



United Nations Environment Programme



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MEDITERRANEAN ACTION PLAN

Tenth Ordinary Meeting of the Contracting Parties
to the Convention for the Protection of the
Mediterranean Sea against Pollution and its
Protocols

Tunis, 18-21 November 1997

MONITORING FOR COMPLIANCE CONTROL

In collaboration with:



WHO



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TABLE OF CONTENTS

	Page
BACKGROUND	
1. INTRODUCTION	1
2. COMPLIANCE CONTROL	2
2.1 Basis for action	2
2.2 Objectives	2
2.3 Activities	3
2.4 Monitoring of the levels and effects of contaminants in the context of MED POL Phase III	3
2.4.1 Compliance monitoring	4
2.4.2 Programme design	4
2.4.3 Data quality assurance programme	4
3. WATER USES (PRESENT AND PLANNED) AND THE ASSESSMENT OF THEIR IMPORTANCE	5
3.1 Maintenance of the ecosystem	5
3.2 Uses of the marine system to be protected	6
3.2.1 Human health	6
3.2.2 Amenities, aesthetics and recreation	6
3.2.3 Aquaculture and fisheries	7
3.2.4 Tourism	7
3.2.5 Industrial water uses	7
3.2.6 Commercial water uses	8
4. QUALITY CRITERIA	8
4.1 Environmental capacity	8
4.2 Water quality criteria - standards	8
4.2.1 Suggested procedure for establishing criteria	9
4.3 Control of discharges based on environmental quality objectives	10
5. POLLUTION SOURCES	13
5.1 Point sources	13
5.2 Diffuse (non-point) sources	13
6. COMPLIANCE MONITORING PROGRAMME	14
6.1 Scope of activity	14
6.2 Monitoring area	14
6.2.1 Area assessment	16
6.2.2 Maps	17
6.3 General design	17
6.4 Preparation of preliminary report	18

6.5	Sampling	18
6.5.1	Matrices and locations	19
6.5.1.1	Point sources	19
6.5.1.2	Diffuse sources	21
6.5.2	Sampling frequency	22
6.5.3	Reference methods	22
7.	COMPLIANCE MONITORING IN THE MARINE ENVIRONMENT	23
7.1	Substances regulated under the Barcelona Convention	23
7.1.1	Regulated substances	23
7.1.2	Measures adopted by Contracting Parties	24
7.2	Media in which contaminants should be monitored	24
7.2.1	Compliance monitoring of health-related conditions	24
7.2.2	Compliance monitoring of sea water	25
7.2.3	Compliance monitoring of sediments	28
7.2.3.1	Introduction	28
7.2.3.2	Useful methods	28
7.2.3.3	Objectives of sediment toxicity tests	29
7.2.3.4	Sediment characterization	31
7.2.3.5	Sampling and storage of test sediment	31
7.2.3.6	Assessing contaminated sediments	31
7.2.3.7	Water quality criteria approach	32
7.2.4	Compliance monitoring of biota	32
7.2.4.1	Definitions	33
7.2.4.2	Sensitive biomonitors	33
7.2.4.3	Selection of contaminants	34
7.2.4.4	Selection of organisms	34
8.	COMPLIANCE MONITORING IN "HOT SPOT" AREAS	36
8.1	Definitions	36
8.2	"Hot spots" indicators (primary)	36
8.3	Compliance monitoring in "hot spot" areas	36
9.	ANALYTICAL QUALITY CONTROL	37
9.1	General	37
9.2	Quality control programme	37
9.3	Analytical methods	37
9.4	Control of analytical performance	37
9.4.1	Precision and accuracy	37
9.4.2	Evaluation of daily performance	38
9.4.3	Quality control charts	38
9.4.3.1	Shewhart quality control charts	38
9.4.3.2	Precision control charts	38
9.4.3.3	Accuracy control charts	39
9.5	Data handling and reporting	39
10.	ATTAINABILITY ANALYSES	39
11.	ENFORCEMENT	43

12.	ORGANIZATION	45
12.1	Establishment of a coastal water control organization	46
	12.1.1 Collection of information	46
	12.1.2 Decision and approval of pollution control policy	46
	12.1.3 Implementation of policy	47
	12.1.4 Monitoring of results achieved	47
12.2	Management of wastewater facilities (collection, treatment and disposal)	47
12.3	Monitoring of coastal waters and effluents	48
12.4	Research	48
13.	STEPS ILLUSTRATING PROCEDURE FOR MONITORING OF COMPLIANCE CONTROL	49
14.	REFERENCES	51

BACKGROUND

Following the first phase of the implementation of the MED POL Programme (MED POL - Phase I) from 1975-1980, the Contracting Parties to the Barcelona Convention approved a ten-year long-term Programme (MED POL - Phase II, 1981-1990) consisting of a monitoring and research component. In 1991 the Contracting Parties extended MED-POL Phase II until 1995 and the Programme was subsequently extended until 1996 to enable its completion and the formulation of the next phase.

In 1992 the Bureau of the Contracting Parties requested the Secretariat to organise the preparation of an in-depth evaluation of the MED POL Programme by experts and scientists external to the MAP office, with the intention to use this evaluation in the drafting of Phase III of MED POL. This evaluation was presented to the Eighth Ordinary Meeting of the Contracting Parties in October 1993 (UNEP, 1993a). During this meeting the Contracting Parties formally agreed to the preparation of MED POL Phase III, covering the period 1996-2005, and set a number of basic objectives and principles for its preparation (UNEP 1993b, Annex IV).

The meeting of experts on the preparation of MED POL Phase III held in Izmir, in June 1994, after reviewing and discussing the achievements and shortcomings of Phases I and II of the MED POL Programme, prepared a draft Programme for MED POL Phase III which was submitted for approval to the Joint Meeting of the Scientific and Technical Committee and the Socio-Economic Committee in April 1995. The document was not considered by the Joint Meeting due to lack of time and consequently the delegations were requested to provide comments to the Secretariat in writing. After reviewing the comments received and taking into account the results of the informal consultation meeting on MED POL III (Athens, December 1995), the document was revised to bring it in line with the Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (MAP Phase II) which was approved by the Contracting Parties in June 1995. The revised document was submitted to the Meeting of MED POL National Coordinators (Athens, March 1996), the Meeting of MAP Focal Points (Athens, May 1996) and finally the Extraordinary Meeting of the Contracting Parties (Montpellier, 1-4 July 1996), where it was adopted (UNEP, 1996).

According to the Annex of the MED POL Phase III Programme, two basic types of monitoring will be organised, compliance and trend monitoring. The contents of the document refer to the compliance monitoring and is proposed as a guide for the Contracting Parties for the implementation of this type of activity, taking into consideration that compliance monitoring will be applied for compliance with the national regulatory conditions.

The present document was presented to Meeting of MED POL National Coordinators held at Delphi in May 1997, and has been revised according to the comments made at that meeting with a view to its submission to the Tenth Ordinary Meeting of the Contracting Parties.

I. INTRODUCTION

The uncontrolled discharge of liquid waste into the Mediterranean Sea over past decades caused such severe damage to the marine environment that all Mediterranean countries decided to combat the situation by ratifying and implementing the Barcelona Convention and its related Protocols. The Mediterranean Action Plan (MAP), which was the outcome of this common determination, constitutes the essential mechanism for identifying problems and implementing related management techniques.

During MAPs first decade, the problem of inadequate pollution control programmes was recognized as one of the main reasons for the deterioration of the marine environment: discharge of liquid waste without proper treatment, failure to carry out environmental impact assessment studies (EIA), miscalculation of the environmental capacity of the Mediterranean Sea, unsatisfactory operation of existing wastewater treatment plants, etc.

MAP has now entered its third decade and the need for efficient control of the main pollution sources around the Mediterranean Sea has become evident: ratification of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources (LBS Protocol) and the Genoa Declaration constitute the first steps in this direction.

The Coordinating Unit for the Mediterranean Action Plan (UNEP/MAP) is actively involved in this common effort and has prepared this document to serve as a tool for proper compliance monitoring control of effluents and the ambient marine system, including "hot spot" areas.

The purpose of this document is to provide practical instructions and guidance for the collection and evaluation of the information needed for compliance monitoring of effluents and the ambient marine system.

The technical aspects can be found in the attached list of publications and supplementary technical documents (i.e. handbooks and manuals).

The importance of evaluating the environmental capacity of a water body, the elaboration of regional planning and assessment, the development of quality criteria and quality objectives, and the proper handling of monitoring data are highlighted as these aspects are frequently ignored or underestimated.

As this document represents a first step towards the elaboration of pollution control programmes, further action involving greater technical detail will have to be initiated in the near future in relation to effective implementation of the LBS Protocol.

Some indicative ideas are listed below:

- management techniques for industrial and urban pollution sources (river loads);
- development and implementation of quality criteria for effluents and the ambient marine environment;
- measures to control diffuse sources of pollution;
- continuous up-to-date evaluation of point sources of pollution;
- preparation of an attainability analyses document;
- elaboration of a document for the compliance monitoring of sediments;
- establishment of a body for enforcement of the Protocols;
- identification of sensitive and "hot spot" areas in the Mediterranean;
- development and elaboration of inspection procedures.

Certain countries have already elaborated and implemented some of these measures, but what are lacking are well-defined operational methods suitable to the special conditions of the Mediterranean environment.

2. COMPLIANCE CONTROL

2.1 Basis for action

Compliance with the provisions of MAP-Phase II, the Barcelona Convention and its Protocols (in particular the LBS and Dumping Protocols), and specifically with the decisions and recommendations adopted by the meetings of the Parties to the Convention¹, is the key to successful environmental protection of the Mediterranean Sea. The most relevant decisions and recommendations pertinent to the abatement, prevention and control of pollution are:

- (a) the relevant targets of the Genoa Declaration, adopted by the Contracting Parties in 1985², to be achieved as a matter of priority during the second decade of the Mediterranean Action Plan;
- (b) the specific action plans, programmes and measures adopted by the Contracting Parties in the context of implementation of the LBS Protocol³, and
- (c) the relevant decisions of the Contracting Parties, especially paragraph 6 of the Barcelona Resolution adopted by the Conference of Plenipotentiaries (Barcelona, 9-10 June 1995).

2.2 Objectives

The following are the specific objectives of this programme element:

- (a) to monitor on a continuous basis the implementation of action plans, programmes and measures for the control of pollution adopted or recommended by the Contracting Parties, and to assess the effectiveness of their implementation;
- (b) to identify problems experienced by the Contracting Parties in implementing these action plans, programmes and measures, and to formulate proposals that may assist in overcoming them⁴; and
- (c) to keep the Contracting Parties regularly informed about the status of implementation of the action plans, programmes and measures adopted⁵.

¹ Article 13.3 of the Barcelona Convention (1995) and Article 10 of the LBS Protocol (1996).

² Genoa Declaration. UNEP (OCA)/IG.56/5.

³ The common measures adopted so far are included in MAP Technical Reports Series No. 95

⁴ Paragraph 17.25 (b) of Agenda 21.

⁵ Paragraph 17.35 (b) of Agenda 21.

2.3 Activities

The stated objectives will be achieved through:

- (a) analysis and evaluation at a national, subregional or regional level of data and information generated on action plans, programmes and measures for the control of pollution⁶;
- (b) compliance monitoring programmes⁷ carried out by national MED POL collaborating institutions;
- (c) analysis and evaluation of data and information from national compliance monitoring programmes transmitted through the National Coordinators for MED POL;
- (d) target-oriented research in support of national compliance monitoring programmes; and
- (e) preparation of consolidated reports for the Contracting Parties on the status of implementation of the action plans, programmes and measures, including recommendations on ways and means to improve the efficiency of their implementation.

2.4 Monitoring of the levels and effects of contaminants in the context of MED POL Phase III

1. Two basic types of monitoring are identified within the framework of the MED POL - Phase III Programme namely compliance monitoring and trend monitoring. Surveys are also being carried out in order to complement the monitoring data and facilitate decision-making for management purposes.

2. Compliance monitoring is defined as the collection of data through surveillance programmes to verify that the regulatory conditions for a given activity are being met e.g. concentration of mercury in effluents. If a case of non-compliance is identified, appropriate enforcement can be put into effect and escalated until compliance is achieved.

3. Trend monitoring is defined as the repeated measurement of concentrations or effects over a period of time to detect possible changes with time. This type of monitoring will provide information that can be used to assess the state of the environment and the effectiveness of the pollution control measures taken. If the effectiveness of these measures is deemed inadequate, additional action may be taken, for example, the formulation of new measures or the revision of existing ones, etc.

4. Depending on the matrices and parameters included in the programme, monitoring will be carried out for the following purposes:

- (a) compliance monitoring;
- (b) trend monitoring.

⁶ Article 26 of the Barcelona Convention (1995); Articles 4, 5 and 6 of the Dumping Protocol (1995); and Article 13 of the LBS Protocol (1996).

⁷ Article 12 of the Barcelona Convention (1995), and Article 8 of the LBS Protocol (1996).

2.4.1 Compliance monitoring

- **Compliance monitoring of health-related conditions** (e.g. sanitary quality of bathing areas and waters used for aquaculture, quality of seafood). This type of monitoring is of national scope, although data may also be used for regional assessments. A comprehensive approach to microbiological and health-related monitoring of recreational and shellfish-growing areas is set out in considerable detail in documents WHO/UNEP (1994) and (1996).
- **Compliance monitoring of effluents** to determine whether there is compliance with the common measures adopted concerning concentrations of contaminants in effluents (e.g. mercury, cadmium); and
- **Compliance monitoring in "hot spot" areas** to determine whether there is compliance with the environmental quality objectives or limit values set (e.g. DDT in water).

2.4.2 Programme design⁸

For both compliance and trend monitoring, it is essential that the question being posed is both capable of being tested and specific, i.e. within a statistical context. The question must relate to a specific environmental compartment, i.e. water, suspended material, sediment or biota. The sequence to be followed is:

- to identify meaningful levels of change and the confidence limits of that change to be detected (e.g. with what precision can a 20 per cent loss in number of species of a benthic sediment-living community be detected?);
- to obtain knowledge of special and temporal variability of the element being sampled from a desk study or pilot study;
- to apply power analyses in order to rationalize the programme⁹;
- to select elements of the programme taking into account logistic constraints¹⁰;
- to define data quality objectives and decide *a priori* on the statistical methods to be applied in analyzing the data; and
- to select sampling sites and sampling frequency based on the foregoing information.

2.4.3 Data quality assurance programme

After a scientifically-based national monitoring programme has been designed, a data quality assurance (DQA) programme is required in order to ensure reliability of the data. The programme must cover all aspects of the data quality assurance required, including:

⁸ See Guidelines for monitoring chemical contaminants in the sea using marine organisms. UNEP Reference Methods for Marine Pollution Studies No. 6.

¹⁰ See also new experimental designs (Underwood, Aust. J., Mar. Sci. 1993)

- trained staff;
- appropriate facilities, sampling and measuring equipment and other consumables;
- regular calibration, maintenance, and servicing of the equipment;
- sampling that conforms to sampling design;
- sample handling procedures, including, for example, transportation, preservation, storage, tissue dissection, bone grinder, homogenization, sub-sampling (sub-sampling includes all steps up to measurement);
- regular checks of the accuracy and precision of routine measurements, by analyses of appropriate reference materials (where available) and documentation of the results on control charts;
- external quality assessment (e.g. participation in intercalibration exercises);
- standard operating procedures (written protocols with precise descriptions of all elements of the measurement and quality control procedures);
- recording of all calculations such as data translation and transcription prior to final documentation (record books and/or computers); and
- data evaluation procedures (e.g. converting data into a report).

The results obtained by sampling, measurement and observation must not only be of sufficient analytical (accuracy and precision) quality but must also meet the requirements of the objectives¹¹ and be comparable on a Mediterranean-wide basis.

3. WATER USES (PRESENT AND PLANNED) AND THE ASSESSMENT OF THEIR IMPORTANCE

3.1 Maintenance of the ecosystem

Many of the principal human uses of marine waters depend upon successful maintenance and enhancement of the existing ecosystems or, in a few cases, upon creating and continuing new and artificial ecosystems for specific purposes.

The ecosystem includes all of the biological and non-biological (geological, physical, and chemical) components of the environment and their highly complex interaction. Studies of ecosystems must include all that is within the body of water as well as imports into and exports from it. Research in such situations has shown that the biotic elements include producers of organic material, several levels of consumers, and decomposers. In the least complex situation, these act at rates controlled by the abiotic factors to transfer energy and recycle materials.

¹¹ Experience with quality assurance programmes, largely based on the practices of MED POL, is described in Contaminant Monitoring Programmes using Marine Organisms: Quality Assurance and Good Laboratory Practice (Reference Methods of Marine Pollution Studies No. 57, UNEP 1990).

3.2 Uses of the marine system to be protected

Coastal marine waters serve a wide variety of exceptionally important human uses. Many of these uses yield significant local benefits such as the production of shellfish, as well as recreational activities. Other uses involve regional benefits due to the global unity of the marine system, because local factors influence, and are influenced by, water quality at distant points.

Many human uses of marine waters directly depend on the nature and quality of the biological, chemical, and physical systems present. Efforts to protect and enhance these uses will be limited mainly by our ability to understand and protect the environmental conditions that are essential for the biota.

3.2.1 Human health

Ideally, criteria for coastal waters in regard to human health should be sets of quantitative exposure-response relationships between environmental exposure factors and effects on the pollution groups exposed. When dealing with human subjects, it is often difficult to establish even a basic cause-effect relationship, and even more difficult to obtain a graded response.

Seawaters are becoming increasingly contaminated chemically and microbiologically and may be a health hazard for man. One of the scientific approaches to demonstrating the relationship between water quality and disease is an epidemiological survey.

Monitoring of water quality is one of the means of assessing the potential risk. However, the recovery of pathogens from bathing waters does not necessarily indicate that the incidence of disease will be significantly increased.

3.2.2 Amenities, aesthetics and recreation

The aesthetic qualities of water relate to the general principles laid down in common law. They concern the beauty and quality of water and their concept may vary according to the individual in question. It is not possible to develop any rationale for these qualities by quantifying definitions; nevertheless, decisions on quality factors best reflect the public interest.

Aesthetic qualities provide general rules for protecting water against environmental damage; they represent minimal requirements for freedom from pollution and are essential to the enjoyment of a nation's water resources.

The enjoyment of amenities greatly depends not merely on the availability of an activity, but on the aesthetic satisfaction it affords. Aesthetic satisfaction can be a very positive force in promoting public health and well being. It is experienced through the senses of sight, smell, taste and touch.

As an optimum, when developing criteria to protect aesthetic quality there must be knowledge of the relationship between quality and other environmental factors, how it is detected by the senses, and the related degree of adverse or favourable reaction. In seeking such information, it is obviously necessary to be sure that the population whose reaction is to be assessed is reasonably representative of those whose interests the criteria adopted are intended to protect. In many coastal areas, this may mean ensuring an appropriate balance between the reactions of residents and non-residents, whose requirements and sensitivity may differ.

3.2.3 Aquaculture and fisheries¹²

The basis for major marine and coastal fisheries is the capture of wild species produced in estuaries, coastal waters and oceans. The quality and quantity of the available supply of useful species are controlled by the nature and efficiency of the several ecosystems upon which each species depends for its life cycle. Serious pollution at any point in the lower reaches of a river, an estuary, or inshore ocean might, therefore, interrupt the necessary pattern and reduce catches.

Estuaries play a particularly useful role as far as fisheries are concerned. They serve as spawning grounds, nursery areas, havens for parasites and predators, as well as highly productive and rich sources of food. As recipients of waste both from rivers entering them and cities and industries along their shores, estuaries are naturally more susceptible to immediate damage by pollution than any other part of the marine system. Although these inshore stretches of water are exceptionally vulnerable to physical and chemical damage, open waters along the coast can also be harmed, by waste disposal.

Pollutants can be detrimental to fisheries by reducing the numbers of species as a result of mortality directly caused by toxicity, smothering, intolerable heat, or other deadly changes. Species may also decrease when a pollutant causes sublethal stress that significantly interferes with feeding, movement, reproduction, or some other essential function.

3.2.4 Tourism

Tourism constitutes a major economic activity in a number of countries. Its expansion will continue and is desirable both for the economy and for the social well being of the community. In addition, it can promote job creation and regional development.

Environmental resources are a major element of tourism and a healthy environment is a vital ingredient for tourist areas. Unrestrained growth of tourism would diminish the quality of tourist areas and possibly their income-earning capacity.

The competent authorities should ensure that decisions on tourism development plans are based on the fullest information available concerning their environmental implications. An environmental impact assessment should be carried out for major tourism developments so as to evaluate potential damage to the environment in the light of the growth in tourism envisaged and peak demand.

In terms of residual waste, the most widespread problem in resort communities is water pollution through the discharge of inadequately treated effluents. Water bodies, which are among the most attractive resources for tourism development, are also frequently used for the cheap and convenient disposal of sewage.

3.2.5 Industrial water uses

Industry uses water for many purposes, for example, cooling, cleaning of equipment, production, washing, etc. Using water for the final disposal of industrial effluents is another important factor that must be mentioned.

Seawater is mostly used for receiving industrial effluents and the criteria for establishing ambient and effluent quality standards are mentioned elsewhere. The use of

¹² UNEP, 1987

seawater in industrial units themselves is rather limited, and only concerns cooling, washing of floors, etc. In these cases, no special environmental quality standards higher than those applied for bathing and fishing purposes are required. Special precautions are only taken to protect cooling towers, etc, from the salinity of seawater, and the washing of floors causes no special problems.

3.2.6 Commercial water uses

Ports, ship reception facilities and transport are the main fields of commercial activity related to seawater use. Marinas, on the other hand, are usually included in the tourism sector.

Seawater is mainly used to wash and clean ships' equipment and for the discharge of ship effluents. This form of use has seldom been taken into consideration in development plans, hence the present bad conditions to be found in almost all ports and reception facilities in the Mediterranean. It is only recently that regulations for port reception facilities have started to be applied in an effort to limit marine pollution caused by ships.

Criteria for the implementation of ambient and effluent quality standards for sea traffic have yet to be analyzed and assessed.

4. QUALITY CRITERIA

4.1 Environmental capacity¹³

Throughout history, the sea has been used to receive human waste. Only recently has such use been questioned because of the possible loss on restricted use of marine resources. The recognition that such marine pollutants as artificial radionuclides can jeopardize human health through the consumption of seafood or through exposure on beaches, and disasters such as that at Minamata Bay (mercury poisoning), have resulted in restrictions being placed upon the release of certain substances into the marine environment. However, to the scientific community some of these restrictions appear to be arbitrary because they are not based upon up-to-date concepts. There needs to be an awareness that the marine environment has to be treated as a resource for society as a whole and that the capacity of waters and sediment to receive waste must be assessed continually if resources are to remain renewable.

Various terms are used to describe the extent to which the environment is able to accommodate waste without unacceptable effects. One such term is "environmental capacity". This is a property of the environment and can be defined as the environment's capacity to accommodate a particular activity or rate of activity without any unacceptable impact.

4.2 Water quality criteria - standards

Water quality criteria specify the concentrations of water constituents which, if not exceeded, are expected to result in an aquatic ecosystem suitable for water use at a higher level. These criteria are based on scientific facts obtained from experimental or *in situ* observations that depict the responses of organisms to a defined stimulus or material under identifiable or regulated environmental conditions for a specified period of time.

¹³ United States Environmental Protection Agency (US/EPA), 1972

The aim of water quality criteria is not to ensure the same degree of safety or survival and propagation at all times to all organisms within a given ecosystem. The intention is not only to protect essential and significant life in water, as well as the direct users of water, but also to protect life that is dependent on living in water for its existence or may intentionally or unintentionally consume any edible portion of such life.

The word "criterion" should not be used interchangeably with or as a synonym for the word "standard". Criterion means a constituent concentration or level associated with a degree of environmental effect upon which scientific judgement may be based. As currently utilized in connection with the water environment, it means a designated concentration of a constituent that, when not exceeded, will protect an organism, an organism community, or a prescribed water use of quality at an adequate level of safety. In some instances, criterion may in fact be a narrative statement rather than a constituent concentration.

On the other hand, a standard connotes a legal requirement for a particular reach of water or an effluent. A water quality standard may use a water quality criterion as a basis for regulation or enforcement, but the standard may differ from a criterion because of prevailing local natural conditions, such as naturally occurring organic acids, or because of the importance of a particular stretch of water, economic considerations, or the level of safety that may be sought for a particular ecosystem.

Quality criteria have been designed to provide long-term protection. They thus constitute a basis for effluent standards, but it is not intended that they should become effluent standards.

4.2.1 Suggested procedure for establishing criteria

- (a) to undertake a critical review of the relevant documentation;
- (b) to determine the physical, chemical and biological characteristics, including variability in space and time, that influence the desired use or property of the environment. This can be achieved in part through preliminary field observations and laboratory experiments. Such data, together with judicious use of mathematical modeling techniques, will limit the number of variables to be considered;
- (c) to establish the relative importance of each characteristic, usually to within an order of magnitude. This again can be achieved in both the field and laboratory and will further limit the number of variables to be considered;
- (d) to determine the amount of stress being inflicted on the water mass to be protected. This should be expressed in appropriate units (e.g. concentration, mass, volume, energy, number of organisms). This will help to define the magnitude of the problem;
- (e) to determine the chemical and physical fate and distribution of the stress in the system taking into account time factors. This will require chemical, physical and/or biological analyses of various compartments in the system as well as hydrological data;
- (f) to determine the portions of the population or use in the area to be protected (or chosen for study) that are subject to each of several different levels of risk. This information will concern several different levels of risk and will be needed when deriving standards from the criteria. It requires an estimation of the rates of input to defined portions of the system;

- (g) to determine the exposure/response relationship relevant to the local system in question. This is a fundamental and almost universally applicable procedure and will involve determination of the most vulnerable point in the system (e.g. top predator, man, fish, life stage, required food organism, enzyme, physiological process);
- (h) to make experimental exposures in the laboratory and/or field whenever possible so as to establish a family of exposure response curves reflecting the effects of expected variations in conditions and pollutant input on observed response;
- (i) to estimate the effects of several degrees of target response on trophic levels immediately above and below target. This will provide a first estimate of the probability of remote effects in the ecosystem and requires consideration of patterns of biomagnification.

4.3 Control of discharges based on environmental quality objectives

Various methods have been employed to control the discharge of polluting materials into a body of water. The oldest method is probably the imposition of identical limits on all discharges. This method is often called "uniform emission standards". It is now being superseded in some countries by control based upon a reference to the environmental or ambient quality levels necessary to maintain the receiving water in a fit state for its legitimate and required uses.

The "environmental quality objectives" system is based on the philosophy of controlling discharges so that the quality of the receiving water body at any specified place is suitable for its established legitimate uses. The procedure for the control of discharges based on environmental quality objectives is illustrated in Figure 1.

The upper left part of the diagram concerns the derivation of the environmental quality levels taking into consideration the area of the water body and local uses. The quality objectives for a specific use will be similar throughout the Mediterranean and the process of deciding upon appropriate quality levels in individual cases will be simplified if uses are classified and criteria and quality objectives attached to each use. This is indicated in the upper right part of the diagram.

The next stage is to decide what conditions and restrictions must be applied to the discharge in order to attain the required quality levels. There are two variables to be considered: the discharge point and the pollution load of the effluent. In general, the longer the pipeline in the sea the greater the acceptable polluting load of the effluent. For a defined bathing water area, there will be a seaward limit and the pipeline should discharge beyond this limit. For any given point of discharge, the concentration of faecal coliforms in the effluent must be such that the dilution, dispersion and death-rate of the indicator will reduce the faecal coliform concentration at the boundary of the bathing area to within the limit.

The controlling authority carries out sampling and analysis both of the effluent to ensure that discharge is within the prescribed limits and of the sea water to confirm that the environmental quality within the defined zone meets the use objectives (Compliance monitoring procedure) (Figure 2 supplements Figure 1; they illustrate the control mechanism).

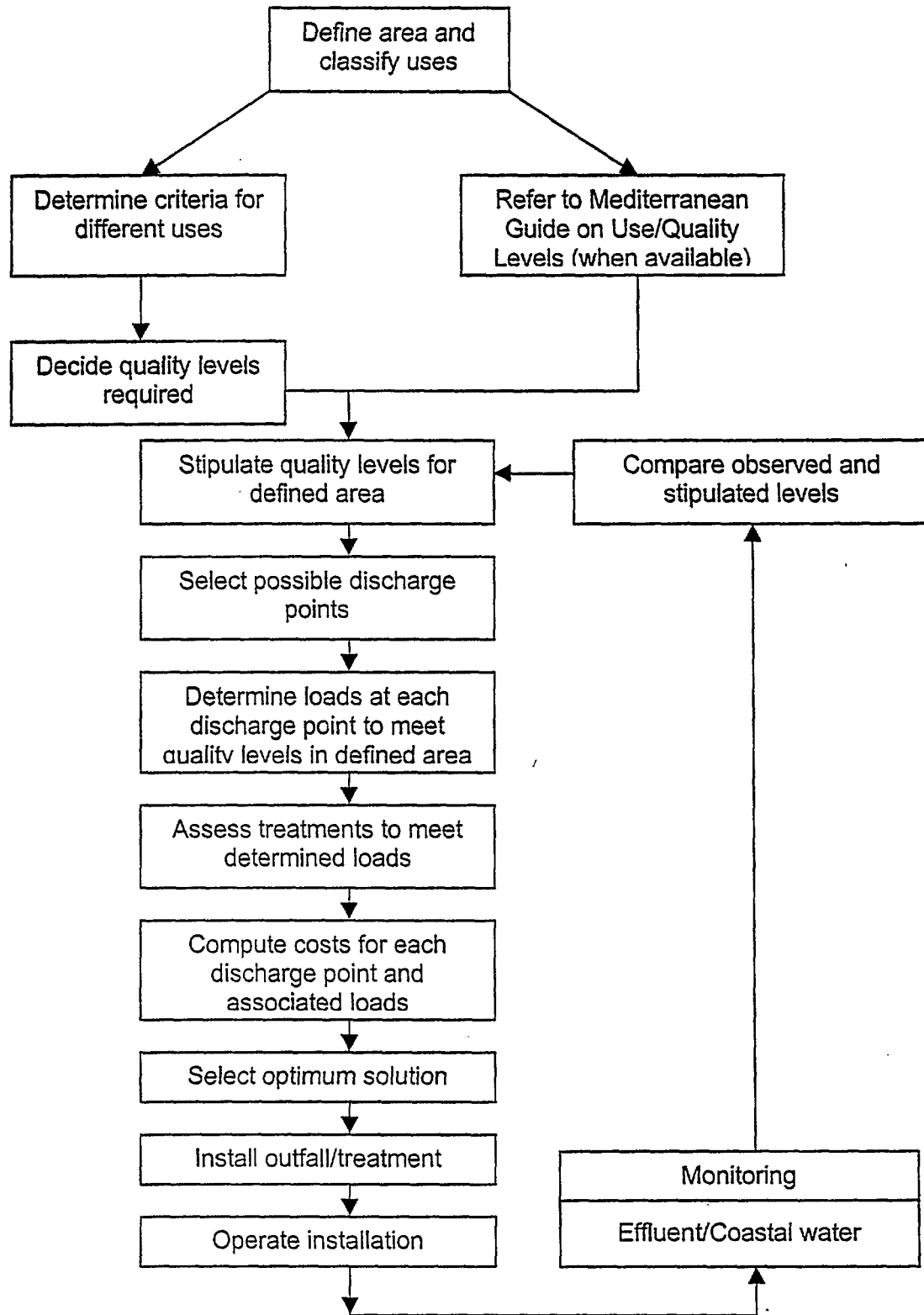


Figure 1

Diagram illustrating procedure for control of discharges by environmental quality objectives based on water use (WHO/UNEP, 1979 and UNEP/WHO, 1996)

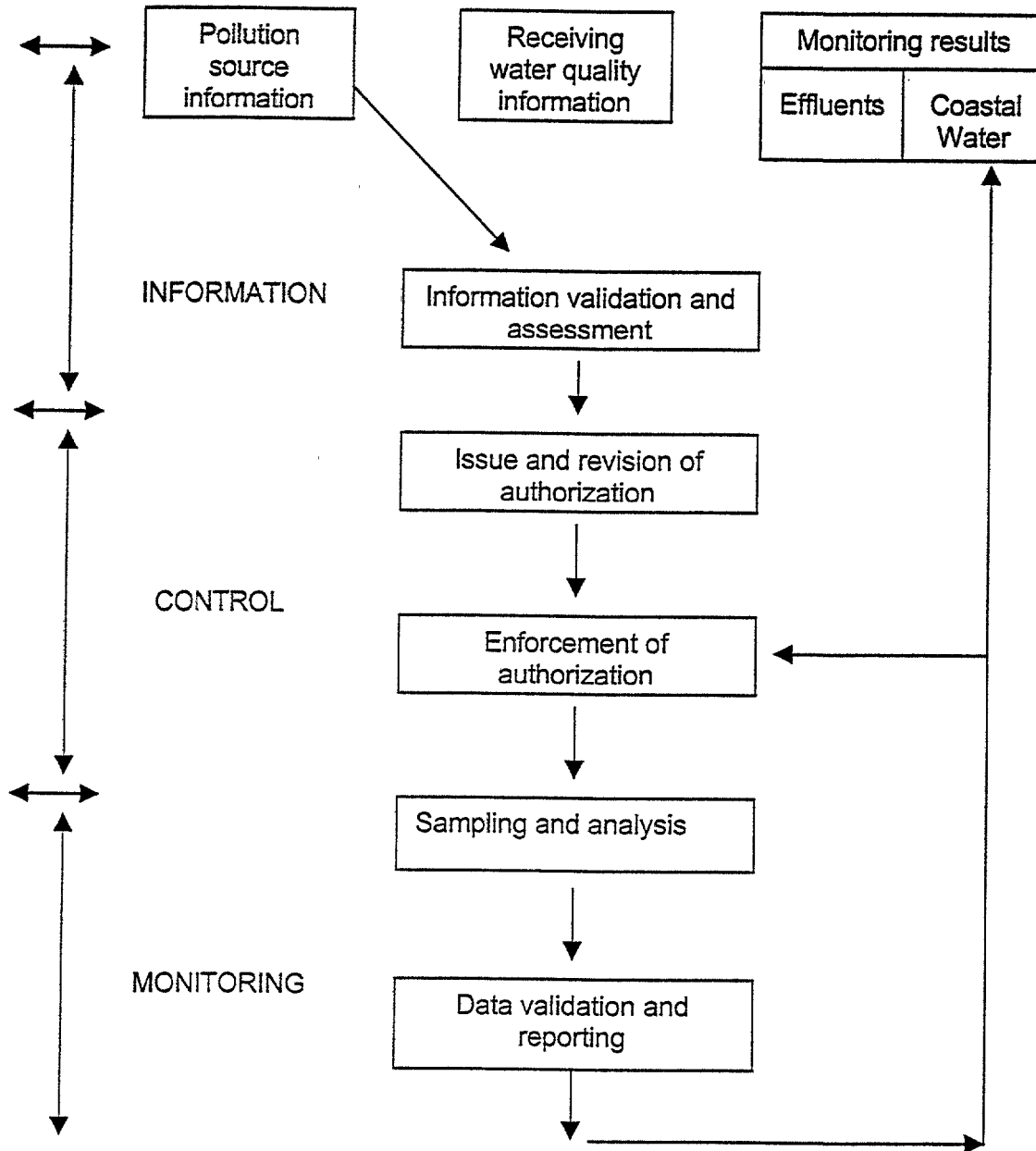


Figure 2.

Diagram illustrating the executive functions of coastal pollution control
(WHO/UNEP, 1979 and UNEP/WHO, 1996)

5. POLLUTION SOURCES

Land-based pollution sources can be classified into two main types: point sources and diffuse (non-point) sources.

5.1 Point sources¹⁴

Point sources are those from which pollutants are continuously or discontinuously discharged into the receiving water body from a single point. Examples of this type of source are:

- (a) Sewer outfalls, including outfalls of municipal or industrial sewage, stormwater outfalls and combined outfalls: They may either discharge into the immediate coastal areas from points above or below sea level, or enter the marine environment away from the coastline via a submarine pipeline;
- (b) Rivers: polluted rivers discharging in coastal areas may be important carriers of pollutants originating from points located inland, far away from the sea;
- (c) Coastal lagoons: These may be also important sources of pollution, particularly if they act as final recipients of wastes;
- (d) Solid waste and sludge disposal and dumping sites: Solid wastes and sludge disposed of directly into the sea, whether from specific points on land or from barges or ships, can be considered as a point source of pollution;
- (e) Accidents and leakages: Discharges of pollutants into the sea as a result of incidental or continuous leakage, or arising out of terrestrial accidents, such as an explosion in a coastal refinery, are also included in the category of point sources.

5.2 Diffuse (non-point) sources

Sources from which pollutants do not flow into the receiving water from a single point but are spread along the coast are considered diffuse sources. They can be classified as:

- (a) Run-off: stormwater which flows in an uncontrolled way into the sea, or leachate reaching the sea from dumping sites in the vicinity of the coastline, are the main examples of diffuse sources;
- (b) Small outfalls: untreated sanitary outfalls that are present in large numbers along the coast behave as diffuse sources;
- (c) Airborne pollution: there is evidence that considerable quantities of lead and possibly other trace metals, DDT, PCBs, low molecular weight petroleum hydrocarbons and other organic substances are transported to the open ocean by the atmosphere, either as particles or in the gas phase (Duce, *et al.* 1976; SCEP, 1979; FAO, 1971, GESAMP, 1989). The sources contributing to airborne pollution are thus also diffuse sources.

¹⁴ WHO/UNEP, 1994

6. COMPLIANCE MONITORING PROGRAMME

6.1 Scope of activity

The aims of a programme to monitor land-based sources of marine pollution for compliance purposes should be:

- (a) to complete the baseline studies necessary to survey the types and amounts of pollutants discharged or dumped into the coastal marine environment in any given area;
- (b) to compile and regularly update an inventory of land-based sources of marine pollution, including data on the probable fate of the pollutants;
- (c) to carry out effluent quality control where criteria or standards already exist and to assess the control measures being implemented;
- (d) to compile data on which to base decisions on the promulgation and implementation of control measures where such measures do not already exist;
- (e) to draw up a database to be used for the environmental impact assessment of any future coastal development.

The outline given in Figure 3 (modified from Mancy Allen, 1978) could be followed when planning an effective compliance monitoring programme. The main flow-chart is shown on the left side of the figure, while the right side contains information regarding the considerations to be taken into account when making a suitable decision. As can be seen in the outline, several factors affect decisions on the planning of a programme, among which financial restrictions may be the most important. A realistic decision on monitoring should always be financially feasible, and the compliance monitoring programme prepared accordingly.

When planning a compliance monitoring programme determining the parameters to be measured is very important. Generally speaking, these will depend on the types of sources present and the pollutants discharged. The determination can be based on data from existing monitoring programmes as well as on the water uses that must be protected. For example, the Mediterranean States agreed on priority parameters for pollution source monitoring in the region within the framework of the Long-term Programme of Pollution Monitoring and Research in the Mediterranean Sea (MED POL Phase II). These parameters were essentially designed for a coordinated regional programme, and the final choice in any particular area would depend mainly on local circumstances. However, consideration must be given to both the precision required and the precision obtainable because these factors may affect the significance, performance, and cost of the monitoring programme.

6.2 Monitoring area

One essential prerequisite of any compliance monitoring programme, and the preparations therefore, is to assess the problem. Prior to establishing the programme, the impact of actual and potential pollution on the various uses of the coastal waters in question should be determined through the acquisition of relevant data (area assessment). The area assessment should include both landward and seaward descriptions of the area, and the data obtained should be noted either on a fact sheet, or on a descriptive map, or on both, depending on the circumstances.

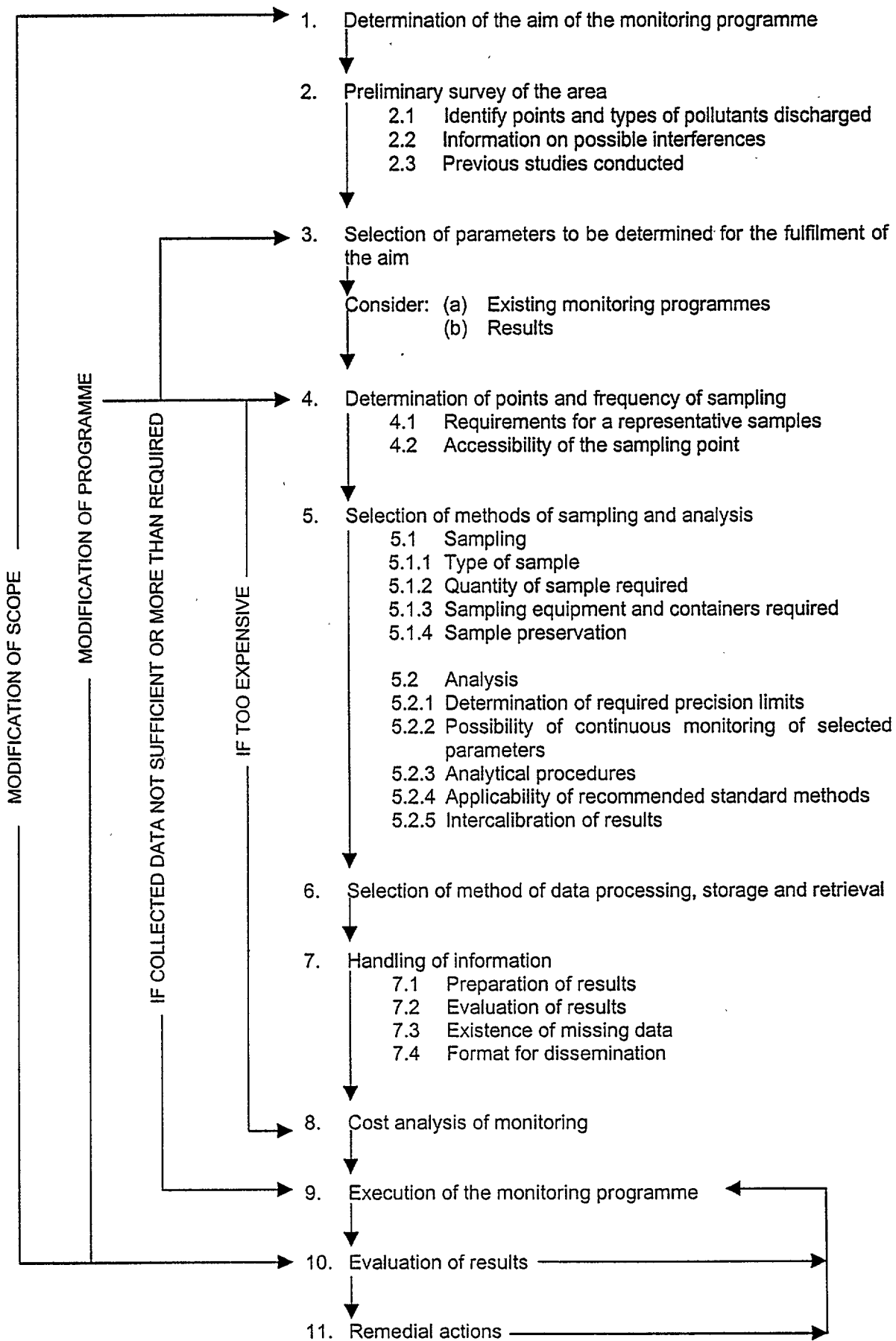


Figure 3.

Suggested flow diagram of an effective compliance monitoring programme
(Mancy, 1978 and WHO/UNEP, 1994)

6.2.1 Area assessment

From the landward side, the following should be noted, wherever appropriate to the aims and objectives of the programme:

- land use: categories of land use within the general area, including use of immediate coastal areas, e.g. industrial, residential, forestry, agricultural, recreational or mixed;
- run-off: identification of rivers and streams, including location, flow and individual monthly discharge into the sea, as well as areas where erosion is known to occur;
- wastewater discharges and outfalls: outfall sites, beach and offshore, including type, e.g. industrial, domestic or mixed, and total daily flow. Industrial discharges should be specified;
- wastewater treatment: location of treatment plants, capacity in m³ per day, and degree of treatment; sludge production and disposal;
- dumping sites: identification of dumping sites in the vicinity of the beach, indicating whether for solid waste, sewage disposal or both, and giving volume of deposit per year;
- coastline: sand, rock, gravel, cliffs. Also, whether shallow or deep water.

From the seaward side, the following should be noted, again wherever appropriate to the aims and objectives of the programme:

- shellfish areas: sites and types of shellfish should be indicated on a map, and information on catches (tonnage per year) should be given;
- fishing grounds: sites, types of fish and, if possible, information on catches, tonnage, etc should be indicated;
- protected areas: information about fish in marine parks and other similar protected areas;
- dumping sites: determination of locations, material and amount dumped;
- marine biota: general information about marine fauna and flora, wildlife and nature reserves should be provided.

The following meteorological and oceanographic observations will also have to be made, wherever relevant:

- winds: drawing up of seasonal wind roses;
- precipitation and air temperature: annual precipitation in tabular form. The same table to include average monthly air temperatures;
- currents and tides: description and seasonal fluctuation of currents, tidal cycles where applicable;

- salinity and temperature: based on existing studies the data should be sufficient to provide information on water column stratification and its seasonal variations;
- depth contours: from nautical charts;
- buoys and other navigational aids: these, as well as any other important obstacles such as wrecks or rocks, should be indicated.

Since a monitoring programme is a prerequisite for compliance monitoring, it is understood that all the above data should be available prior to compliance monitoring, unless specific conditions require additional data and consequently modification of the monitoring programme.

6.2.2 Maps

The use of adequate maps and nautical charts is an essential prerequisite for such a programme. The first step to be taken is to draw up detailed maps of the areas selected for monitoring. These should incorporate as much as possible of the information collected during the area assessment, in particular:

- (a) sewage outlets and any waste or other discharge points;
- (b) inshore and offshore solid waste dumping sites;
- (c) local currents in the coastal waters relative to point sources and beach locations.

The most recent geodetic and nautical maps of the coastal area to be studied should be obtained. The nautical charts are generally of major interest. The situation and use of each map will normally define the appropriate scale. A map of practical size could be the European A3 format (approximately 42 x 60 centimetres). Many copying machines allow for direct reduction from A3 to A4, resulting in economic reproduction and presentation of results.

Each map should be clearly identified by location, coordinates, scale and orientation. This must be done before any copying or reproduction is effected. Identification should include:

- (a) location: use the name of a typical town or conspicuous landmark. Always indicate the country;
- (b) coordinates: give the approximate latitude and longitude of the location;
- (c) scale: this should be graphed, e.g. in divisions of 100 metres or in kilometres, not numerical, as the latter may change with enlargement or reduction;
- (d) orientation: indicate N for north, or give lines for latitude and longitude of the main location;
- (e) date: give date of preparation of map, if available.

6.3 General design

Prior to actual implementation of the compliance monitoring programme, it is essential to decide on:

- (a) the matrices to be monitored;
- (b) the parameters to be monitored in each matrix;
- (c) the number and location of sampling points;
- (d) the frequency of sampling.

The extent of the programme will depend entirely on already-existing resources and on extra resources that can be made available to meet the required demand. These resources consist of:

- (a) trained manpower for sampling and analysis;
- (b) laboratory facilities (apparatus, equipment and materials);
- (c) transport facilities.

It should be borne in mind that in practically all cases the essential minimum is dictated by the provisions of international conventions or other similar legal instruments. In most countries, in order to conform to local requirements, national legislation provides for coverage over and above this minimum.

6.4 Preparation of preliminary report

A brief and concise report stating clearly the aims of the compliance monitoring programme and including information collected during the preliminary survey, a summary of previous studies and related maps, should be prepared. This report should form the basis for finalization of the compliance monitoring programme.

6.5 Sampling

Sampling techniques should be determined with great care as even with the most sensitive analytical techniques it is not possible to obtain more accurate and dependable results than the collected sample can provide.

It is not possible to provide specific sampling instructions that would be suitable and applicable under all conditions. Because of this, only general principles are outlined in the following sections.

The most important principle in sampling is to enable the analysis to be made on samples that are "representative" of the water concerned. In other words, the sample and its source should have the same composition. Furthermore, the sample should be a true representation of the variations in the characteristics of the source over time. Sampling should be performed in a systematic way in order to minimize discrepancies.

Selection of the sampling point location, as well as the frequency of sampling for the determination and monitoring of land-based marine pollution sources, depend mainly on the sensitivity required as well as the resources allocated for the compliance programme. There is a basic difference between the selection of sampling methodology for application by all Mediterranean countries on a common basis and the selection of a methodology in order to comply with national or even local requirements.

6.5.1 Matrices and locations

In programmes aimed at the determination of land-based pollution and compliance, details will have to be determined in the light of the situation existing in each particular locality. These will necessarily differ according to land use and related activities, as well as water use, in the area in question.

In a regional compliance monitoring programme aimed at the determination of land-based marine pollution originating from all Mediterranean countries, mandatory monitoring would be restricted to major sources of pollution, while at the same time allowing for additional components to enable national and local requirements to be met (compliance with local legislation).

In keeping with these general principles, the matrices to be monitored and the location of sampling points should be as explained below.

6.5.1.1 Point sources¹⁵

When samples are to be collected from a point source, the homogeneity of the system should first be verified and, if possible, sampling points should be located where homogeneous distribution of the parameters to be measured is observed. This is not always possible, especially if there are undissolved materials whose density is different to that of the water or if the extent of chemical and/or biological reactions varies in different parts of the system.

When the system is heterogeneous, the number and location of samples to be collected should be adjusted accordingly so that the results are representative. Variations in the homogeneous character of a system over time should be checked because seasonal variations, etc. are possible. Sampling locations near the boundaries of water systems, such as the banks of rivers or the walls of pipes and channels, should be avoided unless these locations are of special interest. The following principles should be adhered to in relation to the different types of point sources:

- Outfalls

The collection of samples from an outfall (domestic sewage or industrial effluent) is described in detail in document WHO/UNEP, 1994. EEC Directives on the following could also be used as a model for:

- (a) urban wastewater: collecting systems, discharges to receiving waters, reference methods, parameters to be measured, limit values etc, necessary for compliance control;
- (b) industrial effluents: limit values, industrial sectors, frequency of sampling, quality objectives, etc. for cadmium in effluents, as a guide for compliance control.

Document US/EPA, 1984 could also serve as general guidance for the basic inspection procedures.

¹⁵ WHO/UNEP, 1994

- Rivers and streams

Monitoring stations on rivers should be established, provided that the river satisfies one of the conditions below:

- (a) the average flow exceeds 100 m³/sec;
- (b) the watershed exceeds 100 km²;
- (c) it is thought to be heavily polluted.

A monitoring station on a river should be located outside the limits affected by tides and waves, at a point downstream from the last effluent discharge at a distance sufficient to obtain homogeneous distribution. If there is any possibility of non-homogeneous distribution of quality at the chosen location, experimental tests of the nature and magnitude of any heterogeneity should be made. If the results indicate that the river is of homogeneous character, one position for sampling will be enough, otherwise either the location of the sampling point should be transferred to a location of a homogeneous character or samples should be taken from several additional locations in addition to the original one selected so that the overall characteristics can be represented. For major rivers, even if they are homogeneous, it is advisable for more than one sample to be taken from different depths on the same cross section, forming a sampling point grid if necessary. In this case, the effect of variations of flow rate at the different points should be taken into consideration when preparing composite samples or estimating the overall input of any specific pollutant into the receiving water. When a limited number of samples needs to be taken in order to determine existing pollutants, if equipment is available, it is recommended that an "integrated" sample be taken from top to bottom in midstream, or from side to side at mid-depth, in such a way that the sample is integrated according to flow. If only a grab or catch sample can be collected, this is best taken in mid-stream at mid-depth (APHA, 1990). On the other hand, for velocity measurements, which are essential in order to determine the flow and, consequently, the total amount of pollutant discharged into the receiving water, sampling should be effected at a point located at 0.6m of the total depth measured from the bottom or, to increase accuracy, at points located 0.2m and 0.8m of the total depth (Linsley, 1964), taking the average of these. Special attention is necessary when dealing with rivers that have a tendency to flood or a seasonally- varying stratification.

Bridges over rivers are easily accessible and convenient sampling points. However, before any decision is taken regarding their use, it should be verified that samples collected from them are valid and representative. Sampling from areas where stagnation may occur and from areas located near the inside bank of a curve in the stream which may not be representative of the main channel should be avoided.

- Solid waste and sludge disposal

Although it is not recommended practice, solid wastes and sludge can, in some countries, be dumped into a receiving water either legally (with an authorization) or illegally, directly from the coast or from barges used for the purpose.

In the case of authorized dumping, the amount of waste should be determined either by weighing the load on specially allocated scales or, if this is not possible, by estimating the amount by volume. All municipalities or other institutions dumping solid wastes and sludge in this way should be obliged to provide information in an appropriate format on the amount and composition of the material dumped. Random sampling is usually carried out by taking one sample for every 500 tons of municipal solid wastes and one sample for every 10 tons of industrial solid wastes, taking into consideration the waste's origin and classification.

Samples should be collected carefully from different parts of the solid waste load, trying to be as representative as possible. In cases where it is proven that a declaration by a particular industry is not correct, all loads coming from that industry should be examined.

The sampling of solid wastes and sludge from unauthorized dumping into receiving water is very difficult, if not impossible. The only possible way of controlling unauthorized dumping and estimating the possible amount is source control. To achieve this, all sources of hazardous wastes should be obliged to fill in a declaration form giving information about the amount, properties and place of disposal of hazardous wastes. The accuracy of the information given in the declaration should be verified through random inspection.

- Major accidents

Major accidents undoubtedly contribute towards marine pollution. If detailed information about the characteristics of the material flowing into the sea as the result of an accident is available, an estimation of the volume of the material in question reaching the sea is enough to determine the amount of pollutant. If an analysis of the material leaking is not available, samples should be collected from the accident site and affected areas.

6.5.1.2 Diffuse sources

Sampling from diffuse sources is a very complicated process for which a generally acceptable procedure is not available. In such cases, the following approaches are suggested:

- (a) collection of a representative sample and estimation of the overall effect;
- (b) determination of the concentrations of selected pollutants in various parts of the receiving marine environment in combination with salinity or other tracers, extrapolating to zero salinity and flow estimations;
- (c) utilization of information obtained from similar situations for which accurate load calculations are available;
- (d) in the case of urban waste, calculation of the population equivalent on the basis of previous experience.

As can be seen from the four possible methods outlined above, only the first two require actual sampling, while the other two are based purely on estimates. The collection of a representative sample in order to make an overall estimate can easily be achieved if the diffuse source is in the form of small outfalls. If this is so, one of the outfalls should be chosen arbitrarily and the results obtained extended to all the others. In the case of a "runoff", it is recommended that a channel at least 50m long perpendicular to the direction of the runoff be constructed, and samples collected from the outlet of this channel. It is considered that a 50m-length collection channel would be sufficient in most cases.

Selecting the location of sampling points in the receiving marine environment in order to apply approach (b) above depends entirely on local conditions. However, the following general principles can still be applied:

- (a) a grid of sampling points should be formed covering all the marine environment immediately affected;
- (b) the depth from which the sample is to be collected should be decided according to local conditions. However, it is recommended that, at points where the depth

exceeds 10m, at least three samples (one below the surface, one at mid-depth, and one at 1m above the bottom) should be collected.

6.5.2 Sampling frequency

The frequency of sampling should be determined in such a way as to represent adequately the true quality and variation, but at the same time it should not exceed the minimum essential requirements in order to avoid unnecessary effort and cost.

The best solution to the question of frequency is the use of instruments that measure continuously and automatically. This is not always possible, however, due to the unavailability of adequate instrumentation and the high cost involved.

A decision on the frequency of sampling can only be taken only after available data have been examined and the variation of characteristics has been evaluated.

When systematical data are not available, the following sampling programme should be followed, at least for major sources:

- (a) hourly sampling during one 24-hour period in each quarter (season) to assess daily cyclic effects;
- (b) daily sampling during seven consecutive days in each season, to determine any weekly cyclic effects;
- (c) weekly samples to delineate seasonal effects and to determine how less frequent sampling would have affected the results.

After a one-year trial period on the basis of the above programme, an evaluation should be made to permit a decision on a suitable sampling frequency that provides the required confidence limit of the means.

If the parameters to be determined show systematic trends or cyclic variations, the time of sampling should be considered in addition to the number of samples. Both should be chosen in such a way as to reflect the actual situation. Whatever the results of the above-mentioned analysis, the frequency of sampling should not be less than once per month. For practical reasons, whenever applicable, the sampling frequency may be adjusted to fit other monitoring programmes, such as the compliance monitoring of the quality of coastal recreational and shellfish-growing areas.

6.5.3 Reference methods¹⁶

Four decades ago, adequate analytical techniques were not widely available to allow chemists to quantify contaminants causing pollution and to assess their impact. As a result of the increased concern to measure potential pollutants in the marine environment, techniques were rapidly adapted from other areas of pure and applied chemistry and a large number of methodologies and data sets began to appear in the scientific literature.

For the more inexperienced scientists, keeping abreast of the scientific literature on methodology is a daunting challenge and it would be difficult to test the many hundreds of methodological modifications (not always improvements) published each year. Most conventional textbooks cannot be re-edited sufficiently rapidly to keep up with the pace of

¹⁶ UNEP/IAEA/IOC, 1990

these developments. Clearly a more dynamic and flexible approach to this issue is required. The UNEP Reference Methods for Marine Pollution Studies series was established in 1983 as an attempt to address this issue and to provide a mechanism for testing, optimizing and updating methodologies and communicating them to marine scientists throughout the world.

By providing a flexible mechanism for technical support, adapted to real environmental problems, United Nations agencies are endeavouring to keep marine environmental scientists well-armed to face these challenges, not alone, but as part of a global team with a common aim.

The Reference Methods programme provides a wide-ranging series of methods and guidelines for marine pollution studies. Each method is self-contained and follows, as closely as possible the format and terminology recommended by the International Standardization Organization (ISO). The methods are designed to be applicable throughout the world and to produce data of sufficient accuracy, reliability and precision to allow meaningful interpretation for the purposes of regional marine pollution studies, as well as interregional comparisons (and so to contribute to UNEP's Global Environmental Monitoring System (GEMS)).

The Reference Method Catalogue (UNEP/IAEA/IOC, 1990) gives a full listing of methods now available and those currently being prepared or tested. Many of the methods are interrelated to form a structured series of texts on monitoring strategy, sampling techniques, analysis, quality assurance and data interpretation. Each text is self-contained and can be updated without altering the rest of the series. The reader should make sure he has the latest edition of each method he or she requires.

In document US/EPA (1974) there is a recommendation on sampling and preservation of samples according to measurement.

7. COMPLIANCE MONITORING IN THE MARINE ENVIRONMENT

7.1 Substances regulated under the Barcelona Convention

7.1.1 Regulated substances

A system that is used in all marine conventions is to regulate the use and/or discharges of certain substances and materials that are known, or at least suspected, to be harmful to the marine environment. The usual procedure has been to define a set of criteria on which to base the selection of a number of substances that should be regulated. Typical criteria were: toxicity, persistence and bioaccumulation. Substances showing high toxicity together with high persistence or ability to bioaccumulate were "banned", which means that they should be eliminated from discharges. A list of such substances was usually referred to as the "Black List" although the term is no longer used. Other substances of environmental concern are identified, although they are considered as being less harmful. The text of the convention usually allows these substances to be discharged, although their discharge should be minimized. Similarly, a list of such substances was usually referred to as the "Grey List".

The regulations in the text of the Barcelona Convention (as it came into force in 1978) are rather general. For example, Article 8 states: "The Contracting Parties shall take all appropriate measures to prevent, abate and combat pollution of the Mediterranean Sea Area caused by discharges from rivers, coastal establishments or outfalls, or emanating from any other land-based sources within their territories". However, the amended Convention which has not yet entered into force is more precise. The text of the LBS Protocol which

came into force in 1983 is somewhat more specific (Articles 5 and 6), whereas in the 1996 amended Protocol the categories of substances, their characteristics, and the sectors of activity that need to be taken into account in the preparation of action plans, programmes and measures for the elimination of pollution from land-based sources and activities are included.

7.1.2 Measures adopted by Contracting Parties

From the viewpoint of human health, the LBS Protocol is the most important. In view of the considerable economic and legal implications of this Protocol, the text itself is similar to the Convention in that it provides a framework for prevention and control measures, with progressive implementation. To date, the Contracting Parties have adopted joint measures under the Protocol (WHO/UNEP, 1995).

7.2 Media in which contaminants should be monitored

The ICES in its role as scientific adviser to PARCOM and partner with PARCOM in the North Sea Task Force (NSTF), responded to a request to recommend to PARCOM and NSTF a scheme to describe in which media the different contaminants or hazardous substances should preferably be monitored. The scheme should also assign sampling priorities among various media in order to make the monitoring more cost effective. The advice given appears below.

It is important to stress that the information contained in the tables should not be used alone but should always be combined with the explanatory text.

The matrices considered included sea water, sediments, and biota, as included in the current Joint Monitoring Programme (JMP). The matrices were selected as those most appropriate for the provision of the most information in relation to each monitoring purpose. They were selected on scientific grounds and did not take any account of the relative costs or convenience of the alternative choices.

In some cases, no matrix was recommended, either because the monitoring of a particular contaminant was not appropriate to the monitoring purpose or because advice could not be given for technical reasons.

The reliability of the information provided by a monitoring programme and its consequent value depend upon the attention paid to quality assurance at all stages of the measurement programme (sample collection, storage, preparation, preconcentration, analysis, standardization and interpretation). Participating laboratories should be required to adopt appropriate procedures in this area.

7.2.1 Compliance monitoring of health-related conditions

Table 1 provides advice on the contaminants and matrices that should be included in a regional or broader survey to assess the possible hazards to human health caused by the presence of selected contaminants in marine foodstuffs. In several cases, primary and secondary choices of matrix are given.

There may be areas of contamination which could give rise to localized increases of concentration in foodstuffs. Such situations are unlikely to be detected or adequately described by large-scale surveys and are better approached through specially designed and targeted monitoring exercises by national or local authorities. In such circumstances, the relevant authorities should assess the most important exposure pathway by which the contaminant reached the public through marine foodstuffs. The monitoring programme

should be directed at that pathway and not be constrained by the advice given in Table 1 in relation to broader scale surveys.

Compliance monitoring of health-related conditions (e.g. sanitary quality of bathing areas and waters used for aquaculture, quality of seafood) is of national importance, but data may also be used for regional assessments. A comprehensive approach to microbiological and health-related monitoring of recreational and shellfish-growing areas is shown in detail in documents WHO/UNEP (1994) and WHO/UNEP (1996).

7.2.2 Compliance monitoring of sea water (Table 2)

The use of water analysis to reflect current levels of marine contamination is attractive in that it concerns the important aqueous phase, the environment in which both biota and sediment exist. The requirements for precision and accuracy of analysis at low concentrations limit the number of determinants that could be considered in offshore waters in relation to mercury, cadmium, copper, zinc and lead, all at secondary matrix level. Even in these cases, it would be essential for each laboratory to establish in-house quality control procedures and for rigorous assessments to be made to establish comparability among laboratories, with particular attention to lead.

In near-shore waters, concentrations may be somewhat more variable and subject to anthropogenic influences, and chromium and nickel analyses might also be considered. The same quality assurance precautions would be needed. In near-shore waters, it is necessary to take account of any correlation between contaminant concentrations and salinity, and of the influence of the concentration and composition of suspended matter on the dissolved contaminants.

Sea water is not a matrix of choice for CBs, as the octane: water partition coefficients indicate that the compounds would be predominantly associated with sediment or biota.

The concentrations of arsenic naturally present in sea water make it difficult to discriminate between anthropogenic influences and natural processes, therefore, sea water is not indicated as an appropriate matrix.

In some sea areas (usually small and isolated areas), the inputs of contaminants are sufficiently large to cause marked elevations of contaminant concentrations in sea water, or changes in concentrations could be expected. In such areas, it might be appropriate for national authorities to give more prominence to water analysis in monitoring programmes. The monitoring of sea water at a more regular frequency than once every five years could be justified:

- (a) in areas with enhanced levels of contaminants, and
- (b) in areas where changes could be expected as a result of known reduction in inputs for example.

A distinction must be made between near-shore waters, where marked salinity gradients may be found and which are more likely to be influenced by riverain or land-based inputs of contaminants, and offshore waters, where gradients are usually substantially less marked and which are more remote from the above-mentioned inputs of contaminants. In document IMCO/FAO/UNESCO/WMO/IAEA/UN/UNEP (1980), Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), Marine Pollution Implications of Coastal Area Development. Rep. Stud. GESAMP, (11): 114 p., there is a synoptic table of a preliminary programme of oceanographic observations that could be used for a compliance monitoring programme for sea water.

Table 1
In relation to the assessment of possible hazards to human health
(Chassard-Bouchaud, 1993)

Matrix	Contaminant																							
	CBs	γ-HCH	Hg ⁵	Cd	Cu ³	Zn ³	As ⁴	Cr ³	Ni ³	Pb	MeHg	TBT ³	Chlordane	Planar CB	PCDD/PCDF	DDT ³	Dieldrin	PAH	PCC	Triazines ³	PPDE ⁴	PBB ⁴		
Shellfish	P	P	P	P						P	P	P		P	P		P	P					P	
Fish muscle			P								P													
Fish liver	S ²	S ²		S ²										S ²	S ²		S ²			S ²			S ²	

P: primary matrix
S: secondary matrix

Notes and qualifications:

1. If fish liver is not a consumed fisheries product, no analysis is needed.
2. If fish liver is not a consumed fisheries product and there remain human health concerns, transfer attention to fish muscle.
3. These contaminants are not normally of concern in respect to the consumption of fisheries products.
4. Arsenic is present in seafood in measurable concentrations, but its chemical form makes it of little concern with respect to human health.
5. Hg should be understood to include methyl-mercury compounds. In countries where public health regulations refer to methyl-mercury rather than total mercury, samples may be analyzed for methyl-mercury.
6. Too little is known about the toxicity to assess potential hazard.

Table 2
In relation to the assessment of existing level of marine pollution (i.e. contamination)
(Chassard-Bouchaud, 1993)

Matrix	Contaminant																						
	CBs	γ-HCH	Hg	Cd	Cu	Zn	As	Cr	Ni	Pb	TBT	MeHg	Chlordane	Planar CB	PCDD/PCDF	DDT	Diel-drin	PAH	PCC	Triazines	PPDE	PBB	
Near-shore water		P	P ¹	P ¹	P ¹	P ¹		P ¹	P ¹	P ¹	S ¹									P			
Offshore water		S	S ¹	S ¹	S ¹	S ¹				S ¹													
Surficial sediments ²	P		P	P	P	P	P ⁵	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P
Shellfish	S ³	S ³	S ¹	S ¹	S ¹	S ¹				S ¹	P	P	S ³	S ³	S ³	S ³	S ³	S ³	S ³	S ³	S ³	S ³	S ³
Fish muscle			T ^{1,4}				S ^{1,4}					S ⁴											
Fish liver	S ⁴			T ^{1,4}						T ^{1,4}		S ⁴	S ⁴	S ⁴	S ⁴	S ⁴	S ⁴	S ⁴	S ⁴		S ⁴	S ⁴	S ⁴

P: primary matrix
S: secondary matrix
T: tertiary matrix

Notes and qualifications:

1. Potential addition/alternative to sediment measurements in areas where sediment conditions are not wholly favourable.
2. Should be accompanied by total organic carbon measurements, size fractionation (<63 μm), and description of the sediment type. Sampling should be carried out following current ICES guidelines.
3. Could be carried out on an opportune basis, as may provide additional information on distribution.
4. Sedentary species only (e.g. flatfish).
5. The signal-to-noise ratio for discriminating between anthropogenic and natural influences is extremely low.

7.2.3 Compliance monitoring of sediments¹⁷

7.2.3.1 Introduction

Although methods for the chemical and biological characterization of water-borne contaminants are applied in regulatory and monitoring programmes in many countries, methods for the assessment of sediments are less widely or uniformly established.

Sediments may act as a sink for, and source of, toxic chemicals through sorption of contaminants to particulate matter. The effects of surface water contamination become integrated over time and space and create a hazard to aquatic communities (both pelagic and benthic), which is not directly predictable from observations of contaminant concentrations in the water column. Sediments can serve as historical records of change due to both man-made pollution and natural environmental causes. For example, lake sediments reflect surface water quality more consistently than do flowing rivers even though there may be seasonal changes in the lake environment, e.g. metal cycling in hypolimnetic waters.

Effects on benthic organisms are of concern because in many ecosystems the sediment community plays an important role in the recycling of detrital material to the pelagic community. In addition, benthic organisms are a critical component of a variety of aquatic food webs. There is thus a need for sediment quality objectives that may be used as a scientific basis for the development of standards to protect ecosystems from the effects of sediment contamination, and to manage contaminated sediment in the long term. Consequently, the main objectives are:

- (a) to consider the methods available for use in developing environmental quality objectives (or criteria) for sediments, and to reach consensus on the methods most appropriate for this purpose;
- (b) to recommend the most appropriate test methods to assess:
 - (i) the toxicity of sediments; and
 - (ii) the toxicity of a particular chemical or group of chemicals for sediment-dwelling organisms.

7.2.3.2 Useful methods

A number of potentially useful methods exist, namely:

- equilibrium partitioning;
- interstitial water quality;
- spiked sediment toxicity;
- reference concentrations;
- apparent effects threshold;
- screening level concentrations;
- sediment quality triad;
- tissue residue.

¹⁷ OECD, 1992

Each method is evaluated with respect to the following characteristics:

- (a) Chemical specificity: can the method be used to derive a concentration for a specific chemical?
- (b) Causality: are the observed effects caused by the specific chemical?
- (c) Chronic effects: does the method consider chronic toxicity endpoints?
- (d) Bioaccumulation: does the method consider food chain accumulation and ingestion of contaminated sediment for (i) benthos, (ii) fish?
- (e) State of development: is the method ready for use (tested, validated, used)?
- (f) Bioavailability: how generally applicable is the method across sediment types? Are sediment quality objectives a function of the bioavailable phase?
- (g) Applicability: is the method applicable to bedded sediments or suspensions?
- (h) Recommendation: on the basis of the foregoing evaluations, can the method be recommended for use in deriving sediment quality objectives?

The results are shown in Table 3.

7.2.3.3 Objectives of sediment toxicity tests

It is important always to be clear about the objectives of contaminated sediment studies as the objectives are vital to selection and/or development of appropriate test systems.

There are a number of reasons for developing and utilizing sediment toxicity tests:

- (a) to assist in setting quality standards for individual compounds;
- (b) to assess the impact of discharges of sediments associated with receiving waters, such as sediment disposal associated with dredging activities;
- (c) to assess the persistence of toxicity in sediments following the alteration, amelioration or cessation of toxic discharges;
- (d) to predict the impact on sediment-dwelling organisms exposed to new substances that may be released into the environment;
- (e) to estimate the degree to which toxicity is responsible for low benthic species diversity in impacted systems.

Table 3
Evaluation of the present state of development of eight methods for deriving sediment quality objectives

Elements/characteristics Method	Chemical specificity	Causality	Chronic effects	Bioaccumulation benthos/fish	State of development	Bioavailability	Applicability (a)	Can be recommended
Equilibrium partitioning	++	++	+	+/-	++b)	++b)	BS*	yes
Interstitial water quality	++	++	+	-/-	-	+	B	yes
Spiked sediment toxicity	++	++	+c)	+/-	+d)	+e)	BS*	yes
Reference concentrations	++	--	--	+/	++	--	BS	no
Apparent effects threshold	++	--	-/+f)	-/-	++	+e)	B	no
Screening level concentrations	++	--	+	-/-	-	+	B	no
Sediment quality triad	--	--	+	-/-	+	-	B	no
Tissue residue	*	*	*	*/-	--	*	B*S*	no

Key:

- ++ High - Low
- + Medium -- Very low
- (a) To bedded sediments (B), suspended sediments (S).
- (b) Well developed for organic chemicals and being developed for metals and other chemicals.
- (c) For freshwater organisms only.
- (d) Methods and guidelines need to be developed.
- (e) If concentrations are properly normalized to reflect biological availability, e.g. by organic carbon or acid volatile sulphides.
- (f) Chronic effects on benthic organisms in field situations can be considered.
- + There is potential for development.

7.2.3.4 Sediment characterization

A wide range of parameters may be relevant in characterizing the sediment associated with solid phase tests; they depend on the purpose of the investigation. The following key parameters are frequently necessary for interpretation of the toxicity test results:

- **Particle size distribution.**
- **Dissolved oxygen.**
- **Organic carbon content.**
- **Total ammonium concentration.**
- **Acid volatile sulphides (AVS).**
- **pH.**

The following may also be relevant on a site-specific basis:

- biochemical oxygen demand;
- chemical oxygen demand;
- nitrate/nitrite;
- chloride;
- sulphate;
- redox (Eh) potential;
- dissolved organic carbon (pore water);
- conductivity;
- salinity;
- hydrogen sulphide;
- suspected or spiked chemical contaminants.

7.2.3.5 Sampling and storage of test sediment

Sediment for toxicity tests should be fresh and handled in a way that minimizes alterations that may affect the toxicity to organisms exposed in the laboratory. When sediment samples undergo toxicity tests, parallel samples are often subjected to chemical, physical and/or biological investigations. The combined objectives of the particular investigation, therefore, determine the sampling design, including the equipment used, sampling points, depth of sediment and time of sampling.

Sediment for biological investigations (evaluation of benthic community structure) are usually processed (screened) and preserved on-site, whereas samples for chemical and physical characterization are handled and stored according to procedures more or less specific to the particular test. For the purpose of sediment toxicity evaluations, it is important to obtain sediments with as little disruption as possible to allow for realistic laboratory evaluation of *in situ* conditions.

7.2.3.6 Assessing contaminated sediments

The ability to define contaminants responsible for toxicity in contaminated sediments provides a unique opportunity for insights concerning remedial and regulatory activities, including:

- (a) identification of discharges responsible for sediment contamination resulting in toxicity;
- (b) identification of unsuspected contaminants responsible for toxicity in sediments;
- (c) identification of point versus non-point source impacts resulting in toxic sediments;
- (d) evaluation of disposal options for dredged materials.

7.2.3.7 Water quality criteria approach

The water quality criteria approach compares the concentrations of individual contaminants present in sediment interstitial water with water quality criteria (WQC). Existing WQC have been developed from a broad range of toxicological studies using a wide range of aquatic organisms. These criteria have been used in the regulatory context to specify contaminant levels that, if not exceeded, will protect 95 per cent of aquatic life from adverse effects.

A major assumption of the approach is that water column organisms used to develop WQC have the same sensitivities as infaunal benthic organisms. It is also assumed that the major route of contaminant exposure is from the interstitial water and exposure from ingestion of contaminants on sediments is not significant.

The principal advantage of this approach is that it relies on existing toxicological databases used to develop WQC. It only requires the additional measurement of the contaminant concentration in the interstitial water.

On the other hand, the approach has several disadvantages: (i) WQC are available only for a limited number of contaminants; (ii) the toxicological data used to develop WQC were from sediment-free bioassays so there is no consideration of the effect that soluble or particulate organic matter, present in interstitial water may have on contaminant bioavailability; (iii) the potential to increase contaminant body burden through ingestion or direct contact with sediment contaminants is not taken into account; and (iv) suitable methods are still being developed for the isolation and measurement of contaminant concentrations in interstitial water.

7.2.4 Compliance monitoring of biota

Marine organisms are commonly used to monitor chemical contaminants in the sea. It is well known that they can concentrate toxicants by uptaking them from water and sediment as dissolved or particulate matter, which enter their organisms via gills, the digestive tract or tegument epithelia. Toxicants are then stored in various tissues and organs, among which a target is generally determined to be used as the main indicator. Elimination and excretion occur via several routes.

It is difficult to find the right species for monitoring purposes. Environmental indicators are suitable for the observation of long-term development in an ecosystem, as well as for planning and controlling effects of anthropogenic activities.

7.2.4.1 Definitions

Figure 4 shows a proposal for the classification of bioindication (Hertz, 1991).

Bioindication means the time-dependent, sensitive response of measurable quantities of biological objects and systems to anthropogenic influences on the environment. In general, a distinction can be made between:

- bioindication as a qualitative method for the detection of the presence of pollutants, and
- biomonitoring as a more quantitative method for the determination of the effects of the pollutants present.

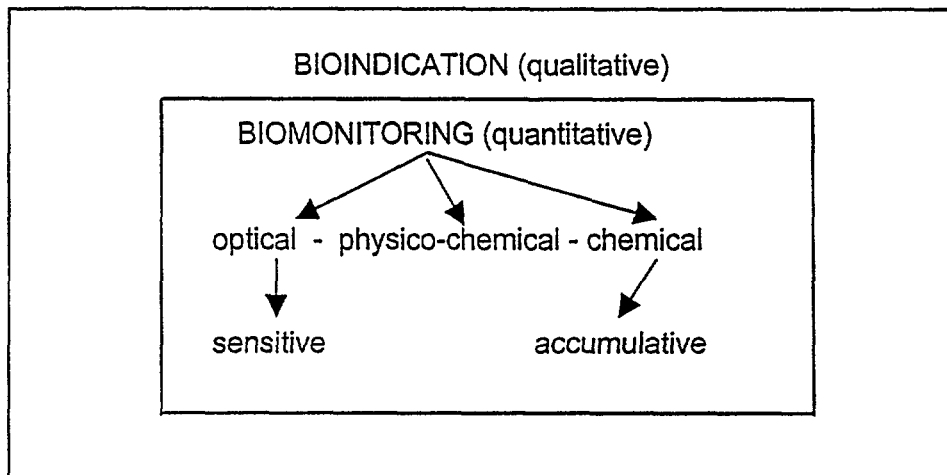


Figure 4.

Classification of bioindication (from Hertz, 1991)

"Biomonitors are organisms which can be used for the recognition and quantitative determination of anthropogenically induced environmental factors". For the detection and recognition of water pollution, biological organisms which respond sensitively and specifically to a given pollutant can be used. In addition, organisms that readily amass the polluting components without changing their chemical nature may be used as accumulators. This classification into sensitive and accumulative biomonitors is now well-accepted terminology.

7.2.4.2 Sensitive biomonitors

They are used in aquatic ecosystems as integrators of the pollution stresses caused by contaminants in order to provide early warning systems. They can be divided into two categories:

- ecological surveys, and
- toxicity testing.

Ecological surveys

These may use indicator species or assessments based on the composition of biological communities and numerical diversity. By making comparisons between affected and control areas, ecological surveys can indicate the health of a water body exposed to pollutant loadings.

Toxicity testing

This is used to obtain basic information about the general toxicity of effluents expected to be introduced into an ecosystem. A great number of toxicity tests have been performed to answer various questions.

7.2.4.3 Selection of contaminants

Among the many possible chemical species that could be considered, the bioaccumulation of heavy metals has been the most extensively studied. They are important polluting elements in many biological systems and correspond to the following trace metals: arsenic, cadmium, chromium, copper, lead, mercury, nickel, tin and zinc.

Many other chemical substances are measured for monitoring purposes: DDT and other chlorinated pesticides, polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons.

The selection of substances to be monitored should be based on the following considerations:

- the aims of the monitoring programme (see Table 4);
- the findings of the pilot study (which contaminant present at a significant level will justify further study?);
- the ability of the analyst to measure these substances with the required accuracy and precision.

7.2.4.4 Selection of organisms

The choice of the test organisms must be guided by several criteria:

- the abundance of the species;
- their geographical range: organisms must be ubiquitous so that the comparisons can be made between areas, countries, continents and possibly hemispheres;
- whether or not they constitute an important link in the food chain;
- the organisms accumulate the contaminant without being affected by the levels encountered;
- the organisms are sessile and thus representative of the area of collection;
- the organisms are sufficiently long-lived, to allow sampling of more than one year class if desired;
- the organisms are of a reasonable size, to give adequate tissue for analysis;

- the organisms are easy to sample all through the year;
- the organisms are easy to handle in experimental work, robust enough to survive in the laboratory, allowing research on the uptake, storage and elimination of contaminants;
- the organisms must offer the possibility of working *in situ* on the population level and with native communities;
- the organisms exhibit high concentration factors;
- the organisms are tolerant of brackish waters, to allow comparisons to be made between estuarine and offshore sites.

Table 4

Chemical substances commonly measured in marine organisms for compliance monitoring purpose (UNEP/FAO/IAEA, 1993)

<u>Trace metals</u>	
Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg) Nickel (Ni), Tin (Sn) and Zinc (Zn).	
<u>DDT and its metabolites</u>	
o,p' - DDD, p,p'-DDD, o,p'-DDE, o,p'-DT and p,p' - DDT.	
<u>Chlorinated pesticides other than DDT</u>	
Aldrin, Alpha-Chlordane, Trans-Nonachlor, Dieldrin, Heptachlor, Heptachlor epoxide, Hexachlorobenzene, Lindane (gamma-BHC) and Mirex.	
<u>Polychlorinated biphenyls (PCBs)</u>	
Measurements are usually restricted to either a small number of individual compounds (known as congeners) or to the total concentration of PCBs.	
<u>Polyaromatic hydrocarbons</u>	
These can include:	
2-ring compounds Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, 2,6-Dimethylnaphthalene and Acenaphthene.	
3-ring compounds Fluorene, Phenanthrene, 1-Methylphenanthrene and Anthracene.	
4-ring compounds Fluoranthrene, Pyrene and Benz(a) anthracene	
5-ring compounds Chrysene, Benzo(a)pyrene, Benzo(e)pyrene and Dibenz(a,h)anthracene	
For the purposes of the long-term programme for pollution monitoring and research in the Mediterranean Sea (MED POL - Phase II), the following chemical contaminants were identified for analysis in marine organisms.	
<u>Category I (mandatory)</u>	<u>Category II (optional)</u>
total mercury	total arsenic
organic mercury	radionuclides
cadmium	polynuclear aromatic hydrocarbons
halogenated hydrocarbons	

8. COMPLIANCE MONITORING IN "HOT SPOT" AREAS ¹⁸

8.1 Definitions

"Hot spot" areas are:

- (a) **Point sources** on the coast which potentially **affect** human health, ecosystems, biodiversity, sustainability or the economy in a significant manner. They are the **main points where high levels of pollution loads** originating from domestic or industrial sources are being discharged;
- (b) Defined **coastal areas** where the **coastal marine environment is subject to pollution** from one or more point or diffuse sources on the coast which potentially **affect** human health in a significant manner, ecosystems, biodiversity, sustainability or the economy.

8.2 "Hot Spot" indicators (primary)

- biochemical oxygen demand (BOD), chemical oxygen demand (COD);
- nutrients (phosphorus, nitrogen);
- total suspended solids;
- oil (petroleum hydrocarbons);
- heavy metals;
- persistent organic pollutants;
- radioactive substances (whenever applicable);
- litter;
- microorganisms (faecal coliforms, E.coli, faecal streptococci);
- organisms (e.g macroalgae for the soluble phase, mussels for the particulate phase and a detritus feeder for the sediment phase).

8.3 Compliance monitoring in "hot spot" areas

Compliance monitoring in "hot spot" areas would follow the basic steps referred to in previous chapters for regular areas, except that it would require an extended and more frequently repeated programme. It would demand more resources and would often involve an element of research, e.g. on the dispersion and fate of pollutants in the marine environment after discharge. Ultimately, a series of extended monitoring programmes may lead to new achievements in terms of pollution control, which may then result in a redefinition of the scope of activities, new programming, new choice of monitoring parameters, etc.

9. ANALYTICAL QUALITY CONTROL¹⁹

9.1 General

The role of the analytical laboratory is to provide qualitative and quantitative data to be used in decision-making. To be of value, the data must accurately describe the characteristics or the concentration of constituents in the sample submitted to the laboratory. In many cases, an approximate answer or incorrect result is worse than no answer at all because it will lead to faulty interpretations.

Decisions made using water and wastewater data are far-reaching. Water quality standards are set to establish satisfactory conditions for a given water use. The laboratory data define whether that condition is being met, and whether the water can be used for its intended purpose. If the laboratory results indicate a violation of the standard, action is required on the part of pollution control authorities. With the present emphasis on legal action and social pressures to abate pollution, the analyst should be aware of his responsibility to provide laboratory results that are a reliable description of the sample. Furthermore, the analyst must be aware that his professional competence, the procedures he has used, and the reported values may be used and challenged in court. To meet this challenge satisfactorily, the laboratory data must be backed up by an adequate programme to document the proper control and application of all the factors that affect the final result.

9.2 Quality control programme

Because of the importance of laboratory analyses and the resulting action, a programme to ensure the reliability of the data is essential. It is recognized that all analysts practice quality control to varying degrees, depending somewhat upon their training, their professional pride, and awareness of the importance of the work they are doing. However, under the pressure of the daily workload, analytical quality control may easily be neglected. Consequently, an established, routine control programme applied to every analytical test is important in assuring the reliability of the final results.

9.3 Analytical methods

The need to standardize of methods within a single laboratory is readily apparent. Uniform methods in collaborating laboratories are also important so that the methodology does not constitute a variable in comparison or joint use of data among laboratories. Uniformity of methods is particularly important when laboratories are providing data to a common data bank, or when several laboratories are cooperating in joint field surveys. A lack of standardization of methods raises doubts as to the validity of the results reported. If the same constituent is measured by different analytical procedures within a single laboratory, or in several laboratories, the question of which procedure is superior arises, and why the superior method is not used throughout.

9.4 Control of analytical performance

9.4.1 Precision and accuracy

Precision refers to reproducibility among replicate observations. In an analytical quality control programme, it is determined not on reference standards, but by the use of actual water samples that cover a range of concentrations and a variety of interfering materials usually encountered by the analyst. Obviously, such data should not be collected

¹⁹ US/EPA, 1973, UNEP/IOC/IAEA/FAO, 1990 and OECD, 1996

until the analyst is thoroughly familiar with the method and has obtained a reproducible standard curve. For colorimetric analyses, the initial standard curve should include a blank and a series of at least eight standards encompassing the full concentration range to be used for routine sample analyses. Subsequently, at least two standards (a high and a low) should be analyzed to verify the original standard curve. For other measurements, such as pH, conductivity, turbidity, etc., instruments should be standardized according to the manufacturer's instructions and sound, scientific practices.

Accuracy refers to a degree of difference between observed and known, or actual, values. Again, accuracy should be determined on actual water samples routinely analyzed, and preferably on the same series as those used in the precision determinations.

9.4.2 Evaluation of daily performance

Once valid precision and accuracy data are available on the method and the analyst, systematic daily checks are necessary to ensure that valid data are being generated.

In order to prove that reproducible results are being obtained (i.e., precision of the method), it is necessary to run replicate samples. Although the frequency of such replicate analyses is, by nature, dependent on such factors as the original precision of the method, the reliability of the instrumentation involved, and the experience of the analyst, it is good laboratory technique to run duplicate analyses at least 10 per cent of the time. The resulting data should accord favourably with the known precision of the method. If they do not, the system is not under control and the results are subject to question.

A most convenient way of recording the obtained precision and accuracy data is through the preparation of quality control charts. Plotting of the data systematically is a response to the question of whether or not the laboratory analyses are under control, and is useful in observing the development of positive or negative trends.

9.4.3 Quality control charts

Quality control charts were originally developed for the control of production processes where large numbers of items were being manufactured and inspected on an essentially continuous basis.

There are various systems currently available for plotting data in the form of cumulative sum charts. One system that has been in continuous use is that of Anon. (1969). It has proved very useful in monitoring the validity of data generated by a contracting laboratory and is currently being used routinely to record intra-laboratory performance in technical operations daily.

9.4.3.1 Shewhart quality control charts

Shewhart (1931) chart concepts and other statistical techniques have refined and quantified the search for quality in manufacturing. Although originally developed to control production processes where large number of articles were being manufactured and inspected on an essentially continuous basis, the same concepts have been readily adapted to laboratory operations where the analyst produces comparatively fewer results on an intermittent basis.

9.4.3.2 Precision control charts

These charts are developed by collecting data for many samples, a minimum of 15 to 20, run in duplicate under assumed controlled conditions.

9.4.3.3 Accuracy control charts

As in the above system, these charts developed by collecting data for many samples, a minimum of 15 to 20, but on spiked samples (preferably) or standards under assumed controlled conditions. Again, these data should be generated over an extended period of laboratory time, and be representative of normal operating conditions.

9.5 Data handling and reporting

To obtain meaningful data on water quality, the laboratory must first collect a representative sample and deliver it unchanged for analysis. The analyst must then complete the proper analysis in the prescribed fashion. Having accomplished this step, one other important step must be completed before the data are of use. This includes the permanent recording of the analytical data in meaningful, exact terms, and reporting it in proper form to some storage facility for future interpretation and use.

10. ATTAINABILITY ANALYSES²⁰

Consideration of the suitability of water body for a given use is an integral part of the water quality standards review and revision process. This is intended to assist States in answering three central questions:

1. What are the aquatic protection uses currently being achieved in the water body?
2. What are the potential uses that can be attained based on the physical, chemical and biological characteristics of the water body? and,
3. What are the causes of any impairment of the uses?

Attainability analyses therefore are methods and approaches that can be used to address the above questions as related to the protection of the marine environment.

The data and information collected from the water body survey provide a basis for evaluating whether it is suitable for a particular use. It is not envisaged that each body of water would necessarily have a unique set of uses. Rather the characteristics necessary to support a use could be identified so that water bodies possessing those characteristics might be grouped together as likely to support particular uses.

The complexity of an aquatic ecosystem does not lend itself to simple evaluations, so there is no single formula or model that will provide all the answers. Thus, the professional judgment of the evaluator is the key to the interpretation of the data collected.

The most common desktop evaluations of use attainability are statistical analyses of water quality monitoring data to determine the frequency of violation of criteria for the designated aquatic use. Statistical evaluations of contraventions of water quality criteria should consider the confidence intervals for the number of violations that are attributable to random variations (rather than actual water quality deterioration).

For example, in the case of a monitoring station with 12 dissolved oxygen observations per year with a standard of 5 mg/l DO, if statistical analyses of the DO observations indicate that the upper and lower confidence limits for the frequency of random violations of the 5 mg/l DO standard cover a range of one to four violations per year, a

²⁰ US/EPA, 1983

regulatory agency should be cautious in deciding whether actual use impairment has occurred unless more than four violations are observed annually.

The development of a manual on attainability analyses should be a priority in a compliance monitoring programme.

Among the tools applicable to use of attainability analyses, particularly chemical evaluations, is use of indices. Many water quality indices have been developed. The Denius water quality index is presented here as an example to show its applicability.

This index includes 11 variables and has a scale that decreases with increased pollution, ranging from 0 to 100. The index is computed as the weighted sum of its subindices. The 11 variables included in the index are: dissolved oxygen, biochemical oxygen demand, escherichia coli, alkalinity, hardness, specific conductivity, chlorides, pH, temperature, coliform, and colour. This index is unique in that the calculated water quality index could be matched to specific water uses. Denius proposed different descriptor language for different index ranges depending on the specific water use under consideration, as illustrated in Figure 5. The index values can be derived from the following formula:

$$Q = \frac{5(\text{DO}) + 214(\text{BOD})^{-0.642} + 400(5\text{E.Coli})^{-0.30} + 300(\text{Coli})^{-0.30} + 535(\text{SC})^{-0.3565} + 62.9(\text{Cl})^{-0.207} + 10^{1.974 - 0.00132(\text{HA})} + 54(\text{ALK})^{-0.178} + 10^{0.235 \text{pH} + 0.440}}{5 + 2 + 4 + 3 + 1 + 5 + 1 + 0.5 + 1 + 1} + \frac{8(\text{Ta-Ts}) + 224 + 128(\text{C})^{-0.288}}{2 + 1}$$

Note: If the pH is between 6.7 and 7.3, 100 should be substituted for the pH expression. If the pH is greater than 7.3, the pH expression should be 10.

DO	=	dissolved oxygen in per cent saturation
BOD	=	biochemical oxygen demand in mg/l
E.Coli	=	escherichia coli as E.coli per ml
Coli	=	coliform per ml
SC	=	specific conductivity expressed in microohms per cm at 25°C
Cl	=	chlorides in mg/l
HA	=	hardness as ppm CaCO ₃
ALK	=	alkalinity as ppm CaCO ₃
pH	=	pH units
Ta	=	actual temperature
Ts	=	standard temperature (average monthly temperature)
C	=	colour units

Once the quality unit is determined based on the above calculation, a comparison with Figure 5 should reveal the quality of the water for a specific use.

PERCENT

100	PURIFICATION NOT NECESSARY	ACCEPTABLE FOR WATER SPORTS	ACCEPTABLE FOR ALL FISH	PURIFICATION NOT NECESSARY	A	A	
90	MINOR PURIFICATION REQUIRED			MINOR PURIFICATION NECESSARY FOR INDUSTRY REQUIRING QUALITY WATER	C	C	
80					C	C	
70	NECESSARY TREATMENT RECEIVING MORE EXTENSIVE	BECOMING POLLUTED - STILL ACCEPTABLE BACTERIA COUNT	MARGINAL FOR TROUT	NO TREATMENT NECESSARY FOR NORMAL INDUSTRY	E	E	
60			DOUBTFUL FOR SENSITIVE FISH		A	A	
50	DOUBTFUL	DOUBTFUL FOR WATER CONDUCT	HARDY FISH ONLY	EXTENSIVE TREATMENT FOR MOST INDUSTRY	B	B	
40	NOT ACCEPTABLE	ONLY BOATING NO WATER CONTACT	COARSE FISH ONLY	ROUGH INDUSTRY USE ONLY	L	L	
30		OBVIOUS POLLUTION APPEARING	NOT ACCEPTABLE		OBVIOUS POLLUTION APPEARING	E	E
20		OBVIOUS POLLUTION NOT ACCEPTABLE			NOT ACCEPTABLE	OBVIOUS POLLUTION NOT ACCEPTABLE	
10						NOT ACCEPTABLE	
	PUBLIC WATER SUPPLY	RECREATION	FISH-SHELLFISH AND WILD LIFE	INDUSTRIAL AND AGRICULTURAL	NAVIGATION	TREATED WASTE TRANSPORTATION	

Figure 5.

General rating scale for the quality unit (US/EPA,1983)

Another useful index is the contamination index, which helps to assess the contribution of anthropogenic sources of metal contamination in sediments over time. The Wedepohl ratio compares the amount of metal in the sediment sample with the concentration in an average shale (or sandstone). If, for example, scientists have measured silicon and aluminum, then have correlated metals with Si/Al ratios, a contamination factor (Cf) may be computed as follows:

where:

$$C_f = (C_o - C_p) / C_p$$

C_o = surface sediment concentration
 C_p = predicted concentration, derived from the statistical relation between the Si/Al ratio and the log metal content of old, pre-pollution sediments.

Thus, $C_f < 0$ when the observed metal concentration is less than the predicted value; $C_f = 0$ when observed and predicted are the same; $C_f > 0$ when the observed is greater than the predicted value.

The contamination index (C_i) is found by adding together contamination factors for metals in a given sediment.

Then,

$$C_i = \sum_{n=1}^n C_f = \sum_{n=1}^n (C_o - C_p) / C_p$$

The toxicity index (T_i) is related to the contamination index and is expressed by the following equation:

$$T_i = \sum_{i=1}^i (M_i / M_1) \cdot C_{fi}$$

where: M_i = the "acute" any time criterion for any of the metals,
but M_1 is always the criterion value for the most toxic of the metals.

The "acute" any time criterion is defined as the concentration of a material that may not be exceeded in a given environment at any time. When evaluating toxicity indices, sampling stations should be characterized by their minimum salinities. This is because the toxicity of metals is often greater in freshwater than in saltwater.

A more detailed discussion of the development of the contamination index may be found in the US/EPA publication, Chesapeake Bay: A Profile of Environmental Change (1983a) and A Framework for Action (1983c).

11. ENFORCEMENT²¹

It is important to emphasize that enforcement is but one component of environmental quality management (EQM). As such, it must be consistent with the other components. For example, if legislation, development of standards, and permit conditions are not clear and unambiguous to both the discharger and to the regulatory agency, enforcement will be difficult, if not impossible.

One characterization of the components of EQM is:

- perception of an environmental quality problem;
- data collection, analysis, development of strategies to "solve" the problem;
- legislation and elaborating regulations;
- development and promulgation of standards;
- issuance of permits;
- application of environmental instruments to induce initial compliance;
- enforcement of permit conditions against non-complying activities.

There should be feed-back from each component of the EQM cycle to other components. It is also important to emphasize that all levels of government are involved in and carry out activities with respect to environmental management.

One of the important questions with respect to EQM and its the enforcement component is the allocation of management tasks among the levels of government. In addition, an integral problem of environmental quality management is the allocation of resources among the components of the EQM cycle and within the enforcement component.

Multiple actors are involved in each component of environmental quality management, including enforcement. An illustrative list of actors and their roles is given below:

Public agencies: as regulatory bodies at all levels of governments of general jurisdiction and special agencies, such as the water authorities in the United Kingdom, the Genossenschaften in Germany, air quality management districts in the United States, and the river basin agency in France. Their role consists of:

- elaborating regulations;
- setting standards and developing guidelines;
- issuing permits, making inspections;
- monitoring discharges, checking accuracy of data collected at discharges (i.e. self-monitoring data);
- imposing sanctions for non-compliance;
- developing cooperative agreements with public and private dischargers;
- assisting in environmental audits;
- publicizing the performance of dischargers both good and bad, maintaining and providing access to information on discharging activities;
- developing and operating a complaint response system;
- promoting cleaner process technologies.

²¹ OECD, 1985

Public agencies as dischargers: same role as for private entities/ activities.

Courts:

- determining whether or not a discharging activity has been in compliance;
- determining whether or not standards are "fair", or "reasonable";
- determining whether or not the regulatory agency has performed its designated functions;
- imposing judicial sanctions.

Private sector, e.g., industrial activities, agricultural operations, mining operations, forest products operations, institutional operations. They are or should be involved in:

- elaborating regulations;
- setting standards and developing guidelines;
- self-monitoring of quality of input raw materials; self-monitoring of discharges;
- developing cooperative agreements with regulatory bodies performing environmental audits.

Trade associations

- submitting evidence for elaborating regulations, standard setting proceedings, performing research on pollution control and process modification technology;
- participating in the development of guidelines for environmental audits.

Insurance companies

- requiring environmental audits as a condition of providing insurance coverage;
- establishing various standards of operations for activities before providing insurance coverage.

Public interest groups: e.g. environmental groups

- elaborating regulations;
- endorsing;
- monitoring of performance of the private sector and public agencies;
- participating in joint groups with the private sector and public bodies in developing standards and monitoring procedures;
- initiating court proceedings against private and public polluting activities, as well as against public regulatory agencies.

Enforcement can be improved by developing nine courses of action:

- at the level of regulations;
- at the level of permits;
- improving monitoring;
- developing cooperative agreements;
- developing environmental auditing;
- strengthening controls and sanctions;
- devising incentive measures;
- enhancing information and publicity;
- increasing agency capacity.

Because the contexts of enforcement do not all involve the same elements, these suggestions do not necessarily apply to all contexts or countries. Moreover, governments should fix their own enforcement priorities.

Mediterranean countries cover a broad spectrum of stages of political, social and economic development, and the most appropriate form of organizing controls will vary accordingly. Experience in different countries, however, does provide some general guidance. One major consideration is the extent to which the responsibilities are apportioned between central and local government.

Central government determines national policy, enacts legislation and retains overall, ultimate control. It has been found advantageous at central government level to arrange for formal consultation and liaison among the ministries involved in various aspects of coastal pollution such as health, industry, tourism, fisheries, local affairs, navigation and marine matters.

The extent to which central government itself carries out executive duties or delegates them to local or regional authorities will be influenced by the resources and technical capabilities of the latter. It must also be borne in mind that municipalities are usually responsible for sewerage and disposal. They are dischargers and it might not be deemed appropriate for an authority to issue authorizations to itself and enforce them.

Supply of information covers the collection and processing of existing information, as well as the gathering of additional information and access to routine monitoring data. Evaluation of the data that governs the conditions to be attached to the authorization may be carried out at the information stage and then transmitted to the control stage at which the authorization is issued. The discharge is monitored to ascertain the extent of compliance with the authorization, and the receiving water is also monitored to confirm its quality. Monitoring consists of collecting samples, transporting them to a laboratory and analyzing them. The analytical results are fed back to the control authority normally responsible for enforcement and to the information collection stage. At regular intervals, the data will be scrutinized and at agreed intervals the conditions of the authorization will be reviewed. An annual report may be prepared and published.

The collection and interpretation of the data is a complex operation calling for a high degree of technical skill. In some countries, facilities may exist for this work to be carried out regularly. Where, there are management authorities for inland waters, these may have or acquire the necessary competence. For many countries, data collection and evaluation may best be carried out by single specialized institutions serving the whole country.

12. ORGANIZATION

The organizational requirements for an effective pollution management programme cover a wide range of activities that must be undertaken in order to achieve practical results in combating water pollution with the least expenditure of time and money. The following elements have frequently been included in national programmes:

- establishment of a coastal water control organization;
- management of wastewater facilities (collection, treatment and disposal);
- monitoring of coastal waters and effluents;
- research.

12.1 Establishment of a coastal water control organization

The main tasks of a coastal water control organization are:

- collection of information;
- decision on and approval of pollution control policy;
- implementation of policy;
- monitoring of results achieved.

All these elements generally fall under the responsibility of one organizational body, but in some cases they may be spread over one or more different administrative structures. The advantage of combining all these aspects under the same organization is enhanced synchronization among the various technical departments and a single pattern of thought, thus avoiding controversy among several agencies responsible.

12.1.1 Collection of information

Knowledge of the existing situation is very important for the development of an appropriate water pollution control policy and strategy, in order to enable decision-makers to base the policy on precise and realistic data without making theoretical estimations.

The information should cover the condition of the coastal and inland waters (i.e. rivers) in the water catchment area, an estimation of the hydraulic and pollution loads of all pollution sources (land-based and offshore), and the content of development plans for the region in order to predict the future impact on the environment.

This procedure should be executed within the shortest possible period of time so as to prevent any inconsistency between the start and the end of the data collecting operation. Simple, quick and precise methods of data collection and interpretation are therefore very important. In this context, the introduction and implementation of computerized systems is strongly recommended.

The data collected should be renewed at regular intervals in order to keep it updated as changes occur. Here again, the importance of computer systems should be highlighted.

12.1.2 Decision and approval of pollution control policy

After the data have been collected, the main outlines of the pollution control strategy should be planned and analyzed. The scientists, managers, technicians, etc. responsible for the technical aspects of environmental measurements should elaborate a strategy based on simple and reliable control methods, taking into account all possible data and the related environmental impact. A well-designed and argued technical plan involving the least possible financial expenditure has the greatest chance of being approved by the decision-makers. It should be emphasized in this context that highly sophisticated control methods with a higher risk of failure and greater financial cost should be avoided.

Due to the complexity of environmental problems and the multitude of technical, financial, social and political aspects involved in any pollution control strategy, the decision-makers involved should consider all possible implications deriving from the proposed policy. Cooperation between the regional authorities and governmental and international agencies is thus essential when reviewing the adequacy of the policy to be implemented.

12.1.3 Implementation of policy

After the policy has been approved, the water control organization is responsible for its implementation. A high level of education and experience among the manpower employed is a basic prerequisite for successful implementation. In addition, discipline on the part of public opinion, industry, communities, etc., convinced of the need for the policy, as well as cooperation between them and the implementing body responsible, is the second condition to be fulfilled in order to achieve permanent results. A simple and effective policy that leads to rapid and visible improvements in the marine environment is the most persuasive argument.

Implementation of the policy consists of the following general steps:

- legal cover (regulations, laws, etc);
- technical measures (i.e. installation of treatment plants, changes in industrial production, etc.);
- advertising campaigns aimed at the public.

These measures should be taken simultaneously in order to obtain the aforementioned cooperation and acceptance of the policy by interested bodies.

12.1.4 Monitoring of results achieved

Once a policy has been applied correctly, the expected results will subsequently be achieved. Nevertheless, the conditions of the policy's implementation need to be monitored constantly as practice has shown that even the best strategy for combating pollution will fail if there has not been continuous monitoring of the conditions.

The relevant monitoring department of the organization will be responsible for the regular inspection of industrial processes, wastewater installations, agricultural activities, etc. detecting failures, lack of maintenance, operating problems, etc. A high level of professional experience on the part of the monitoring personnel is essential for this procedure in order to ensure that the organization's authority remains at the topmost level. The second task of a monitoring mechanism is to monitor water quality and effluents.

12.2 Management of wastewater facilities (collection, treatment and disposal)

The administrative organization of wastewater installations is an essential part of the successful implementation of a pollution control plan in addition to the efficient engineering aspect. Experience has shown that even facilities of very sophisticated design have failed to work successfully because of bad administrative organization and support.

No one type of administrative organization can be recommended as being universally suitable because economic, political and geographical conditions vary from one country to another. The following are some of the major factors that have to be taken into account when drawing up an organizational scheme suitable for a particular case:

- existing organization of water supply;
- size of the area;
- development plans in the area;
- regional organizational scheme in the country.

12.3 Monitoring of coastal water and effluents

Monitoring the quality of coastal water and effluents is usually part of the control programme of a water pollution control authority and is frequently the latter's administrative responsibility.

This aspect of monitoring programmes covers effluent sampling and analysis. The control authorities undertake sampling and analysis not only of effluents in order to verify compliance with the prescribed limits but also of sea water to ensure that water uses are adapted to the prevailing conditions. This is mentioned separately, however, as water quality monitoring is also used for purposes other than pollution control.

Not only is a water quality monitoring programme essential for continuous estimation of sea water conditions before the effects of any pollution incite the authorities to take action, but it is also of valuable assistance to the control bodies. This knowledge is an important constituent of the information required in order to decide upon and implement pollution control strategies and estimate the impact on the marine environment of any development plans.

12.4 Research

Research programmes in support of coastal pollution control management are always oriented towards applied technical methods, eschewing theoretical considerations, which are mostly the responsibility of universities and other scientific institutions. The organizational scheme for establishing appropriate research programmes varies according to the administrative structure in each country.

From the organizational point of view, an autonomous scientific-technical body, acting as scientific adviser to the water pollution control organization is the optimal solution. In some cases, the authorities' technical needs are covered by contracts with research bodies (universities, institutes, etc) which carry out the scientific work on their behalf. This is the least expensive solution and is widely used in order to save costs.

An applied research programme must cover the following elements:

- pilot-plant studies on water pollution control techniques;
- development of full-scale projects for wastewater treatment methods;
- elaboration of new cost-effective sampling and analysis techniques;
- cost-benefit analysis of applied technical pollution control measures.

The operational pattern for rapid execution of such a programme should be as follows:

- (a) task definition and priorities set by the water pollution control organization;
- (b) timetable for programme completion;
- (c) approval of completed intermediate work phases by the supervising authorities.

13. STEPS ILLUSTRATING PROCEDURE FOR MONITORING OF COMPLIANCE CONTROL

Summarizing the various principles and guidelines set out in the previous chapters, the following is a brief description of the steps needed to implement a compliance control monitoring programme.

Where appropriate, it is indicated whether the technical information that is a prerequisite for such control is contained in UNEP documentation.

1. Identification of the monitoring programme's aims.
2. Definition of the area and classification of uses:
need to develop quality criteria in relation to effluents and the ambient marine environment, as well as how to determine assimilative capacity.
3. Information from previous studies conducted.
4. Survey of the area (WHO/UNEP, 1994) - area assessment:
 - 4.1 Landward side:
 - land use;
 - run-off;
 - wastewater discharges and outfalls (identification of sources of pollution and pollutants discharged);
 - waste treatment;
 - dumping sites;
 - coastline morphology.
 - 4.1 Seaward side:
 - shellfish areas;
 - fishing grounds;
 - bathing waters;
 - protected areas;
 - dumping sites.
5. Programme design and execution:
 - 5.1 Matrices and locations:
 - 5.1.1 Point sources:
(WHO/UNEP, 1979)
 - outfalls:
need to develop and elaborate inspection procedures;
 - rivers and streams:
need to develop river basin management;
 - solid waste - sludge disposal;
 - major accidents.
 - 5.1.2 Diffuse sources:
lack of measures for the control of diffuse sources of pollution.
 - 5.1.3 Health-related conditions
(WHO/UNEP, 1994, 1995 and 1996).

- 5.1.4 Sea water
(UNEP/IOC/IAEA/FAO, 1990).
- 5.1.5 Sediments:
need to prepare a document on compliance monitoring in sediments.
- 5.1.6 Biota
(UNEP/FAO/IAEA, 1993, UNEP/IAEA/IOC, 1990
UNEP/IOC/IAEA/FAO, 1990
WHO/UNEP, 1994, 1995 and 1996).
- 5.2 Selection of parameters.
- 5.3 Determination of points and frequency of sampling
(UNEP/IAEA/IOC, 1990).
- 5.4 Selection of methods of sampling and analysis
(UNEP/IAEA/IOC, 1990).
 - 5.4.1 Sampling:
 - type of sampling;
 - quantity of samples required;
 - sampling equipment and containers required;
 - sampling preservation.
 - 5.4.2 Analysis:
 - determination of required precision limits
(UNEP/IOC/IAEA/FAO, 1990);
 - possibility of continuous monitoring of selected parameters;
 - analytical procedures (analytical quality control)
(UNEP/FAO/IAEA, 1993);
 - applicability of recommended standard methods
(UNEP/IAEA/IOC, 1990);
 - intercalibration of results
(UNEP/IAEA/IOC, 1990).
- 5.5 Selection of method of data processing, storage and retrieval
(UNEP/FAO/IAEA, 1993).
- 5.6 Handling of information
(UNEP/FAO/IAEA, 1993).
- 5.7 Cost analysis:
A document on the principles of cost analysis for the execution of a programme is lacking.
- 5.8 Execution of the programme.
- 5.9 Evaluation of the results (attainability analyses):
development of an attainability analyses document.
- 6. Enforcement of laws and regulations in cases of violation of effluent standards and quality objectives: development of a document on the enforcement of protocols and national laws and regulations.

7. Remedial actions:
elaboration of a document on the integral assessment of the state of pollution in an entire area and the necessary remedial action to be taken, commencing with regional planning, reclassification of uses, revision of effluent standards and quality objectives, and ending with enforcement.

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