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**GUIDELINES FOR THE MANAGEMENT OF DREDGED MATERIAL**

The Joint Meeting of the Scientific Committee and the Socio-Economic Committee, held at Athens from 3 to 7 May 1993, requested the Secretariat to prepare guidelines related to Section B of Annex I to the Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, adopted in 1976 (hereinafter "the Dumping Protocol"). Subsequently, the amended text of the Dumping Protocol, adopted by the Contracting Parties in June 1995, called for the preparation and adoption of guidelines for the dumping of dredged material (Art.6).

A First Meeting of Government-designated Experts on the Preparation of Guidelines on the Management of Dredged Material, supported by the Government of Spain, was held in Valencia (Spain) from 20 to 22 May 1996 to consider a first set of draft guidelines prepared by the Secretariat. The Meeting reviewed the text and requested the Secretariat to amend the draft guidelines on the basis of the discussions held at that Meeting (UNEP(OCA)/MED WG.114/4).

A Second Meeting hosted by the Government of Malta, was held at Sliema (Malta) from 30 November to 2 December 1998 with the financial support of the European Commission (UNEP(OCA)/MED WG.149/4). The Meeting revised the draft guidelines prepared by the Secretariat and agreed on a text which was transmitted to the Meeting of MED POL National Coordinators (Reggio Calabria, 20-23 June 1999) for approval.

The present document is the text of the Guidelines as it was presented to the Meeting of MED POL National Coordinators. The text will incorporate the final comments and amendments of the MED POL National Coordinators and will be transmitted to the Contracting Parties for adoption.

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## Preface

These guidelines are designed to assist the Contracting Parties in the implementation of the Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea, hereinafter referred to as "the Protocol", with regard to the management of dredged material; the Protocol was signed by 16 Contracting Parties in 1995, but has not yet entered into force.

Some aspects of these guidelines are an adaptation to the technical-economic context of the Mediterranean basin of the Dredged Material Assessment Framework, adopted on 8 December 1995 by the Contracting Parties to the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, of 13 November 1972, as amended in 1993.

It is, however, implicitly recognised that the general considerations and detailed procedures described in the guidelines are not applicable in their entirety to all national or local situations.

## Introduction

Dredging activities are an essential part of port and harbour activities.

Two main dredging categories can be distinguished:

- **Capital dredging**, mainly for navigational purposes, to enlarge or deepen existing channel and port areas, or to create new ones; this type of dredging activity also includes some technical activities on the seabed such as trenches for pipes or cables, tunnelling, removal of material unsuitable for foundations, or removal of overburden for aggregate extractions;
- **Maintenance dredging**, to ensure that channels, berths or construction works are maintained at their designed dimensions.

All these activities may produce large quantities of material that have to be eliminated. A small part of this material may be polluted by human activities to such an extent that serious ecological conditions have to be imposed where the sediments are dredged or dumped.

It must be also recognised that dredging operations as such may harm the marine environment, especially when they take place in the open sea close to sensitive areas (aquaculture areas, recreational areas, ...). This is the case in particular when dredging operations have a physical impact (increased turbidity) or lead to the re-suspension or the re-releasing of major pollutants (heavy metals, organic or bacterial pollutants).

In view of the foregoing, the Contracting Parties are urged to exercise control over dredging operations in parallel with that exercised over dumping. Use of Best Environmental Practice (BEP) for dredging activities is an essential pre-condition for dumping, in order to minimise the quantity of material that has to be dredged and the impact of the dredging and dumping activities in the maritime area.

Advice is available from a number of international organisations, including the Permanent International Association of Navigation Congresses (PIANC) 1986: Disposal of Dredged Material at Sea (LDC/SG9/2/1). Through its Environmental Policy Framework and close links with industry in developing Cleaner Industrial Production Technologies, the United National Industrial

Development Organisation (UNIDO) is able to offer expert advice and training to enhance capabilities to develop an integrated management plan for dredged waste materials.

## **1. REQUIREMENTS OF THE DUMPING PROTOCOL**

1.1 Under Article 4.1 of the Protocol, the dumping of waste and other matter is prohibited.

Nevertheless, pursuant to Article 4.2 (a) of the Protocol, this principle may be waived and the dumping of dredged material authorised under certain conditions.

1.2 Under Article 5, dumping requires a prior special permit from the competent national authorities.

1.3 Furthermore, in accordance with Article 6 of the Protocol, the permit referred to in Article 5 shall be issued only after careful consideration of the factors set forth in the Annex to the Protocol. Article 6.2 provides that the Contracting Parties shall draw up and adopt criteria, guidelines and procedures for the dumping of wastes or other matter listed in Article 4.2 so as to prevent, abate and eliminate pollution.

1.4 These Guidelines for the Management of Dredged Material, which include advice on dredged material sampling and analysis, have been prepared for the purpose of providing guidance to the Contracting Parties on:

- (a) fulfilment of their obligations relating to the issue of permits for the dumping of dredged material in accordance with the provisions of the Protocol;
- (b) transmission to the organisation of reliable data on the input of contaminants to Protocol waters by the dumping of dredged material.

1.5 In view of the foregoing, these guidelines are designed to allow Contracting Parties to manage dredged material without polluting the marine environment. In accordance with Article 4.2 (a) of the Dumping Protocol, these guidelines relate specifically to the dumping of dredged material from ships and aircraft. They do not concern either dredging operations or the disposal of dredged material by methods other than dumping.

1.6 The guidelines are presented in two parts. Part A deals with the assessment and management of dredged material, while part B provides guidance on the design and conduct of monitoring of marine dumping sites.

The guidelines commence with a guidance on the conditions under which permits might be issued. Sections 4, 6 and 7 address the relevant considerations in the Annex to the Protocol, namely, the characteristics and composition of the dredged material (part A), the characteristics of the dumping site and method of deposit (part B), and general considerations and conditions (part C). Section 5 provides additional guidance on the sampling and analysis of dredged material.

## **CONDITIONS UNDER WHICH PERMITS FOR DUMPING OF DREDGED MATERIAL MAY BE ISSUED**

### **PART A**

#### **ASSESSMENT AND MANAGEMENT OF DREDGED MATERIAL**

##### **1. CHARACTERISATION OF DREDGED MATERIAL**

1.1 For the purpose of these guidelines, the following definitions apply:

- "dredged material" means any sedimentary formation (clay, silt, sand, gravel, rocks, and any indigenous parent rock material) removed from areas that are normally or regularly covered by sea water, by using dredging or other excavation equipment;
- "dumping" means any deliberate disposal in the sea of dredged material from vessels, irrespective of whether the material has previously been transported.

##### **2. DISPOSAL OF DREDGED MATERIAL**

2.1 In the vast majority of cases, dumping harms the natural environment so before taking any decision to grant a dumping permit other methods of disposal should be considered. In particular, all possible uses of dredged material should be considered (see Technical Annex 3)

##### **3. DECISION MAKING PROCESS**

3.1 Proper dumping site selection rather than a test application is recommended. Site selection to minimise the impact on commercial or recreational fishery areas is a major consideration in resource protection and is covered in greater detail in Part C of the Annex to the Protocol. (Further guidance for the application of Part C of the Annex is given in Section 7 below).

3.2 In order to define the conditions under which permits for the dumping of dredged material may be issued, the Contracting Parties should develop on a national and/or regional basis, as appropriate, a decision-making process for evaluating the properties of the material and its constituents, having regard to the protection of human health and the marine environment.

3.3 The decision-making process is based on a set of criteria developed on a national and/or regional basis, as appropriate, which meet the provisions of Articles 4, 5, and 6 of the Protocol and are applicable to specific substances. These criteria should take into consideration the experience acquired on the potential effects on human health and the marine environment.

These criteria may be described in the following terms:

- (a) physical, chemical and geochemical characteristics (e.g. sediment quality criteria);



- (b) biological effects of the products of the dumping activity (impact on marine ecosystems);
- (c) reference data linked to particular methods of dumping or to dumping sites;
- (d) environmental effects that are specific to dumping of dredged material and are considered undesirable outside and/or in close proximity to the designated dumping sites;
- (e) the contribution of dumping to already-existing local contaminant fluxes (flux criteria)

3.4 Criteria should be derived from studies of sediments that have similar geochemical properties to those to be dredged and/or to those of the receiving system. Depending upon the natural variation in sediment geochemistry, it may be necessary to develop individual sets of criteria for each area in which dredging or dumping is conducted.

3.5 The decision-making process, with respect to the background natural baseline reference level and to some specified contaminants or biological responses, may lay down an upper and a lower reference threshold, giving rise to three possibilities:

- (a) material which contains specified contaminants or which causes biological responses in excess of the relevant upper threshold should generally be considered as unsuitable for dumping at sea;
- (b) material which contains specified contaminants or which causes biological responses below the relevant lower threshold should generally be considered of low environmental concern for dumping at sea;
- (c) material of intermediate quality should be subject to more detailed assessment before suitability for dumping at sea can be determined.

3.6 When the criteria and the associated regulatory limits cannot be met (case (a) above), a Contracting Party should not issue a permit unless detailed consideration in accordance with Part C of the Annex to the Protocol indicates that dumping at sea is, nonetheless, the least detrimental option, compared with other disposal techniques. If such a conclusion is reached, the Contracting Party should:

- (a) implement a programme for the reduction at source of pollution entering the dredged area, where there is a source that can be reduced by such a programme, with a view to meeting the established criteria;
- (b) take all practical steps to mitigate the impact of the dumping operation on the marine environment including, for example, the use of containment (capping) or treatment methods;
- (c) prepare a detailed marine environment impact hypothesis;
- (d) initiate monitoring (follow-up activity) designed to verify any predicted adverse effects of dumping, in particular with respect to the marine environment impact hypothesis;

- (e) issue a specific permit;
- (f) report to the Organisation on the dumping which has been carried out, outlining the reasons for which the dumping permit was issued.

When it is unlikely that dredging management techniques will alleviate the harmful effects of contaminated material, selective dredging or separation of the more contaminated fractions (e.g. by use of hydrocyclones) may be employed to minimise the quantities of material for which such measures are required.

3.7 With a view to evaluating the possibility of harmonising or consolidating the criteria referred to in paragraphs 3.3 - 3.6 above, including any sediment quality criteria, the Contracting Parties are requested to inform the Organisation of the criteria adopted, as well as the scientific basis on which these criteria were developed.

3.8 An important element of these guidelines for the management of dredging activities is the preparation of a marine environment impact hypothesis (see Part B, paragraphs 5.1 and 5.2) for each marine dumping operation. In concluding their assessments of the environmental implications of these operations, prior to the issue of a permit, the Contracting Parties should formulate impact hypotheses in accordance with the guidance provided in Part B, paragraphs 5.2 - 7.1. This impact hypothesis will provide the principal basis for the design of post-operational monitoring activities.

#### **4. ASSESSMENT OF THE CHARACTERISTICS AND COMPOSITION OF DREDGED MATERIAL**

##### Physical characterisation

4.1 For all dredged material to be dumped at sea, the following information should be obtained:

- quantity of dredged material (gross wet tonnage);
- method of dredging (mechanical dredging, hydraulic dredging, pneumatic dredging, and application of BEP<sup>1</sup>);
- rough preliminary determination of sediment characteristics (i.e. clay / silt / sand / gravel / rock).

4.2 In order to assess the capacity of the site to receive dredged material, both the total amount of material and the anticipated or actual loading rate at the dumping site should be taken into consideration.

##### Chemical and biological characterisation

4.3 A chemical and biological characterisation will be needed to fully assess the potential impact. Information may be available from existing sources, for example from field observations on the impact of similar material at similar sites, or from previous test data on similar material tested not more than five years previously, and from knowledge of local discharges or other

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<sup>1</sup> Best Environmental Practice

sources of pollution, supported by a selective analysis. In such cases, it may be unnecessary to measure again the potential effects of similar material in the vicinity.

4.4 Chemical, and as appropriate biological, characterisation will be necessary as a first step in order to estimate gross loading of contaminants, especially for new dredging operations. The requirements for the elements and compounds to be analysed are set out in Section 5.

4.5 The purpose of testing under this section is to establish whether the dumping at sea of dredged material containing contaminants might cause undesirable effects, especially the possibility of chronic or acute toxic effects on marine organisms or human health, whether or not arising from their bioaccumulation in marine organisms and especially in food species.

4.6 The following biological test procedures might not be necessary if the previous physical and chemical characterisation of the dredged material and of the receiving area, and the available biological information, allows an assessment of the environmental impact on an adequate scientific basis.

If, however:

- the previous analysis of the material shows the presence of contaminants in quantities exceeding the upper reference threshold in paragraph 3.5 (a) above or of substances whose biological effects are not understood,
- if there is concern for the antagonistic or synergistic effects of more than one substance,
- or if there is any doubt as to the exact composition or properties of the material,

it is necessary to apply suitable biological test procedures.

These procedures, which should involve bio-indicators species may include the following:

- acute toxicity tests;
- chronic toxicity tests capable of evaluating long-term sub-lethal effects, such as biotests covering an entire life cycle;
- tests to determine the potential for bioaccumulation of the substance of concern;
- tests to determine the potential for alteration of the substance of concern.

4.7 Substances in dredged material may undergo physical, chemical and biochemical changes when deposited in the marine environment. The susceptibility of dredged material to such changes should be considered in the light of the eventual fate and potential effects of the dredged material. This may be reflected in the impact hypothesis and also in a monitoring programme.

#### Exemptions

4.8 Dredged material may be exempted from the testing referred to in paragraphs 4.3 and 4.6 of these guidelines if it meets one of the criteria listed below; in such cases, the provisions of the Parts B and C of the Annex to the Protocol (see Sections 6 and 7 below) should be taken into account.

- (a) dredged material is composed almost exclusively of sand, gravel or rock; such materials are frequently found in areas of high current or wave energy, such as streams with large bed loads or coastal areas with shifting bars and channels;
- (b) dredged material is composed of previously undisturbed geological material;
- (c) dredged material is for beach nourishment or restoration and is composed predominantly of sand, gravel or shell, with particle sizes compatible with material on the receiving beaches.

In the case of Capital dredging projects national authorities may, taking into account the nature of the material to be dumped at sea, exempt part of that material from the provisions of these guidelines, after representative sampling. However Capital dredging in areas which may contain contaminated sediments should be subject to characterisation in accordance with these guidelines, notably paragraph 4.4.

## 5. GUIDELINES ON DREDGED MATERIAL SAMPLING AND ANALYSIS

### Sampling for the purpose of issuing a dumping permit

5.1 For dredged material which requires detailed analysis (i.e. which is not exempted under paragraph 4.9 above), the following guidelines indicate how sufficient analytical information may be obtained for the purpose of issuing a permit. Judgement and knowledge of local conditions will be essential in the application of these guidelines to any particular operation (see paragraph 5.11).

5.2 An *in situ* survey of the area to be dredged should be carried out. The distribution and depth of sampling should reflect the size of the area to be dredged, the amount to be dredged and the expected variability in the horizontal and vertical distribution of contaminants. In order to evaluate the number of samples to be analysed, different approaches might be retained.

5.3 Two examples of these different approaches are given below:

a. The number of sampling stations should be adjusted to the area to be dredged by applying the formula  $N = \sqrt{px/25}$ , where  $x$  is the area in square metres and  $N$  the number of sampling stations where  $N \geq 4$ . According to the exchange characteristics of the area to be dredged, the number of sampling stations should be smaller for open areas (cf. "Recommendations for the management of dredged material in the port of Spain" (Cedex 1994)).

b. The table that follows gives an indication of the number of samples to be analysed in relation to the number of  $m^3$  to be dredged in order to obtain representative results, assuming a reasonably uniform sediment in the area to be dredged.

<b>Amount dredged (m<sup>3</sup> <i>in situ</i>)</b>	<b>Number of stations</b>
Up to 25 000	3
from 25 000 to 100 000	4 - 6
from 100 000 to 500 000	7 - 15
from 500 000 to 2 000 000	16 - 30
> 2 000 000	extra 10 per million m <sup>3</sup>

Core samples should be taken where the depth of dredging and the expected vertical distribution of contaminants warrant; otherwise a grab sample is considered appropriate. Sampling from the dredger is not acceptable.

5.4 Normally, the samples from each location should be analysed separately. However, if the sediment is clearly homogeneous with respect to sediment features (grain-size fractions and organic matter load) and expected level of contamination, it may be possible to take composite samples from adjacent locations, two or more at a time, provided care has been taken to ensure that the results give a justified mean value for the contaminants. The original samples should be retained until the procedure for the issue of a permit has been completed, in case the results indicate that further analysis is necessary.

#### Sampling in the case of the renewal of a dumping permit

5.5 If a survey indicates that the material is essentially below the lower reference threshold in paragraph 3.5 (b) above and no new events of pollution have taken place indicating that the quality of the material has deteriorated, surveys need not be repeated.

5.6 If the dredging activity involves material with a contaminant content between the upper and lower reference thresholds in paragraph 3.5 (a) and (b) above, it may be possible, on the basis of the initial survey, to reduce either the number of sampling stations or the number of parameters to be measured. However, sufficient information must be provided to confirm the initial analysis for the purpose of issuing a permit. If such a reduced sampling programme does not confirm the earlier analysis, the full survey should be repeated. If the number of parameters for repetitive measurement is reduced, a further analysis of all the parameters listed in Technical Annex I list is advisable at appropriate intervals not exceeding 5 years.

5.7 However, in areas where there is a tendency for sediments to show high levels of contamination, or where contaminant distribution changes rapidly in response to varying environmental factors, analysis of the relevant contaminants should be frequent and linked to the permit renewal procedure.

#### Provision of Input Data

5.8 The sampling scheme described above provides information for the purpose of issuing permits. However, the scheme can at the same time provide a suitable basis for estimating of total inputs and, for the time being in the current situation, can be considered the most accurate approach available for this purpose. In this context it is assumed that materials exempt from analysis represent insignificant inputs of contaminants and therefore it is not necessary to calculate or to report contaminant loads.

### Parameters and methods

5.9 Since contaminants concentrate mainly in the fine fraction (# 2 mm) and even more specifically in the clay fraction (# 2 Fm), analysis should normally be carried out on the fine fraction sample (# 2 mm). It will also be necessary, in order to assess the likely impact of contaminant levels to provide information on:

- grain size fractions (% sand, silt, clay);
- load of organic matter;
- dry matter (% solids).

5.10 In those cases where analysis is required, it should be mandatory for metal substances listed in Technical Annex 1 (Primary group determinants). With respect to organochlorines, polychlorobiphenyls (PCBs) should be analysed on a case-by-case basis in non-exempt sediments because they remain a significant environmental contaminant. Other organohalogens should also be measured if they are likely to be present as a result of local inputs.

5.11 In addition, the authority responsible for issuing permits should carefully consider specific local inputs, including the likelihood of contamination by arsenic, polycyclic aromatic hydrocarbons (PAH) and organotin compounds. The authority should make provision for the analysis of these substances as necessary.

The following should be taken into account in this connection:

- potential routes by which contaminants could reasonably have been introduced into the sediments;
- probability of contamination from agricultural and urban surface run-off;
- spills of contaminants in the area to be dredged, in particular as a result of port activities;
- industrial and municipal waste discharges (past and present);
- source and prior use of dredged material (e.g. beach nourishment); and
- substantial natural deposits of minerals and other natural substances.

5.12 Further guidance on the selection of determinants and methods of contaminant analysis under local conditions, and on procedures to be used for harmonisation and quality assessment purposes, will be found in the Technical Annexes to these guidelines as adopted, and updated periodically, by the Contracting Parties.

## **6. CHARACTERISTICS OF THE DUMPING SITE AND METHOD OF DEPOSIT**

6.1 Matters relating to dumping site selection criteria are addressed in greater detail in studies prepared by GESAMP' (Reports and Studies No. 16: Scientific Criteria for the Selection of Waste Disposal Sites at Sea, IMO 1982) and by ICES (Ninth Annual Report of the Oslo Commission, Annex 6).

The selection of a site for dumping at sea does not only involve the consideration of environmental parameters, but also economic and operational feasibility.

6.2 In order to be able to assess a new dumping site, basic information on the characteristics of the dumping site have to be considered by national authorities at a very early stage of the decision-making process.

For the purpose of studying the impact, this information should include the geographical coordinates of the dumping area (latitude, longitude), the distance to the nearest coastline as well as proximity of the dumping area to the following:

- recreational areas;
- spawning, recruitment and nursery areas of fish, crustaceans and molluscs;
- known migration routes of fish or marine mammals;
- commercial and sport fishing areas;
- mariculture areas;
- areas of natural beauty or significant cultural or historical importance;
- areas of special scientific, biological or ecological importance;
- shipping lanes;
- military exclusion zones;
- engineering uses of the seafloor (e.g. potential or ongoing seabed mining, undersea cables, desalination or energy conversion sites).

The dumping of dredged material should not interfere with nor devalue legitimate commercial and economic uses of the marine environment. The selection of dumping sites should take into account the nature and extent of both commercial and recreational fishing, as well as the presence of aquaculture areas, spawning, nursery and feeding areas.

6.3 In view of uncertainties regarding in the diffusion of marine contaminants giving rise to transboundary pollution, dumping of dredged material in the open sea should be prohibited.

6.4 For dredged materials, the only data to be considered for this purpose should include information on:

- disposal method (e.g. vessels, hopper discharge; and other controlled methods, like discharge through pipes);
- dredging method (e.g. hydraulic or mechanical), having regard to Best Environmental Practice (BEP).

6.5 For the evaluation of dispersal characteristics, the use of mathematical diffusion models requires the collection of certain meteorological, hydrodynamic and oceanographic data. In addition, data on the speed of the vessel dumping the material and the rate of dumping should also be made available.

6.6 The basic assessment of a site, whether a new or existing includes the consideration of possible effects that might arise due to the increase in certain constituents or to interaction (e.g. synergistic effects) with other substances introduced in the area, either through other dumping, input from rivers, discharges from coastal areas, exploitation areas, maritime transport, or through the atmosphere.

The existing stress on biological communities as a result of such activities should be evaluated before any new or additional dumping operations are conducted.

The possible future uses of resources and amenities in the sea receiving area should be kept in mind.

6.7 Information from baseline and monitoring studies at existing dumping sites will be important in the evaluation of any new dumping activity at the same site or nearby.

## **7. GENERAL CONSIDERATIONS AND CONDITIONS**

### **NATURE, PREVENTION AND MINIMISATION OF THE IMPACT OF DISPOSAL OF DREDGED MATERIAL**

7.1 Particular attention should be given to dredged material contaminated by hydrocarbons and containing substances that have a tendency to float following re-suspension in the water column. Such materials should not be dumped in a manner or at a location which may interfere with fishing, shipping, amenities or other beneficial uses of the marine environment.

7.2 In selecting dumping sites, the habitats of rare, vulnerable or endangered species must be avoided, taking into account the preservation of the biodiversity.

7.3 In addition to toxicological effects and bioaccumulation of the constituents of dredged material, other potential impacts on marine life should be considered, such as:

- alteration of the sensorial and physiological capacities and the behaviour of fish in particular in respect of natural predators;
- nutrient enrichment;
- oxygen depletion;
- increased turbidity;
- modification of the sediment composition and blanketing of the sea floor.

#### **Physical impact**

7.4 All dredged materials, whether or not contaminated, have a significant physical impact at the point of disposal. This impact includes covering of the seabed and a localised increase in the levels of suspended solids.



The physical impact may also extend to zones outside the dumping zone as such, resulting from the forward movement of the dumped material due to wave and tidal action and residual current movements, especially in the case of fine fractions.

In relatively enclosed waters, oxygen-consuming sediments (e.g. organic carbon-rich) could adversely affect the oxygen regime of receiving systems. In the same way, dumping of sediments with high levels of nutrients may significantly affect the nutrient fluxes and, subsequently, in extreme cases, contribute significantly to the eutrophication of the receiving zone.

### **Chemical impact**

7.5 The chemical impact of dredged material disposal on the marine water quality and the marine biota, is mainly from the dispersion of pollutants in association with suspended particles, and the release of pollutants from the dumpsite sediments.

The binding capacity of contaminants may vary considerably. Contaminant mobility is dependant upon several factors among which are chemical form of contaminant, contaminant partitioning, type of matrix, physical state of the system (e.g. pH, TE, ..), waterflow, suspended matter (organic matter), physico-chemical state of the system, type of interactive processes, such as sorption/desorption - or precipitation/dissolution - mechanisms, and biological activities.

### **Bacteriological impact**

7.6 Bacteriologically, dredging activities and dumping of dredged material may involve a resuspension, of sedimentary flora, particularly faecal bacteria, which are trapped in the sediment. Studies carried out show that, in particularly on dredging sites, there is a significant correlation between turbidity and concentrations of germs tested (faecal coliforms, faecal streptococci).

### **Biological impact**

7.7 The immediate biological consequence of this physical impact includes smothering of benthic flora and fauna in the dumping area.

Nevertheless, in some instances, after dumping activities stop, there may be a modification of the ecosystem, in particular when the physical characteristics of the sediments in the dredged material are very different to those in the receiving zone.

In certain special circumstances, disposal may interfere with migration of fish or crustaceans (e.g. if dumping is in the coastal migration path of crabs).

In other respects, the chemical pollution impact resulting from the dispersion of pollutants associated with suspended matter, and from the contaminants "relargage" from the sediments which are accumulated on the dumping site, can induce a change in the composition, biodiversity and abundance of benthic communities.

### **Economic impact**

7.8 An important consequence of the physical presence of dumping of dredged material is interference with fishing activities and, in some instances, with navigation and recreation. The former concerns both the smothering of areas that may be used for fishing and interference with fixed fishing gear; shoaling following dumping can lead to navigational hazards and clay or silt

deposition may be harmful in recreational areas. These problems can be aggravated if the spoil is contaminated with bulky harbour debris such as wooden beams, scrap metal, pieces of cable etc.

### **Approaches to management**

7.9 This section deals only with management techniques to minimise the physical effects of disposal of dredged material. Measures to control the contamination of dredged materials are covered in other sections of these guidelines.

7.10 The key to management lies in careful site selection (see section 5) and assessment of the conflict between marine resources, the marine environment and activities. These notes are intended to supplement these considerations.

7.11 To avoid excessive use of the seabed, the number of sites should be limited as far as possible and each site should be used to the maximum extent possible without interfering with navigation (sand-shoals formation).

All measures should be taken to allow recolonization to take place once deposition stops.

7.12 Effects can be reduced by ensuring as far as possible that the sediments in the dredged material and receiving area are similar. Locally, the biological impact may be further reduced if the sedimentation area is naturally subject to physical disturbance (horizontal and vertical currents). Where this is not possible, and the materials are clean and fine, a deliberately dispersive style of dumping should be utilised so as to limit blanketing to a small site.

7.13 With capital and maintenance dredging, the material may be different in character to the sediments at the receiving site and re-colonisation may be affected. Where bulky material such as rock and clay are deposited, there may be interference with fishing activity, even in the long term.

7.14 Temporal restrictions on dumping activities may have to be imposed (for example tidal and seasonal restrictions). Interference with fish or crustacean migration or spawning or with seasonal fishing activities may be avoided by imposing a calendar for dumping operations.

Trench digging and refilling activities may also interfere with migratory patterns and similar restriction measures are needed.

7.15 Where appropriate, disposal vessels should be equipped with accurate positioning systems for example, satellite systems. Disposal vessels should be inspected and operations controlled regularly to ensure that the conditions of the dumping permit are being observed and that the crew is aware of its responsibilities under the permit. Ships' records and automatic monitoring and display devices (e.g. black-boxes), where these have been fitted, should be inspected to ensure that dumping is taking place at the specified dumping site.

Where solid waste is a problem, it may be necessary to specify that the disposal vessel (or dredger) is fitted with a grid to facilitate removal for disposal (or recovery) on land, rather than being dumped at sea.

7.16 Monitoring is an essential component of management action (see Part B).

## **8. DISPOSAL MANAGEMENT TECHNIQUES**

8.1 Ultimately, the problem of disposal of contaminated dredged material can only be resolved effectively by implementing programmes and adopting measures for the progressive elimination of polluting discharges into the waters from which the dredged materials are taken.

Until this objective is met the problems caused by contaminated dredged material could be resolved by using appropriate disposal management techniques.

8.2 "Disposal management techniques" are actions and processes by which the impact of persistent and potentially toxic substances contained in dredged material may be reduced to or maintained at a level that does not constitute a hazard to human health, harm living resources and marine life, damage amenities or interfere with other legitimate uses of the sea.

8.3 In any event, such techniques must be used in full conformity with relevant considerations in the Annex to the Dumping Protocol such as comparative assessment of alternative disposal options, and should always be associated with post-disposal monitoring (ecological follow-up) to assess the effectiveness of the techniques and the need for any follow-up management action.

## **PART B**

### **MONITORING OF DREDGED MATERIAL DUMPING OPERATIONS**

#### **1. DEFINITION**

1.1 In the context of assessing and regulating the environmental and human health impacts of dredged material dumping operations, monitoring is defined as all measures whose purpose is to determine, from the repeated measurement of a contaminant or an effect, whether direct or indirect, of the introduction of this contaminant into the marine environment, the spatial and temporal modifications undergone by the receiving zone as a result of the activity under consideration.

#### **2. RATIONALE**

2.1 Monitoring of dredged material dumping operations is generally undertaken for the following reasons:

- (i) to establish whether the permit conditions have been respected - conformity control - and consequently have, as intended, prevented adverse effects on the receiving area as a consequence of dumping;
- (ii) to improve the basis on which permit applications are assessed by improving knowledge of the field effects of major discharges which cannot be directly estimated by a laboratory evaluation or from the literature;
- (iii) to provide the necessary evidence to demonstrate that within the framework of the Protocol the monitoring measures applied are sufficient to ensure that the dispersive and assimilative capacities of the marine environment are not exceeded, and so do not cause damage to the environment.

#### **3. OBJECTIVES**

3.1 The purposes of monitoring are to determine contaminant levels in all sediments above the lower reference threshold in paragraph 3.5(b) of the guidelines and in bio-indicator organisms, the biological effects and consequences for the marine environment of the dumping of dredged material and, ultimately, to help managers to combat exposure of organisms to dredged materials and associated contaminants.

#### **4. STRATEGY**

4.1 Monitoring operations are expensive since they require considerable resources both to carry out measurement and sampling programmes at sea and the subsequent analytical work on the samples.

In order to approach the monitoring programme in a resource-effective manner, it is essential that the programme should have clearly defined objectives, that the measurements made can meet those objectives, and that the results should be reviewed at regular intervals in relation to the objectives.

Since the effects of dredged material dumping are likely to be similar in many areas, there appears to be little justification for monitoring all sites, particularly those receiving small quantities of dredged material. It would be more effective to carry out more detailed investigations at a few carefully chosen sites (e.g. those subject to large inputs of dredged material) in order to obtain a better understanding of the processes and effects involved.

In zones which present the same physical, chemical and biological characteristics, or nearly the same characteristics, there is strong presumptive evidence that the effects of dredged material dumping are similar. On scientific and economic grounds, it is very difficult to justify monitoring of all sites, particularly those receiving small quantities of dredged material (e.g. less than 25,000 tons per year). It is therefore more appropriate and cost-effective to concentrate on detailed investigations at a few carefully chosen sites (e.g. those subject to large inputs of dredged material) in order to obtain a better understanding of the processes and effects involved.

## **5. IMPACT HYPOTHESIS**

5.1 In order to establish such objectives, it is first necessary to derive an impact hypothesis describing predicted effects on the physical, chemical and biological environment both of the dumping zone and of the zones outside it. The impact hypothesis forms the basis for defining the field monitoring programme.

5.2 The aim of an impact hypothesis is to provide, on the basis of the available information, a concise scientific analysis of the potential effects of the proposed operation on human health, living resources, marine life, amenities and other legitimate uses of the sea. For this purpose, an impact hypothesis should incorporate information on the characteristics of the dredged material and on conditions at the proposed dumping site. It should encompass both temporal and spatial scales of potential effects.

One of the main requirements of the impact hypothesis is to produce criteria which describe the specific environmental effects of dumping activities, taking into account the fact that such effects have to be avoided outside the designated dredging and dumping zones (see Part A, Section 3).

## **6. PRELIMINARY EVALUATION**

6.1 The preliminary evaluation should be as comprehensive as possible. The primary areas of potential impact should be identified as well as those considered to have the most serious consequences for human health and the environment. Alterations to the physical environment, risks to human health, devaluation of marine resources, and interference with other legitimate uses of the sea are often seen as priorities in this regard.

6.2 The expected consequences of dumping (targets) could be described in terms of the habitats, processes, species, communities and uses affected by the dumping. The precise nature of the change, response, or interference (effect) predicted could then be described. The target and the effect could be described (quantified) together in sufficient detail to eliminate any doubt as to the parameters to be measured during post-operational field monitoring. In the latter context, it might be essential to determine "where" and "when" the impacts can be expected.

## **7. REFERENCE BASELINE**

7.1 In order to develop an impact hypothesis, it may be necessary to conduct a baseline survey which describes not only the environmental characteristics, but also the variability of the environment. It may also be helpful to develop sediment transport, hydrodynamic and other mathematical models, to determine the possible effects of dumping.

Where either physical or chemical effects at the seabed are expected, it will be necessary to examine the benthic community structure in areas where the dredged material disperses. In the case of chemical effects, it may also be necessary to examine the chemical quality of the sediments and the biota (including fish), in particular the major pollutant contents.

In order to assess the impact of the proposed activity on the surrounding environment, it will be necessary to compare the physical, chemical and biological quality of the affected areas with reference sites located away from dredged material dumping pathways. Such areas can be identified during the early stages of the impact assessment.

## **8. IMPACT HYPOTHESIS VERIFICATION: DEFINING THE MONITORING PROGRAMME**

8.1 The measurement programme should be designed to ascertain that physical, chemical and biological changes in the receiving environment are within those projected and do not exceed the predicted impact hypothesis.

The measurement programme should be designed to determine:

- (a) whether the zone of impact differs from that projected; and,
- (b) whether the extent of changes outside the zone of direct impact is within the scale predicted.

The first question can be answered by designing a sequence of measurements in space and time that circumscribe the projected zone of impact to ensure that the projected spatial scale of change is not exceeded.

The second question can be answered by making physical, chemical and biological measurements that provide information on the extent of change that occurs outside the zone of impact, after the dumping operation takes place (verification of a null hypothesis).

Then, before any programme is drawn up and any measurements are made, the following questions should be addressed:

- (i) what testable hypothesis can be derived from the impact hypothesis?
- (ii) what exactly should be measured to test these impact hypotheses?
- (iii) in what compartment or at which locations can measurements most effectively be made?
- (iv) for how long should measurements continue to be made to meet the original aim?

- (v) what should be the temporal and spatial scale of the measurements made?
- (vi) how should the data be processed and interpreted?

8.2 It is recommended that the choice of contaminants to be monitored should depend primarily on the ultimate purposes of monitoring. It is definitely not necessary to monitor regularly all contaminants at all sites and it should not be necessary to use more than one substrate or effect to meet each aim.

## 9. MONITORING

9.1 The dumping of dredged material has its primary impact at the seabed. Thus although a consideration of water column effects cannot be discounted in the early stages of monitoring planning, it is often possible to restrict subsequent monitoring to the seabed.

9.2 Where it is considered that effects will be largely physical, monitoring may be based on remote methods such as side-scan sonar, to identify changes in the character of the seabed, and bathymetric techniques (e.g. echo sounding) to identify areas of dredged material accumulation. Both of these techniques will require a certain amount of sediment sampling to establish ground-truth. In addition, multispectral scanning can be used for monitoring the dispersion of suspended material (plumes, etc.).

9.3 Tracer tests may also prove useful in following the dispersal of the dredged material and assessing any minor accumulation of material not detected by bathymetric surveys.

9.4 Where, in relation to the impact hypothesis, either physical or chemical effects at the seabed are expected, it will be necessary to examine the benthic community structure in areas where the dredged material disperses. In the case of chemical effects, it may also be necessary to examine the chemical quality of the biota (including fish).

9.5 The spatial extent of sampling will need to take into account the size of the area designated for dumping, the mobility of the dumped dredged material and water movements which determine the direction and extent of sediment transport. It should be possible to limit sampling within the dumping site itself if effects in this area are considered to be acceptable and their detailed definition unnecessary. However, some sampling should be carried out to aid the identification of the type of effect which may be expected in other areas and for reasons of scientific rigour.

9.6 The frequency of surveying will depend on a number of factors. Where a dumping operation has been going on for several years, it may be possible to establish the effect at a steady state of input and repeated surveys would only be necessary if changes are made to the operation (quantities or type of dredged material dumped, method of disposal, etc.).

9.7 If it is decided to monitor the recovery of an area which is no longer used for dumping dredged material, more frequent measurements might be needed.

## **10. NOTIFICATION**

10.1 The Contracting Parties should inform the Organisation of their monitoring activities.

Concise reports on monitoring activities should be prepared and transmitted to the Organisation as soon as they are available, in conformity with Article 26 of the Barcelona Convention.

Reports should detail the measurements made, results obtained and how these data relate to the monitoring objectives and confirm the impact hypothesis. The frequency of reporting will depend upon the scale of dumping activity, the intensity of monitoring and the results obtained.

## **11. FEEDBACK**

11.1 Information gained from field monitoring (and/or other related research) can be used to:

- (a) modify or, in the best of cases, terminate the field monitoring programme;
- (b) modify or revoke the permit;
- (c) refine the basis on which applications for permits are assessed.

# **TECHNICAL SUPPLEMENTS TO THE GUIDELINES FOR THE MANAGEMENT OF DREDGED MATERIAL**

## **TECHNICAL ANNEX 1**

### **Analytical Requirements for the Assessment of Dredged Material**

1. This Annex amplifies the analytical requirements set out in paragraphs 5.9 - 5.12 of the Guidelines for the Management of Dredged Material.

2. An integrated approach is essential. It includes a tiered approach under which the following are assessed in sequence:

- the physical properties;
- the chemical properties;
- the biological properties and effects.

At each tier it will have to be determined whether there is sufficient information to allow a management decision to be taken or whether further analysis is required. Further information determined by local circumstances can be added at each tier.

3. As a preliminary to the tiered analysis scheme, information required under section 4.1 of the guidelines will be available. In the absence of appreciable pollution sources and if the visual determination of sediment characteristics leads to the conclusion that the dredged material meets one of the exemption criteria under paragraph 4.9 of the guidelines, the material will not require further analysis.



4. It is important that, at each stage, the assessment procedure takes account of the method of analysis.
5. Analysis should be carried out on the fraction of the sediment (# 2 mm).

### **Tier I: PHYSICAL PROPERTIES**

In addition to the preliminary assessment of the characteristics of the sediments required by paragraph 4.1 of these guidelines, it is strongly recommended that the following be determined:

- distribution of grain size (% of sand, silt, clay);
- humidity ratio (%);
- amount of organic matter.

### **Tier II: CHEMICAL PROPERTIES**

#### Primary group determinants:

In all cases where chemical analysis is required, the concentrations of the following trace metals should be determined:

Cadmium (Cd)	Chromium (Cr)
Copper (Cu)	Lead (Pb)
Mercury (Hg)	Nickel (Ni)
Zinc (Zn)	Tin (Sn)

In certain cases, the analysis may also include other metal pollutants. In the case of mercury, special attention should be paid to speciation.

Where dry matter analysis is required, the ratio of fresh weight/dry weight has to be considered, and the analysis has to be made on the interstitial water.

When examining the toxic trends of contaminated dredged sediment, the analysis should also include the leaching water before the dumping operation. Lastly, the total organic carbon should be measured.

With regard to organic pollutants, the total PCB content should be estimated. If local circumstances so require, the analysis should be extended to families of congeners.

In any event, the analysis must be carried out on the fraction of the sediment (# 2mm).

The polycyclic aromatic hydrocarbons (PAH) and the tributyltin compounds (TBT) and their degradation products should also be measured.

The measurement of PCB and PAH and TBT will not be necessary when:

- sufficient information from previous investigations indicates the absence of contamination ;

- there are no known sources (point or diffuse) of contamination nor historic inputs;
- the sediments are predominantly coarse; and
- the levels of total organic carbon are low.

Secondary group determinants:

Based upon local information on sources of contamination (point or diffuse sources) or historic inputs, other determinants may need to be measured for instance: arsenic; organophosphorus pesticides; organochlorine pesticides; organotin compounds; polychlorinated dibenzodioxins (PCDD); polychlorinated dibenzofurans (PCDF).

### **Tier III: BIOLOGICAL PROPERTIES AND EFFECTS**

In a significant number of cases the physical and chemical properties do not allow the biological impact to be measured directly. Moreover, they do not adequately identify all the physical disturbances nor constituents associated with sediments present in the dredged material.

If the potential impact of the dredged material to be dumped cannot be adequately assessed on the basis of chemical and physical characteristics, biological measurements should be made.

#### **1. Toxicity bioassays**

The primary purposes of the biological bioassays is to provide direct measures of effects of all sediment constituents acting together, taking into account their bioavailability. For ranking and classifying the acute toxicity of harbour sediments prior to maintenance dredging, short term bioassays may often suffice as screening tool :

- C To evaluate the effects of the dredged material, bioassays for acute toxicity can be carried out with pore water, on elutriate or the whole sediment. In general, a set of 2-4 bioassays is recommended with organisms from different taxonomic groups (e. g. crustaceans, molluscs, polychaetes, bacteria, echinoderms);
- C In most bioassays, survival of the test species is used as an endpoint. Chronic bioassays with sub-lethal endpoint (growth, reproduction, etc.) covering a significant part of the test species life cycle may provide a more accurate prediction of potential impacts of dredging operations. However, standard test procedures are still under developments.

The outcome of sediment bioassays can be unduly influenced by factors other than sediment-associated chemicals. Confounding factors like ammonia, hydrogen sulphide, grain size, oxygen content and pH should therefore be determined during the bioassays.

Guidance on the selection of appropriate test organisms, use and interpretation of sediment bioassays is given by e.g. EPA/CE (1991/1994) and IADC/CEDA (1997) while guidance on sampling of sediments for toxicological testing is given by e.g. ASTM (1994).

## 2. Biomarkers

Biomarkers may provide early warning of more subtle (biochemical) effects at low and sustained levels of contamination. Most biomarkers are still under development but some are already applicable for routine application on dredged material (e.g. one which measures the presence of dioxin-like compounds - Murk *et al.*, 1997) or organisms collected in the field (e.g. DNA strand/breaks in flat fish).

## 3. Microcosm experiments

There are short-term microcosm tests available to measure the toxicant tolerance of the community e.g. Pollution Induced Community Tolerance (PICT) (Gustavson and Wangberg, 1995).

## 4. Mesocosm experiments

Because of the costs and time involved these experiments cannot be used for issuing permits but are useful in cases where the extrapolation of laboratory testing to field conditions is complicated or when environmental conditions are very variable and hinder the identification of toxic effects as such. The results of these experiments would be then available for future decisions on permits.

## 5. Field observations of benthic communities

*In situ* monitoring of benthic communities (fish, benthic invertebrates) in the area of the disposal site can provide important indications of the condition of marine sediments. Field observations give an insight into the combined impact of physical disturbance and chemical contamination. Guidelines on the monitoring of benthic communities are provided by e.g. the Paris Convention, 1992, ICES.

## 6. Other biological properties

Where appropriate, other biological measurements can be applied in order to determine, for example, the potential for bioaccumulation and for tainting.

### SUPPLEMENTARY INFORMATION

The need for this information will be determined by local circumstances and may form an essential part of the management decision. Appropriate data might include: redox potential, sediment oxygen demand, total nitrogen, total phosphorus, iron, manganese, mineralogical information or parameters for normalising trace metal data (e.g. aluminium, lithium, scandium see Technical Annex 2).

## TECHNICAL ANNEX 2

### NORMALISATION TECHNIQUES FOR STUDIES ON THE SPATIAL DISTRIBUTION OF CONTAMINANTS<sup>2</sup>

#### 1. Introduction

Normalisation in this discussion is defined as a procedure to compensate for the influence of natural processes on the measured variability of the concentration of contaminants in sediments. Most contaminants (metals, pesticides, hydrocarbons) show high affinity to particulate matter and are, consequently, enriched in bottom sediments of estuaries and coastal areas. In practice, natural and anthropogenic substances entering the marine system are subjected to a variety of biogeochemical processes. As a result, they become associated with fine-grained suspended solids and colloidal organic and inorganic particles. The ultimate fate of these substances is determined, to a large extent, by particulate dynamics. They therefore tend to accumulate in areas of low hydrodynamic energy, where fine material is preferentially deposited. In areas of higher energy, these substances are "diluted" by coarser sediments of natural origin and low contaminant content.

It is obvious that the grain size is one of the most important factors controlling the distribution of natural and anthropogenic components in the sediments. It is, therefore, essential to normalise for the effects of grain size in order to provide a basis for meaningful comparisons of the occurrence of substances in sediments of various granulometry and texture within individual areas or among areas. Excess levels, above normalised background values, could then be used to establish sediment quality.

For any study of sediments, a basic amount of information on their physical and chemical characteristics is required before an assessment can be made on the presence or absence of anomalous contaminant concentrations. The concentration at which contamination can be detected depends on the sampling strategy and the number of physical and chemical variables that are determined in individual samples.

The various granulometric and geochemical approaches used for the normalisation of trace elements data as well as the identification of contaminated sediments in coastal sediments has been extensively reviewed by Loring (1988). Two normalisation approaches widely used in oceanography and in atmospheric sciences have been selected here. The first is purely physical and consists of characterising the sediment by measuring its content of fine material. The second approach is chemical in nature and is based on the fact that the small size fraction is usually rich in clay minerals, iron and manganese oxo-hydroxides and organic matter. Furthermore, these components often exhibit a high affinity for organic and inorganic contaminants and are responsible for their enrichment in the fine fraction. Chemical parameters (e.g., Al, Sc, Li) representative of these components may thus be used to characterise the small size fraction under natural conditions.

It is strongly suggested that several parameters be used in the evaluation of the quality of sediments. The types of information that can be gained by the utilisation of these various parameters are often complementary and extremely useful considering the complexity and diversity of situations encountered in the sedimentary environment. Furthermore, measurements of the normalising parameters selected here are rather simple and inexpensive.

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<sup>2</sup> Extract from 1989 ACMP Report (Section 14) ICES Coop. Res. Rep. 167, pp. 68-75

This report presents general guidelines for sample preparation, analytical procedures, and interpretation of physical and chemical parameters used for the normalisation of geochemical data. Its purpose is to demonstrate how to collect sufficient data to normalise for the grain-size effect and to allow detection, at various levels, of anomalous concentrations of contaminants within coastal sediments.

## **2. Sampling Strategy**

Ideally, a sampling strategy should be based on a knowledge of the source of contaminants, the transport pathways of suspended matter and the rates of accumulation of sediments in the region of interest. However, existing data are often too limited to define the ideal sampling scheme. Since contaminants concentrate mainly in the fine fraction, sampling priority should be given to areas containing fine material that usually correspond to zones of deposition.

The high variability in the physical, chemical and biological properties of sediments implies that an evaluation of sediment quality in a given area must be based on a sufficient number of samples. This number can be evaluated by an appropriate statistical analysis of the variance within and between samples. To test the representativity of a single sediment specimen at a given locality, several samples at one or two stations should be taken.

The methodology of sampling and analysis should follow the recommendations outlined in the "Guidelines for the Use of Sediments as a Monitoring Tool for Contaminants in the Marine Environment" (ICES 1987). In most cases, the uppermost layer of sediments collected with a tightly closing grab sampler (Level I in the Guidelines) is sufficient to provide the information concerning the contamination of the sediments of a given area compared to sediments of uncontaminated locations or other reference material.

Another significant advantage of using sediments as monitoring devices is that they have recorded the historical evolution of the composition of the suspended matter deposited in the area of interest. Under favourable conditions, the degree of contamination may be estimated by comparison of surface sediments with deeper samples, taken below the biological mixing zone. The concentrations of trace elements in the deeper sediment may represent the natural background level in the area in question and can be defined as baseline values. This approach requires sampling with a box-corer or a gravity corer (Levels II and III in the Guidelines).

## **3. Analytical Procedures**

Typical analytical procedures to be followed are outlined in Figure 2. The number of steps that are selected will depend on the nature and extent of the investigation.

### **3.1 Grain size fractionation**

It is recommended that at least the amount of material <63 Fm, corresponding to the sand/silt classification limit, be determined. The sieving of the sample at 63 Fm is, however, often not sufficient, especially when sediments are predominantly fine grained. In such cases, it is better to normalise with lower size thresholds since the contaminants are mainly concentrated in the fraction <20 Fm, and even more specifically in the clay fraction (# 2 Fm). It is thus proposed that a determination be made, on a sub-sample, of the weight fraction # 20 Fm and that # 2 Fm with the aid of a sedimentation pipette or by elutriation. Several laboratories are already reporting their results relative to the content of fine fractions of various sizes and these results may be useful for comparison among areas.

### 3.2 Analysis of contaminants

It is essential to analyse the total content of contaminants in sediments if quality assessment is the goal of the study, and it is thus recommended that the unfractionated sample (#2 mm) be analysed in its entirety. The total content of elements can be determined either by non-destructive methods, such as X-ray fluorescence or neutron activation, or by a complete digestion of the sediments (involving the use of hydrofluoric acid (HF)) followed by methods such as atomic absorption spectrophotometry or emission spectroscopy. In the same way, organic contaminants should be extracted with the appropriate organic solvent from the total sediment.

An individual size fraction of the total sediment may be used for subsequent analysis, if required, to determine the absolute concentrations of contaminants in that fraction, providing that its contribution to the total is kept in perspective when interpreting the data. Such size fraction information might be useful in tracing the regional dispersal of metals associated with specific grain-size fractions, when the provenance of the material remains the same. However, sample fractionation is a tedious procedure that introduces considerable risk of contamination and potential losses of contaminants due to leaching. The applicability of this approach is thus limited.

## 4. Normalisation Procedures

### 4.1 Granulometric normalization

Since contaminants tend to concentrate in the fine fraction of sediments, correlations between total concentrations of contaminants and the weight percent of the fine fraction, determined separately on a sub-sample of the sediment by sieving or gravity settling, constitute a simple but powerful method of normalisation. Linear relationships between the concentration and the weight percentage of the fine fraction are often found and it is then possible to extrapolate the relationships to 100% of the fraction studied, or to characterise the size dependence by the slope of the regression line.

### 4.2 Geochemical normalisation

Granulometric normalisation alone is inadequate to explain all the natural trace variability in the sediments. In order to interpret better the compositional variability of sediments, it is also necessary to attempt to distinguish the sedimentary components with which the contaminants are associated throughout the grain-size spectrum. Since effective separation and analysis of individual components of sediments is extremely difficult, such associations must rest on indirect evidence of these relationships.

Since contaminants are mainly associated with the clay minerals, iron and manganese oxo-hydroxides and organic matter abundant in the fine fraction of the sediments, more information can be obtained by measuring the concentrations of elements representative of these components in the samples.

An inert element such as aluminium, a major constituent of clay minerals, may be selected as an indicator of that fraction. Normalised concentrations of trace elements with respect to aluminium are commonly used to characterise various sedimentary particulate materials (see below). It may be considered as a conservative major element, that is not affected significantly by, for instance, early diagenetic processes and strong redox effects observed in sediments.

In the case of sediments derived from the glacial erosion of igneous rocks, it has been found that contaminant/Al ratios are not suitable for normalising for granular variability (Loring, 1988). Lithium, however, appears to be an ideal element to normalise for the grain size effect in this case and has the additional advantage of being equally applicable to non-glacial sediments.

In addition to the clay minerals, Mn and Fe compounds are often present in the fine fraction, where they exhibit adsorption properties strongly favouring the incorporation of various contaminants. Mn and Fe are easily analysed by flame atomic absorption spectrometry and their measurement may provide insight into the behaviour of contaminants.

Organic matter also plays an important role as scavenger of contaminants and controls, to a major degree, the redox characteristics of the sedimentary environment.

Finally, the carbonate content of sediments is easy to determine and provides additional information on the origin and the geochemical characteristics of the sediments. Carbonates usually contain insignificant amounts of trace metals and act mainly as a diluent. Under certain circumstances, however, carbonates can fix contaminants such as cadmium and copper. A summary of the normalisation factors is given in Table 1.

#### 4.3 Interpretation of the data

The simplest approach in the geochemical normalization of substances in sediments is to express the ratio of the concentration of a given substance to that of the normalising factor.

Normalisation of the concentration of trace elements with respect to aluminium (or scandium) has been used widely and reference values on a global scale have been established for trace elements in various compartments: crustal rocks, soils, atmospheric particles, river-borne material, marine clays and marine suspended matter (cf., e.g., Martin and Whitfield, 1983; Buat-Menard and Chesselet, 1979).

This normalisation also allows the definition of an enrichment factor for a given element with respect to a given compartment. The most commonly used reference level of composition is the mean global normalised abundance of the element in crustal rock (Clarke value). The enrichment factor EF is given by:

$$EF_{\text{crust}} = (X/Al)_{\text{sed}} / (X/Al)_{\text{crust}}$$

where X/Al refers to the ratio of the concentration of element X to that of Al in the given compartment.

However, estimates of the degree of contamination and time trends of contamination at each sampling location can be improved upon by making a comparison with metal levels in sediments equivalent in origin and texture.

These values can be compared to the normalised values obtained for the sediments of a given area. Large departures from these mean values indicate either contamination of the sediment or local mineralization anomalies.

When other variables (Fe, Mn, organic matter and carbonates) are used to characterise the sediment, regression analysis of the contaminant concentrations with these parameters often yields useful information on the source of contamination and on the mineralogical phase associated with the contaminant.

A linear relationship between the concentration of trace constituents and that of the normalisation factor has often been observed (Windom *et al.*, 1989). In this case and if the natural geochemical population of a given element in relation to the normalising factor can be defined, samples with anomalous normalised concentrations are easily detected and may indicate anthropogenic inputs.

According to this method, the slope of the linear regression equation can be used to distinguish the degree of contamination of the sediments in a given area. This method can also be used to show the change of contaminant load in an area if the method is used on samples taken over intervals of some years (Cato, 1986).

A multi-element/component study in which the major and trace metals, along with grain size and organic carbon contents, have been measured allows the interrelationships between the variables to be established in the form of a correlation matrix. From such a matrix, the most significant ratio between trace metal and relevant parameter(s) can be determined and used for identification of metal carriers, normalisation and detection of anomalous trace metal values. Factor analyses can sort all the variables into groups (factors) that are associations of highly correlated variables, so that specific and/or non-specific textural, mineralogical, and chemical factors controlling the trace metal variability may be inferred from the data set.

Natural background levels can also be evaluated on a local scale by examining the vertical distribution of the components of interest in the sedimentary column. This approach requires, however, that several favourable conditions are met: steady composition of the natural uncontaminated sediments; knowledge of the physical and biological mixing processes within the sediments; absence of diagenetic processes affecting the vertical distribution of the component of interest. In such cases, grain-size and geochemical normalisation permits compensation for the local and temporal variability of the sedimentation processes.

## **5. Conclusions**

The use of the granulometric measurements and of component/reference element ratios are useful approaches towards complete normalisation of granular and mineralogical variations, and identification of anomalous concentrations of contaminants in sediments. Their use requires that a large amount of good analytical data be collected and specific geochemical conditions be met before all the natural variability is accounted for, and the anomalous contaminant levels can be detected. Anomalous metal levels, however, may not always be attributed to contamination, but rather could easily be a reflection of differences in sediment provenance.

Geochemical studies that involve the determination of the major and trace metals, organic contaminants, grain size parameters, organic matter, carbonate, and mineralogical composition in the sediments are more suitable for determining the factors that control the contaminant distribution than the measurement of absolute concentrations in specific size fractions or the use of potential contaminant/reference metal ratios alone. They are thus more suitable for distinguishing between uncontaminated and contaminated sediments. This is because such studies can identify the factors that control the variability of the concentration of contaminants in the sediments.



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## TECHNICAL ANNEX 3

### CONSIDERATIONS BEFORE TAKING ANY DECISION TO GRANT A DUMPING PERMIT

This technical Annex was prepared bearing in mind that, although the guidelines strictly only apply to the disposal of dredged material, Contracting Parties are urged to consider other methods of disposal than dumping (e.g. land disposal), and to explore all possible beneficial uses of dredged material, before taking any decision to grant a dumping permit (See Part A, par. 3). The goal of this Technical Annex is not to screen all the possibilities offered by the different techniques, but to give some indications about them.

#### I. BENEFICIAL USES OF DREDGING MATERIAL

Material arising from Capital dredging are often used for construction purposes. This is, however, not normally the case when dredged material result from maintenance dredging. However that may be, if the dredged material is clean or slightly contaminated, it might be regarded as a valuable resource, and consequently, be considered for beneficial use. Nevertheless, before choosing a specific beneficial use, it is necessary to make a cost/benefit analysis to establish that the cost of such an option is not prohibitive (BATNEEC principle : Best available techniques not entailing excessive costs).

Depending on the composition and grain size distribution of the dredged material, it might be used beneficially for construction or environmental enhancement.

### Construction uses

Generally these uses are located in or adjacent to coastal areas or within the waterway margin. Examples are land creation, beaches nourishment, formation of suitable offshore berms, construction of dikes or dams, replacement fill (restoration of former excavation sites of construction materials, obsolete canals and docks, ...).

### Environmental enhancement

Numerous applications of dredged material for the enhancement of the environment can be envisaged. These range from restoration and establishment of wetlands to multipurpose site development, including restoration and establishment of terrestrial habitats, nesting islands, and fisheries;. It also included the construction of artificial reefs, particularly if the dredged material is bulky (for example, rocks). (Any construction of an artificial reef, however, should be preceded by a specific study of the structure's impact on the natural environment: in this case, advice from biologists specialising in fisheries is essential.). In any case, during and after the execution of the project, the impact and the performance of the beneficial use should be monitored.

To assess the possibilities for the beneficial use of material in a specific situation, the following parameters have to be considered : physical characterisation, contaminant status, beneficial use options, site selection, technical feasibility, regulatory acceptability, cost/benefit analysis.

When considering the possibilities other than dumping, if no acceptable beneficial use solution is found, land disposal and/or treatment are the other options.

## **II. LAND DISPOSAL**

When neither sustainable relocation nor beneficial use options are appropriate, disposal in land based confined disposal facilities is usually the only remaining option.

In principle, land based confined disposal sites are preferred for polluted dredged material which is unsuitable for open water disposal.

Various configurations are possible but no one presents a complete safeguard against risk of environmental pollution. Possible pathways resulting in risk are : effluent which is expelled from the disposal sites, during and after the disposal ; leaching and transport of contaminants into surrounding ground and surface water ; animal and plant uptake, dust and gaseous emissions, and excavations.

The potential effects of such sites therefore depend on both the characteristics of the site and its environs (mainly regarding the ground water table situation), and on the characteristics of the dredged material, the latter including the contaminants that are present.

To minimise the transport of contaminants into the ground water and surrounding surface water through advection and diffusion processes, application of insulation layers or hydrological management might be considered. Treatment of surplus water resulting from the expellation of water from the compressed dredged material, might also be considered.

### III. TREATMENT OF DREDGED MATERIAL

Treatment is defined as a way of processing with the aim of reducing the amount of contaminated material (e.g. separation) or reducing the contamination to meet regulatory standards and criteria.

Treatment processes can in general be classified as follows :

- Pretreatment, the goal of which being to reduce the volume of dredged material requiring further treatment or disposal, and to improve the physical quality of the material for further handling and treatment ; the main categories of pretreatment are : dewatering ; size separation ; washing ; density separation ; magnetic separation.
- Biological treatment (degradation of organic substances by micro-organisms);
- Chemical treatment (pH adjustment, oxidation, ion exchange, etc.) ; the categories of chemical treatment are : destruction of organic compounds ; extraction of organic compounds ; extraction of metals ;
- Thermal treatment (thermal desorption, incineration, thermal reduction and vitrification) (Most technologies in this category provide a product such as gravel or bricks which can be used as building material);
- Immobilisation treatment (by chemically binding of the contaminants to the solid particles - fixation - or by physically preventing the contaminants from moving - solidification).
- Pretreatment excess water treatment.

The cost of treatment is generally higher, sometimes considerably greater than the cost of disposal. The cost versus effectiveness ratio is one of the most important questions which every national controlled authority will have to face.

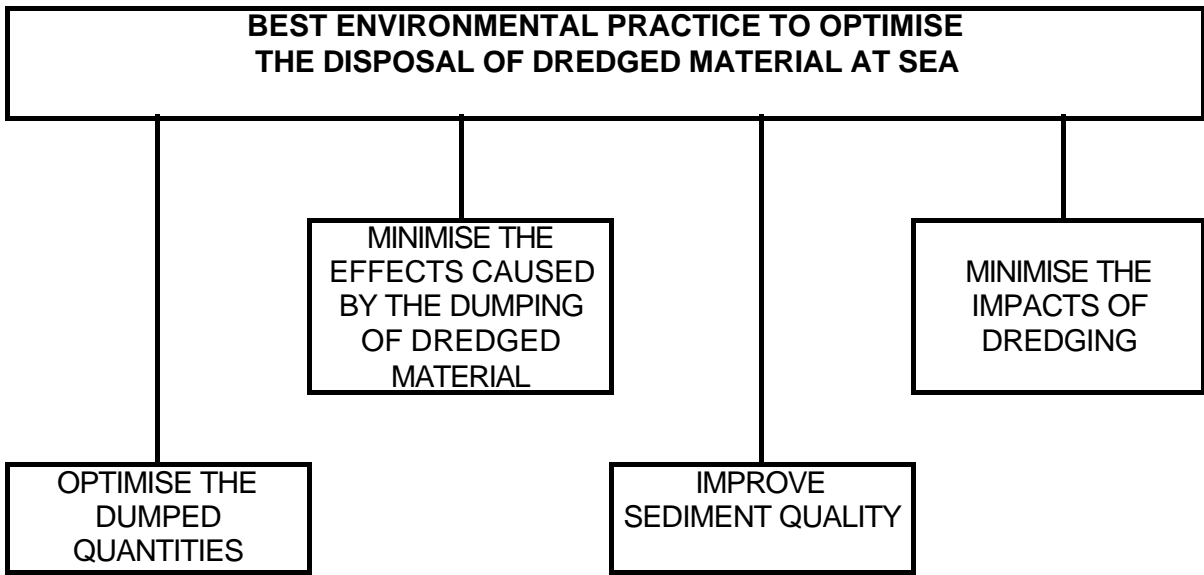
## TECHNICAL ANNEX 4

### DREDGING ACTIVITIES : BEST ENVIRONMENTAL PRACTICE (BEP)

This Technical Annex was prepared bearing in mind that, although the guidelines strictly only apply to the disposal of dredged material, Contracting Parties are encouraged also to exercise control over dredging operations.

This Technical Annex has as its aim to provide guidance to national regulatory authorities, operators of dredging vessels and port authorities on how to minimise the effects on the environment of dredging and disposal operations. Careful assessment and planning of dredging operations are necessary to minimise the impacts on marine species and habitats.

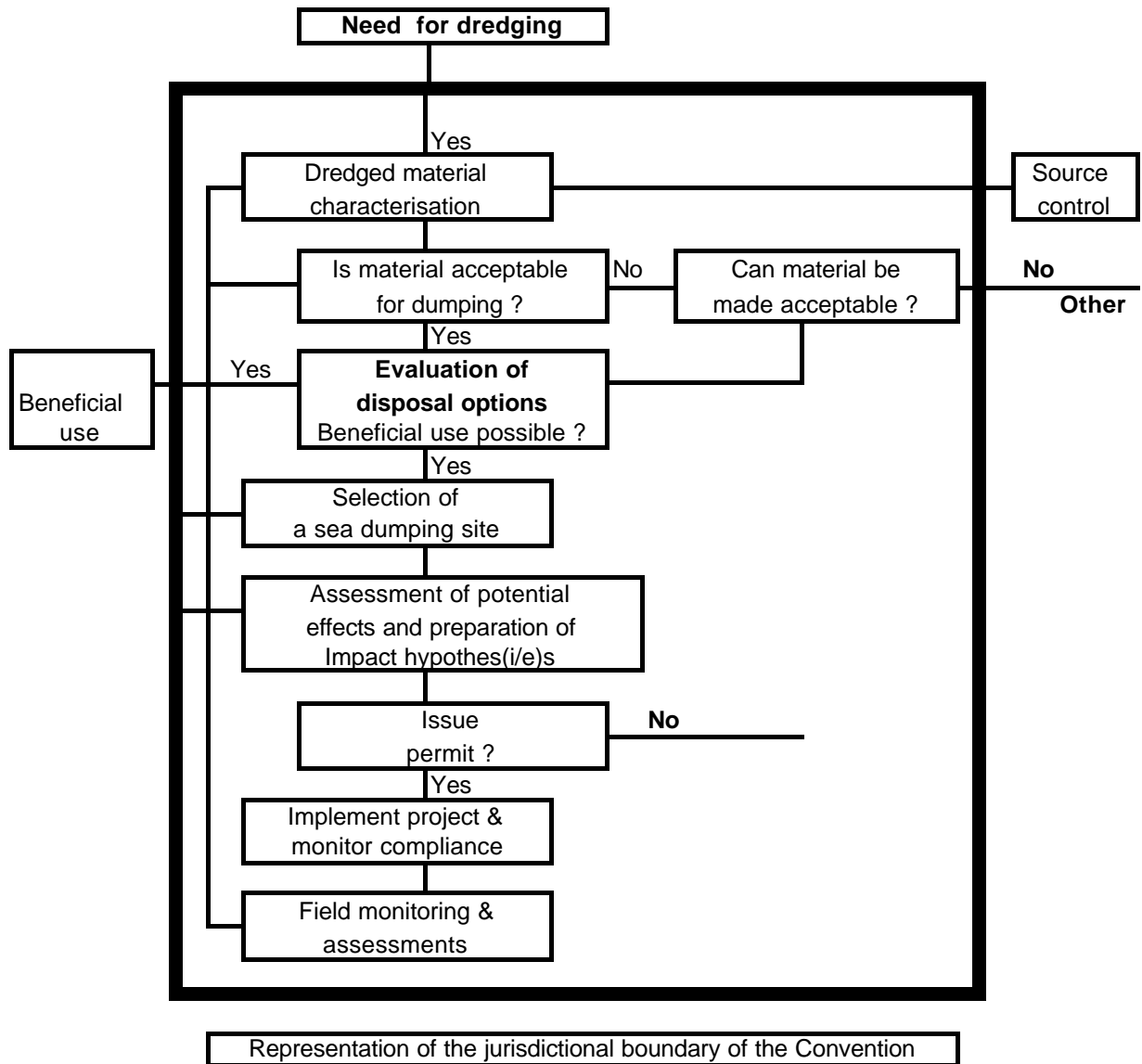
The items given as BEP under the different headings of this Technical Annex are given as examples. Their applicability will generally vary according to the particular circumstances of each operation and it is clear that different approaches may then be appropriate. More detailed information on dredging techniques and processes can be found in Guide 4 of the IADC/CEDA series on Environmental Aspects of Dredging.



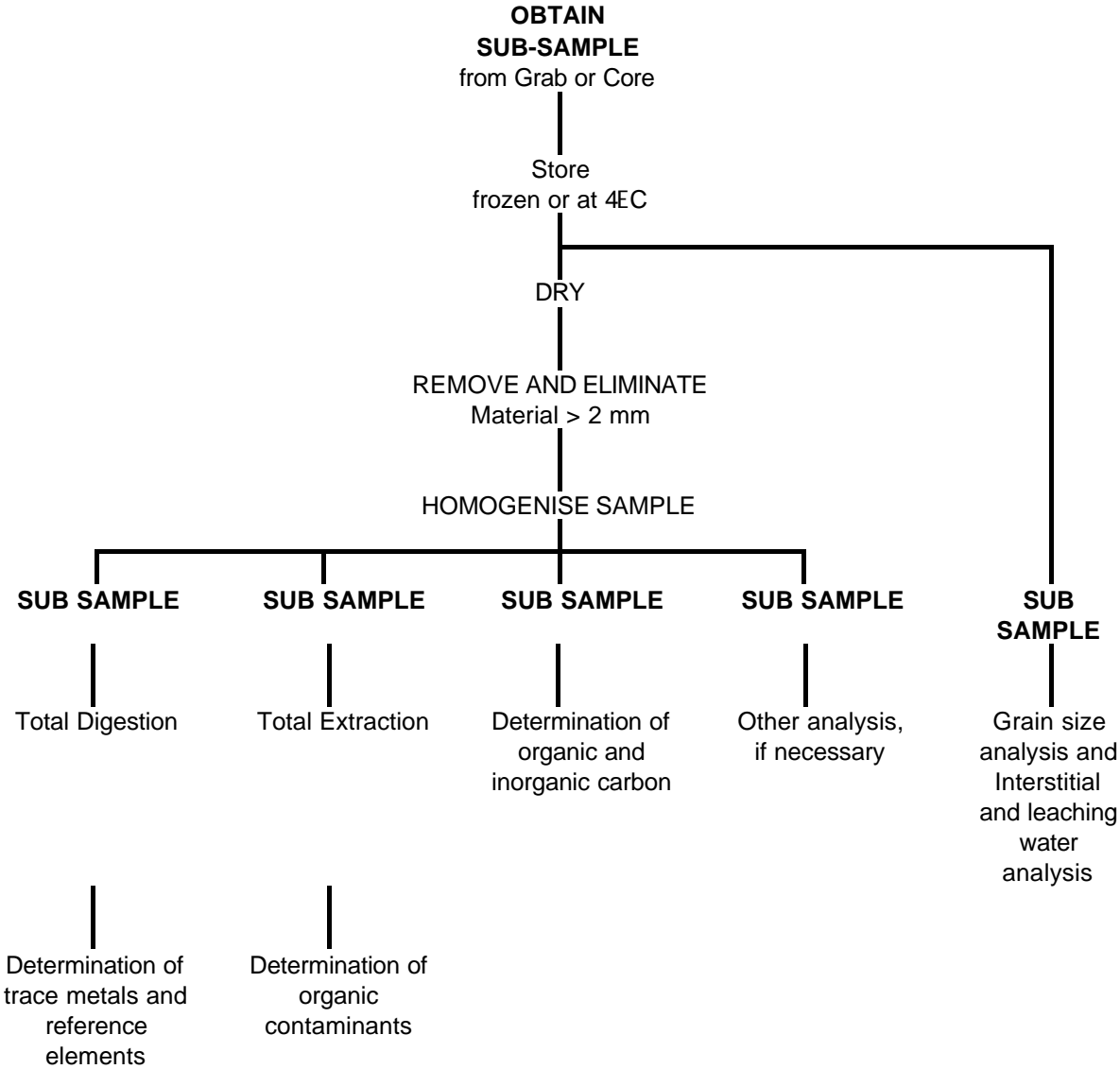
**Point A** - Minimisation of the effects caused by the disposal of dredged material is comprehensively described in the main body of these guidelines

**Point B** - Optimisation of the disposed quantities; **Point C** - "Improvement of sediment quality "; and **Point D** - "Minimise the impacts of dredging" do not fall within the strict remit of the Protocol, but are relevant to the prevention of pollution of the marine environment resulting from the dumping of dredged material.

Figure 1: INDICATIVE FLOW DIAGRAM



**Figure 2 : A TYPICAL APPROACH FOR THE DETERMINATION OF PHYSICAL AND CHEMICAL PARAMETERS IN MARINE SEDIMENTS**



**Table 1: SUMMARY OF NORMALISATION FACTORS**

NORMALISATION FACTOR	GRAIN SIZE (Fm)	INDICATOR	ROLE
<b><u>Textural</u></b>			
Sand	2000 to 63	Coarse-grained metal-poor minerals / compounds	Determines physical sorting and depositional pattern of metals Usually diluent of trace metal concentrations
Mud	< 63	Silt and clay size metal-bearing minerals / compounds	Usually overall concentrator of trace metals
Clay	< 2	Metal-rich clay minerals	Usually fine-grained accumulator of trace metals
<b><u>Chemical</u></b>			
Si		Amount and distribution of metal-poor quartz	Coarse-grained diluter of contaminants
Al		All silicates but used to account for granular variations of metal-rich fine silt and clay size Al-silicates	Chemical tracer of Al-silicates, particularly the clay minerals
Li, Sc		Structurally combined in clay minerals and micas	Tracer of clay minerals, particularly in sediments containing Al-silicates in all size fractions
Organic carbon		Fine-grained organic matter	Tracer of organic contaminants. Sometimes accumulator of trace metals like Hg and Cd.
Fe, Mn		Metal-rich silt and clay size Fe-bearing clay minerals. Fe-rich heavy minerals and hydrous Fe and Mn oxides	Chemical tracer for Fe-rich clay fraction. High absorption capacity of organic and inorganic contaminants
Carbonates		Biogenic marine sediments	Diluter of contaminants. Sometimes accumulate trace metals like Cd and Cu.