (ug/g dry weight)1/

REGION	METHOD	Chromium	Manganese	Nickel	REFERENCE
II					
River Ebro Delta	HNO_3	9.5-20	180-630	22-47	Obiols and Peiro, 1980
Rhône Delta	HNO_3-HClO_4	30-50	-	20-28	Added et al., 1980
Marseille	!200um, HNO_3-HCl	7-230	-	-	Arnoux et al., 1980a, 1980b
Golf de Fos	"	27-32	-		Arnoux et al., 1980a, 1980b
Offshore sediments	HNO_3-HCl	35-65	700-1300		Arnoux et al., 1980c, 1982
Offshore sediments	HNO_3	23-37	280-1500	-	Frignani and Giordani, 1983
IV					
Offshore sediments	HNO_3	9-26	260-2560	9-46	Frignani and Giordani, 1983
V					
Gulf of Trieste	?	67-75	304-593	8-68	Majori et al., 1978
Gulf of Venice	HNO_3	10-64	-	5-40	Angela et al., 1980
Offshore sediments	HNO_3	31-60	52-2340	46-122	Frignani and Giordani, 1983
VI					
Patraikos gulf, Greece	$HF-HNO_3HClO_4$	70-210		69-168	Varnavas and Ferentinos, 1982
Offshore sediments	HNO_3	31-33	83-1700	48-53	Frignani and Giordani, 1983
VIII					
Evoikos gulf, Greece	!61um, 0.5N HCl	87	308	60	Scoullos and Dasenakis, 1982
Gera Gulf, Greece	!61um, 0.5N HCl	7.9-1830	80-570	-	Scoullos et al., 1982
Saronikos Gulf Greece	!55um, 0.5N HCl	45-480	-	-	Angelidis et al., 1982
Thermaikos Gulf Greece	!45um, HNO_3	90-235	-	100-335	Voutsinou-Taliadouri, 1982
Pagasitikos Gulf, Greece	"	110	-	165	"
East Aegian, offshore	"	85	-	145	"
IX					
Erdemli, Turkey	$HF-HNO_3-HClO_4$	534-595	115-787	79-586	Ozkan et al., 1980
X					
River Nile Delta	$HF-HNO_3$	12-150	-	10-100	Moussa, 1982

1/ From Assessment of the present state of pollution by metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation)

Table 14

c) Cadmium, Copper, Lead and Zinc concentrations in Mediterranean sediments (ug/g dry weight)1/

REGION	METHOD	Cadmium	Copper	Lead	Zinc	REFERENCE
II						
Var lagoon, France	$HF-HClO_4-HNO_3$	3.7	15.4	26.4	-	Chabert and Vicente, 1980
Coastal lagoon, Spain	!63um	10-32	10-94	200-2000	500-6200	De Leon et al., 1982
Spain	Conc.HNO_3	0.1-0.3	-	10-50	-	Peiro et al., 1982
River Ebro Delta	HNO_3	0.12-0.37	7.9-21.5	22-48	33-104	Obiols et Peiro, 1980
River Rhône Delta	HNO_3-HClO_4	0.25-5	20-55	9	90-140	Added et al., 1980; Cauwet and Monaco, 1982; Badie et al., 1982
Marseille	!200um $HCl-HNO_3$	1.8-3	29-34	28-1250	120-2550	Arnoux et al., 1980a
Cannes	!63um $HNO_3-H_3PO_4-HCl$	1.8-7	15-80	30-100	50-300	Ringot, 1982
Gulf of Nice	HNO_3-HCl	<0.7-2.4	<2.1-32	3-112	-	Flateu et al., 1982
Italian Estuaries	HNO_3-HCl	0.21-0.55	33-53	30-43	-	Breder et al., 1980
Offshore sediments	HNO_3-HCl	-	30-49	10-28	130-260	Arnoux et al., 1980c,1982
	HNO_3	0.7-1.7	-	-	-	Frignani and Giordani, 1983
III						
Coast of Spain	-	0.02-10	4-230	23-3300	27-1050	De Leon et al., 1984
IV						
Cagliari lagoon	0.4NHCl	-	10-70	64-670	-	Contu et al., 1984
Offshore sediments	HNO_3	0.5-2.5	10-44	19-94	20-56	Frignani and Giordani, 1983
V						
Gulf of Trieste	?	0.3-5.3	9-139	18-470	27-650	Majori et al., 1978
Gulf of Venice	HNO_3	0.1-3.1	34-37	5-54	48-450	Angela et al., 1980
Kastela Bay Yugoslavia	NAA !100um		14-42	-	53-1300	Stegnar et al., 1980
River Po delta	HNO_3	0.16-1.7	1.3-50	9.-73	24-244	Facardi et al., 1984
Mali Ston, Yug.	NAA	0.08-0.22	13-22	-	40-100	Vukadin et al., 1984
Offshore sediments	HNO_3	0.8-1.2	15-30	21-43	54-78	Frignani and Giordani, 1983

1/ From Assessment of the present state of pollution by metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation)

Table 14 (Cont'd)

c) Cadmium, Copper, Lead and Zinc concentrations in Mediterranean sediments (ug/g dry weight)[1/]

REGION	METHOD	Cadmium	Copper	Lead	Zinc	REFERENCE
VI						
Patraikos Gulf, Greece	HF-HNO_3 $HClO_4$	-	23-100	10-40	280-430	Varnavas and Ferentinos, 1982
Kalamata Bay, Greece	HF-HNO_3-$HClO_4$	-	11-56	8-40	-	Varnavas et al., 1984
Gulf of Catania	HNO_3	2.2-4.6	3.8-2.5	4.5-19	25-236	Castagna et al., 1983
Offshore sediments	HNO_3	0.6-1.1	24-29	22.27	55-78	Frignani and Giordani, 198
VIII						
Thermaikos-Kavala Gulf, Greece	<63um HNO_3-$HClO_4$	0.6-1.1	0.6-2.3	6-28	10-28	Fytianos and Vasilikiotis, 1982
Evoikos Gulf,	<61um 0.5N HCl	-	9	37	20	Scoullos and Dasenakis, 1982
Greece	<55um 0.5N HCl	-	-	-	7-95	Angelidis et al., 1980
Gera Gulf, Greece	<61um 0.5N HCl	-	8-160	9-122	12-390	Scoullos et al., 1982
Saronikos Gulf, Greece	<55um 0.5N HCl	-	-	-	5-1360	Angelidis et al., 1982
Thermaikos Gulf, Greece	<45um HNO_3	0.40-2.5	10-50	25-130	8-240	Voutsinou-Taliadouri, 1982
Pagassitikos Gulf, Greece	<45um HNO_3	-	30	30	130	Voutsinou-Taliadouri, 1982
East Aegean offshore	<45um HNO_3	-	20	15	40	Voutsinou Taliadouri, 1982
Izmin Bay	HCl-HNO_3	0.2-49	14-870	20-280	53-860	Uysal and Tuncer, 1984
IX						
Erdemli, Turkey	HNO_3-$HClO_4$-HF	-	31	57	65	Balkas et al., 1978
Alexandria	?	2.8	48	190	180	El Sokkary, 1978
Alexandria Harbour	HNO_3HCl	-	27	-	53	El Sayed et al., 1980
Abu Kir Bay, Egypt	HNO_3	2	12	-	100	Saad et al., 1980
River Nile delta	HF-HNO_3	-	5-77	-	2-120	Moussa, 1982
	HCl-1N		6-74		20-100	Tomma et al., 1980
Cilician basin	HF-HNO_3-$HClO_4$	-	33-50	-	54-81	Ozkan et al., 1980
X						
Damietta estuary Egypt	HNO_3	0.16-2	29-280	-	20-425	Saad and Fahmy, 1984
Western Harbor Alexandria	HNO_3-$HClO_4$	7-64	30-1890	-	23-470	Saad et al., 1984
XIII						
Black Sea, Nearshore	HNO_3	1.3-4.8	10-100	22-88	37-250	Pecheanu, 1982
Offshore		2.8	52	37	75	Pecheaunu, 1982

1/ From Assessment of the present state of pollution by metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation)

Table 14

d) Cadmium, Copper and Zinc in Mediterranean marine organisms 1/

Region	Metal	Species	No.of Samples	Mean concen. mg/Kg FW 2/	Standard deviation	Range
II	Cadmium	Mytilus galloprovincialis	148	169	111	40 - 1060
IV	"	"	70	169	118	70 - 1000
V	"	"	72	157	100	38 - 475
VI	"	"	12	36	8	27 - 52
VIII	"	"	73	97	122	5 - 403
IX	"	"	3	237	135	70 - 400
II	Cadmium	Mullus barbatus	259	31	71	2.5- 590
IV	"	"	214	4	5	2.5- 51
V	"	"	7	49	75	8 - 234
VI	"	"	13	25	14	9 - 50
VII	"	"	11	17	15	7 - 49
VIII	"	"	54	69	55	20 - 205
IX	"	"	5	26	8	20 - 40
X	"	"	21	39	14	14 - 65
II	Cadmium	Thunnus thynnus thynnus	100	53	88	50 - 590
VIII	"	"	4	196	61	116 - 283
II	Copper	Mytilus galloprovincialis	71	1730	1224	504 - 6000
IV	"	"	71	1659	773	650 - 4300
V	"	"	63	1002	855	190 - 4400
VIII	"	"	5	1683	596	1080 - 2800
IX	"	"	7	1466	600	750 - 2650
XI	"	"	3	1300	353	1000 - 1800
II	Copper	Mullus barbatus	173	436	259	200 - 2450
IV	"	"	205	384	126	100 - 1000
V	"	"	2	150	-	140 - 160
VII	"	"	10	926	684	360 - 2700
VIII	"	"	46	548	250	220 - 1470
IX	"	"	7	453	198	222 - 691
X	"	"	23	797	563	69 - 2550

1/ From Assessment of the Present State of Pollution of Metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation).

2/ FW = Fresh weight

Table 14(cont'd)

d) Cadmium, Copper and Zinc in Mediterranean marine organisms 1/

Region	Metal	Species	No.of Samples	Mean concen. mg/Kg FW 2/	Standard deviation	Range
II	Copper	*Mullus surmuletus*	5	705	412	390 - 1520
IX	"	"	9	731	698	323 - 2680
XI	"	"	5	318	50	250 - 400
II	Zinc	*Mytilus galloprovincialis*	69	27768	9528	13000 - 60200
IV	"	"	70	34032	11133	3150 - 63000
V	"	"	62	17195	13195	2500 - 65200
VIII	"	"	6	29300	16183	11900 - 62500
IX	"	"	3	14567	6491	9200 - 23700
II	Zinc	*Mullus barbatus*	170	4248	1264	100 - 9500
IV	"	"	218	3869	988	400 - 7000
V	"	"	2	3065	-	2900 - 3230
VII	"	"	11	4332	864	2700 - 5800
VIII	"	"	40	3499	804	2570 - 6890
IX	"	"	12	5067	1042	3660 - 7400
X	"	"	23	4370	651	3060 - 5870
II	Zinc	*Mullus surmuletus*	5	4222	580	3560 - 5300
IX	"	"	16	3897	1101	702 - 5200

1/ From Assessment of the Present State of Pollution of Metals other than Mercury in the Mediterranean Sea and proposed control measures. UNEP (in preparation).

2/ FW = Fresh weight

Table 15

Heavy metals (ug g^{-1} dry weight*) in *Mytilus* from different regions of the Mediterranean Sea. Values given are ranges 1/

Region	Cadmum	Copper	Zinc	Lead	Nickel	Chromium	Silver	Iron	Mercury	Refs (See 1/
North-west Mediterranean (Ligurian Sea)	0.4-5.9	2.4-154	97.644	2.4-117	0.9-14.1	0.5-28.8	0.1-18.9	149-2200	0.18-0.96	8, 9
Adriatic (Gulf of Trieste)	1.4-1.7	6.2-9.8	87-137	3.8-15				167-219	0.28-1.3	10
Aegean (Saronikos Gulf)	0.06-0.08	4.5	12-87		39	0.11-7.8	0.0009-0.01	17-32	0.06-0.2	11, 12
(Turkey)	6.6-12	36-64	336-452	83-110		26-55		308-356	0.89-1.1	13
South-west Mediterranean (Algeria)	0.3-6.5		7.2-71						0.25-0.63	14

1/ From Assessing Pollution in the Mediterranean Sea. Pollutant and their Ecotoxidological Significance, S. Fawler (1985)

* Where necessary values were converted using a wet/dry weight ratio of 6

Table 16
Chlorinated hydrocarbons in Mediterranean marine organisms

Region	Chlorinated Hydrocarbon	Species	No. of Samples	Mean concen. mg/Kg FW[1]	Standard deviation	Range
II	PCB	*Mytilus galloprovincialis*	17	307	266	22 - 1200
IV	"	" "	13	95	114	5 - 420
V	"	" "	159	84	221	5 - 2622
VIII	"	" "	12	62	12	40 - 80
II	PCB	*Mullus barbatus*	33	813	1496	30 - 8000
IV	"	"	33	417	770	50 - 3950
V	"	"	86	234	473	1 - 3117
VIII	"	"	51	113	204	0 - 1110
IX	"	"	6	9.3	19	0,4 - 52
X	"	"	42	69	75	0 284
VIII	PCB	*Parapenaeus longirostris*	30	12.3	12,2	0 - 51
IX	"	" "	3	1.5	-	0 - 2,5
X	"	" "	11	31	57	0 - 157
II	"	*Carcinus mediterraneus*	10	12.3	12,2	0 - 51
V	"	" "	3	1.5	-	0 - 2,5
X	"	" "	11	31	57	0 - 157
IV	"	*Mullus surmuletus*	6	87	17	60 - 110
V	"	"	9	101	130	5 - 441
IV	"	*Nephrops norvegicus*	28	25	17	8 - 90
II	pp/DDT	*Mullus barbatus*	27	28	35	8 - 170
IV	"	"	33	23	17	6 - 89
V	"	"	102	17	26	0,2 - 205
VIII	"	"	51	23	25	4 - 110
IX	"	"	17	38	29	0,5 - 92
X	"	"	44	8	9	0 - 37
II	"	*Mytilus galloprovincialis*	113	22	23	3 - 150
IV	"	" "	12	7	5	1.2 - 17
VIII	"	" "	180	15	77	0 - 1014
II	"	*Thunnus thynnus thynnus*	21	343	362	25 - 1401
IV	"	*Mullus surmuletus*	6	6	3	4 - 13
V	"	"	11	9	11	0,5 - 40
V	"	*Carcinus mediterraneus*	31	1.7	1.4	0.2 - 5
IX	"	"	6	1.6	0.7	0.4 - 2.6
VIII	"	*Parapenaeus longirostris*	29	0.9	1.4	0 - 6
II	"	" "	4	4.2	3.5	0.3 - 9
X	"	" "	10	0.1	0.2	0 - 0.8

1/ FW = Fresh weight

Table 16 (Cont'd).
Chlorinated hydrocarbons in Mediterranean marine organisms

Region	Chlorinated Hydrocarbon	Species	No.of Samples	Mean concen. mg/Kg FW1/	Standard Deviation	Range
II	Dieldrin	Mullus barbatus	11	6.2	5.3	0.5 - 19
IV	"	"	9	6	3.6	0.5 - 12
V	"	"	67	1.7	4.1	0.1 - 17
X	"	"	35	0.4	1.1	0 - 35
II	"	Mytilus galloprovincialis	2	3.5	-	1 - 6
IV	"	" "	6	2.6	2.6	0.5 - 6
V	"	" "	145	0.8	4.4	0.1 - 56
V	"	Mullus surmuletus	8	0.4	0.2	0 - 0.7
IV	"	Nephrops norvegicus	7	0.9	0.5	0.5 - 1.8
V	"	Carcinus mediterraneus	31	0.5	0.6	0 - 2.4
X	"	" "	4	3.1	4.5	0.4 - 10
II	Aldrin	Mullus barbatus	9	0.5	-	0.5 - 0.5
IV	"	"	9	1.5	1.9	0.5 - 5
IX	"	"	5	0.5	0.4	0 - 1
X	"	"	44	1.5	4.7	0 - 28
IV	"	Mytilus galloprovincialis	6	2	2.1	0.5 - 5
IV	"	Nephrops norvegicus	7	0.6	0.2	0.5 - 1
X	"	Carcinus mediterraneus	5	1.6	2.8	0 - 6.5
IX	"	Paraphenaeus longirostris	4	1.4	1	0 - 2.8
X	"	" "	11	0.2	0.6	0 - 2.2
II	Hexachloro cychlohexane	Mullus barbatus	63	2.6	2.8	0.2 - 12
VIII	"	"	4	5	8	0.8 - 50
IX	"	"	5	3.9	3.9	1 - 11
V	"	Mytilus galloprovincialis	43	1.1	1	0 - 5
VIII	"	" "	55	1.9	1.5	0.4 - 5
V	"	Mullus surmuletus	4	1.2	1.7	0 - 4
V	"	Carcinus mediterraneus	27	0.9	-	0 - 8
IX	"	" "	6	20	-	12 - 34
VIII	"	Parapenaeus longirostris	7	0.7	0.3	0.2 - 1.1
II	Lindane	Mullus barbatus	17	10	14	2 - 36
IV	"	"	9	1.5	1.4	0.5 - 5
V	"	"	62	0.7	0.9	0 - 3.8
II	"	Mytilus galloprovincialis	7	4.6	6	0.5 - 20
IV	"	" "	6	1.7	0.9	0.5 - 3
V	"	" "	36	0.4	0.4	0 - 2

1/ FW = Fresh weight

Table 16 (Cont'd)
Chlorinated hydrocarbons in Mediterranean marine organisms

Region	Chlorinated Hydrocarbon	Species	No.of Samples	Mean concen. mg/Kg FW[1]/	Standard deviation	Range
II	pp/DDD	Mullus barbatus	12	38	52	0 - 180
V	"	"	5	28	40	2.2 - 107
VIII	"	"	78	14	25	0 - 140
IX	"	"	17	16	14	0 - 44
X	"	"	44	1.6	3.8	0 - 21
II	"	Mytilus galloprovincialis	108	15	13	5 - 125
V	"	" "	11	49	124	0 - 440
VIII	"	" "	90	7	7	0 - 45
II	"	Thunnus thynnus thynnus	21	107	98	5 - 117
VIII	"	" "	4	323	422	26 - 1052
V	"	Mullus surmuletus	3	7	6	2 - 15
II	"	Carcinus mediterraneus	10	10	9	1.2 - 26
IX	"	" "	6	4.2	3.7	0 - 10
VIII	"	Parapenaeus longirostris	29	0.8	1.4	0 - 7
IX	"	" "	4	2.2	1.3	0.5 - 4.2
X	"	" "	11	0.4	0.8	0 - 2.7
II	pp/DDE	Mullus barbatus	34	29	14	11 - 70
IV	"	"	33	33	18	7 - 93
V	"	"	43	8	12	0.1 - 75
VIII	"	"	88	33	39	1 - 255
IX	"	"	16	53	42	0,9 - 117
X	"	"	44	15	12	2 - 67
II	"	Mytilus galloprovincialis	114	13	9	2.2 - 42
IV	"	" "	13	6	4	2 - 17
V	"	" "	145	5	13	0.1 - 110
VIII	"	" "	99	10	12	1 - 75
II	"	Thunnus thynnus thynnus	21	352	415	23 - 1582
VIII	"	" "	4	601	659	161 - 1737
IV	"	Mullus surmuletus	6	11	3	6 - 15
V	"	"	10	12	12	0.1 - 33
II	"	Carcinus mediterraneus	10	36	24	14 - 72
V	"	" "	4	2.5	30	0.1 - 6.2
VIII	"	" "	3	23	3	20 - 26
IX	"	" "	7	22	15	0.3 - 45
X	"	" "	4	3.1	3.5	0.7 - 8
IV	"	Nephrops norvegicus	28	3.6	1.8	1.1 - 8
VIII	"	Parapenaeus longirostris	31	1.6	5	0 - 25
IX	"	" "	4	3.1	1.6	1 - 5.4
X	"	" "	11	1.5	2.6	0 - 9

FW = Fresh weight

Table 16 (Cont'd)
Chlorinated hydrocarbons in Mediterranean marine organisms

Region	Chlorinated Hydrocarbon	Species	No.of Samples	Mean concen. mg/Kg FW1/	Standard deviation	Range
II	Lindane	Carcinus mediterraneus	4	19	14	2 - 36
V	"	" "	27	0.2	-	-
IV	"	Nophrops norvegicus	7	0.5	-	-

1/ FW = Fresh weight

Table 17

Chlorinated hydrocarbon residues in euphausiids from different regions of the open Mediterranean. Each sample was a composite sample of several individuals collected during three cruises in 1977 1/

Region	Cruise*	Station*	PCB (DP-5)	pp'DDT ug kg^{-1}	pp'DDD dry***	pp'DDE	SDDT / PCB
Tyrrhenian	Hayes	37	25	3.8	1.8	14	0.80
	(6.77)	37 **	110	73	9.1	33	1.05
		23	30	6.0	3.9	24	1.11
Ionian		14	38	16	4.4	22	1.12
		14 **	57	22	5.4	34	1.08
		4	23	8.8	2.7	11	0.97
Levantine	Atlantis II	3 a	26	3.5	0.7	6.7	0.42
	(4.77)	6 a	65	14	3.0	18	0.53
Levantine	Shikmona	2	26	2.5	1.7	15	0.76
	(7.77)	3	18	4.7	1.3	3.9	0.54
		4	9.8	nd	nd	2.5	0.26

1/ From Assessing Pollution in the Mediterranean Sea. Pollutants and their Ecotoxidological Significance, S. Fawler (1985).

* Hayes between Greece and Crete; Atlantis II between Egypt and Malta; Shikmona between Israel and Crete

** Pure samples of <u>Meganyctiphanes norvegica</u>

*** Dry weight averages 18 per cent of wet weight

Table 18

PCB in marine samples from the Mediterranean Sea during 1974-1976 1/

Sample type	Date	Region	No. of samples	PCB (range)	PCB (X)
				ng l^{-1}	
Sea-water	10.74	North-west Mediterranean	11	1.5-38	13
	2.75	Ligurian	17	1.3-8.6	3.2
	2.75	Aegean	7	0.2-1.3	0.36
	5.75	Ionian	10	0.2-2.0	1.0
		Tyrrhenian and Algero-Provencal Basin	34	0.2-5.9	2.0
	9.75	Algero-Provencal basin	8	0.6-19	4.6
			7	0.6-4.8	2.5
		Tyrrhenian	6	1.5-11.6	4.5
				ng m^{-3}	
Marine air	8.75 to 1.76	Monaco coast	13	0.1-1.0	0.4
	1.76 to 2.76	Monaco coast	12	0.03-0.08	0.06
	9.75	Algero-Provencal basin	4	0.2-0.3	0.25
		Tyrrhenian	2	0.1-0.3	0.2
				ug kg^{-1}	
Sediments	5.75	Ionian	3	0.8-5.1	2.8
		Algero-Provencal basin	5	0.8-9.0	4.0
		Gibraltar sill and Siculo-Tunisian sill	2	0.8	0.8
		Algerian marin	1	9.0	9.0

1/ From Assessing Pollution in the Mediterranean Sea. Pollutants and their Etotoxidological Significance, S. Fawler (1985).

Table 19
Concentrations of natural radionuclides in the Surface waters of the Mediterranean sea 1/

Nuclide	Concentration pCi l^{-1}	Radiation type and emission frequency	Energy MeV	Approximate inventory in surface layer (0-100 m) Ci
^{40}K	366	$beta^-$; 0.89	1.35	1.1×10^{8}
		gamma; 0.11	1.46	-
^{3}H	3	$beta^-$; 1.00	0.019	9.0×10^{5}
^{14}C	0.2	$beta^-$; 1.00	0.16	6.0×10^{4}
^{87}RB	3.3	$beta^-$; 1.00	0.27	9.9×10^{5}
^{238}U	1.4	alpha; 1.00	4.27	4.2×10^{5}
^{234}U	1.5	alpha; 1.00	4.86	4.5×10^{5}
^{226}Ra	$(4.6-5.1) \times 10^{-2}$	alpha; 1.00	4.87	$(1.4-1.5) \times 10^{4}$
^{210}Pb	$(1.1-7.8) \times 10^{-2}$	beta; 0.80	0.017	$(3.3-23) \times 10^{3}$
		$beta^-$; 0.20	0.061	
^{210}Pb	$(0.7-4.8) \times 10^{-2}$	alpha; 1.00	5.41	$(21.-14) \times 10^{3}$

1/ From Radioactivity and the Mediterranean Sea. Data profiles for chemicals for the evaluation of their hazards to the environment of the Mediterranean Sea. UNEP/IRPTC. D.S. Woodhead (1977).

Table 20

Concentrations of some fallout radionuclides in the surface water of the Mediterranean sea 1/

Nuclide	Sampling date	Concentration pCi l^{-1}	Reference	Radiation type and emission frequency	Energy MeV	Approximate inventory in surface layer (0-100 m) Ci
^{3}H	June, 1974	28	Fukai, R., pers. comm.	$beta^{-}$; 1.00	0.019	8.4×10^{6}
^{14}C	Estimated for 1975	0.04	(UNSCEAR, 1977)	$beta^{-1}$; 1.00	0.16	1.2×10^{4}
^{90}Sr-^{90}Y	June, 1973	0.14	(Murray, C.N. and Fukai, R. 1978	$beta^{-}$; 1.00 $beta^{-}$; 1.00	0.54 (^{90}Sr) 2.27 (^{90}Y)	4.2×10^{4}
^{137}Cs	June, 1973	0.19	(Murray, C.N. and Fukai, R. 1978	$beta^{-}$; 0.95 $beta^{-}$; 0.05 gamma; 0.95	0.51 1.18 0.66	5.7×10^{4}
$^{239,240}P$	June, 1973	2.3×10^{-3}	Murray, C.N. and Fukai, R. 1978	alpha; 1.00 alpha; 1.00	5.24 (^{239}Pu) 5.26 (^{240}Pu)	6.0×10^{2}
^{241}Am	Sept. 1975	6.0×10^{-5}	Fukai _et al._	alpha; 1.00	5.64	1.8×10^{1}

1/ From Radioactivity and the Mediterranean Sea. Data profiles for chemicals for the evaluation of their hazards to the environment of the Mediterranean Sea. UNEP/IRPTC. D.S. Woodhead (1977)

Table 21
Estimates of radioactive discharges into the Mediterranean Sea up to 1987 1/

Year	1977		1982		1987	
	Tritium	All other radionuclides excluding tritium	Tritium	All other radionuclides excluding tritium	Tritium	All other radionuclides excluding tritium
Estimated total annual input, Curies	2500	40	5000	60	8000	100
Estimated total cumulative input, Curies	-	-	18000	250	45000	650

1/ From Radioactivity and the Mediterranean Sea. Data profiles for chemicals for the evaluation of their hazards to the environment of the Mediterranean Sea. UNEP/IRPTC. D.S. Woodhead (1977)