



# OSPAR Guidelines for the Management of Dredged Material

(Reference number: 2009/4)<sup>1</sup>

## Preface

1. Introduction
2. Scope
3. Requirements of the 1992 OSPAR Convention
4. Evaluation of Need for Dredging
5. Dredged Material Characterisation
6. Contaminant Source Evaluation and Control
7. Dredged Material Sampling
8. Evaluation of Disposal Options
9. Sea Disposal Site Selection
10. Assessment of Potential Effects
11. Permit or regulation by other means
12. Monitoring
13. Reporting

Background information and supplementary literature to the OSPAR Guidelines for the Management of Dredged Material

Technical Supplements to the draft revised OSPAR Guidelines for the Management of Dredged Material

Technical Annex I: Analytical Requirements for Dredged Material Assessment

Technical Annex II: Normalisation of contaminant concentrations in sediments

Technical Annex III: Best Environmental Practice (BEP)

---

<sup>1</sup> This agreement replaces agreement 2004-8

# OSPAR Guidelines for the Management of Dredged Material

## Preface

These guidelines were adopted at the 2009 Meeting of the OSPAR Biodiversity and Ecosystems Committee. Contracting Parties are obliged to take these guidelines into consideration in their authorisation or regulation procedures for dredged material. It will, however, be implicit that the detailed procedures described in the guidelines will not be applicable in all national or local circumstances.

## 1. Introduction

1.1 Dredging is essential to maintain navigation in ports and harbours as well as for the development of port facilities. Much of the material removed during these necessary activities requires disposal at sea. Most of the material dredged from within the OSPAR maritime area is, by its nature, either uncontaminated or only slightly contaminated by human activity (i.e. at, or close to, natural background levels). However, a smaller proportion of dredged material is contaminated to an extent that major environmental constraints need to be applied when depositing these sediments.

1.2 Within the framework of the Convention for the Protection of the Marine Environment of the North-East Atlantic (hereinafter called the 1992 OSPAR Convention), dredged materials have been listed in Article 3.2 of Annex II as being permitted to be dumped at sea, as an exception from the general prohibition from dumping in Article 3 (2).

## 2. Scope

2.1 The guidelines are designed to assist Contracting Parties in the management of dredged material in ways that will prevent and eliminate pollution in accordance with Annex II to the 1992 OSPAR Convention, and protect marine species and habitats in the OSPAR maritime area in accordance with Annex V. The guidelines in particular address the disposal of dredged material by dumping in the maritime area and the relocation of sediments, due to hydrodynamic and sidecast dredging as well as its subsequent deposition. In the following, "dredged material" includes sediments relocated due to hydrodynamic and sidecast dredging, and "disposal at sea" includes relocation of sediments due to these techniques.

2.2 It is recognised that both removal and disposal of dredged sediments may cause harm to the marine environment. Contracting Parties are therefore encouraged to exercise control over both dredging and disposal operations using a Best Environmental Practice (BEP) approach designed to minimise both the quantity of material that has to be dredged and the impact of the dredging and disposal activities in the maritime area - see Technical Annex III. Contracting Parties are encouraged to develop local, regional and national dredging and disposal management plans in order to minimize the possible impacts and maximizing possible benefits from dredging and disposal. Advice on environmentally acceptable dredging techniques is available from a number of international organisations e.g. the Permanent International Association of Navigation Congresses (PIANC).

2.3 In the context of these guidelines, dredged materials are deemed to be sediments or rocks with associated water, organic matter etc. removed from areas that are normally or regularly covered by water, using dredging or other excavation equipment.

2.4 The terms "dumping" and "disposal" are used in accordance with Article I (f) and (g) of the 1992 OSPAR Convention.

2.5 The guidelines are primarily a scientific and technical framework for assessing dredged material proposed for disposal at sea. While economic considerations are acknowledged, they are not dealt with in detail in these guidelines.

2.6 The schematic shown in Figure 1 provides a clear indication of the stages in the application of this guidance where important decisions should be made. In general, national authorities should use this schematic in an iterative manner ensuring that all steps receive consideration before a decision is made to issue a permit.

### **3. Requirements of the 1992 OSPAR Convention**<sup>2</sup>

3.1 Article 2.1a requires Contracting Parties to take all possible steps to prevent and eliminate pollution and to take the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected.

3.2 Article 4 requires Contracting Parties to take all possible steps to prevent and eliminate pollution by dumping or incineration of wastes or other matter in accordance with the provisions of the 1992 OSPAR Convention, in particular as provided for in Annex II.

3.3 With regard to the dumping of wastes or other matter at sea that are permitted under Article 3(2) of Annex II of the 1992 OSPAR Convention, Article 4 (1)(a) of Annex II requires Contracting Parties to ensure that no such materials are dumped without authorisation or regulation by their competent authorities. In addition, Article 4 (1)(b) of Annex II requires Contracting Parties to ensure that such authorisation or regulation is in accordance with the relevant applicable criteria, guidelines and procedures adopted by the Commission.

3.4 Furthermore, Article 4 (3) of Annex II requires Contracting Parties to keep records and report to the Commission on the nature and quantities of wastes or other matter dumped at sea in accordance with Article 4(1) of Annex II and the locations and methods of dumping used. To this end, OSPAR has agreed on reporting formats for the submission of data on dumping operations at sea.

3.5 Article 2 of Annex V to the OSPAR Convention, requires Contracting parties to protect and conserve the ecosystems and the biological diversity of the maritime area, and to restore, when practicable, marine areas which have been adversely affected and cooperate in adopting programmes and measures for the control of the human activities identified by the application of Appendix 3. To this end, Article 2 (2)(d)(ii) of the OSPAR Strategy on Biological Diversity and Ecosystems, includes dredging for navigational purposes other than within harbours on the candidate list of human activities to be further assessed and controlled by the Commission.

### **4. Evaluation of need for dredging**

4.1 There are a number of dredging activities which may give rise to the need to dispose of sediments. These include:

- a. Capital dredging - for navigation, to enlarge or deepen existing channel and port areas or to create new ones; and for engineering purposes; e.g. trenches for pipes, cables and immersed tube tunnels, removal of material unsuitable for foundations, removal of overburden for aggregate extraction;

---

<sup>2</sup> All Article or Annex references mentioned in this chapter refer to the 1992 OSPAR Convention as amended by the 1998 inclusion of Annex V and Appendix 3.

- b. Maintenance dredging - to ensure that channels, berths or construction works are maintained at their designed dimensions (i.e. counteracting sedimentation and changes in morphology); and
- c. Clean-up dredging - deliberate removal of contaminated material from the marine environment for human health and environmental protection purposes.

4.2 Before beginning a full assessment of the material and the disposal options the question should be asked "Is dredging necessary?". In the event of a subsequent full assessment indicating no acceptable options for disposal it will be necessary to re-address this question in a broader context.

4.3 In addition, attention needs to be given to ensuring that the quantities of material needing to be dredged are minimised as far as is practicable. This is dealt with further in Technical Annex III under 'Optimise the disposed quantities'.

## 5. Dredged material characterisation

5.1 Guidance on the selection of determinants and methods of contaminant analysis, together with procedures to be used for normalisation and quality assurance purposes, will be found in the Technical Annexes. It is envisaged that developments in biological testing techniques might eventually provide sufficient information to assess the potential impact of the contaminants in the material, so that less reliance would need to be placed on chemical testing.

5.2 If dredged material is so poorly characterised that proper assessment cannot be made of its potential impacts on human health and the environment, it shall not be dumped.

### Exemptions from detailed characterisation

5.3 Dredged material may be exempted from the testing referred to in paragraphs 5.5 to 5.10 of these Guidelines (but note that the information listed in paragraph 5.4 below will still be required) if any of the criteria below are met:

- a. it is composed of previously undisturbed geological material; or
- b. it is composed almost exclusively of sand, gravel or rock; or
- c. in the absence of appreciable past and present pollution sources and when the quantity of dredged material from operations does not exceed 10 000 tonnes per year.

In relation to 5.3b and 5.3c the exemption from testing should be supported by local information so as to provide reasonable assurance that the dredged material has not been contaminated.

Dredged material that does not meet at least one of these requirements will need further stepwise characterisation to assess its potential impact (*i.e.* see paragraphs 5.4-5.9).

### Physical characterisation

5.4 The following information is required:

- a. the amount of material;
- b. anticipated or actual loading rate of material at the disposal site;
- c. sediment characteristics preferably by grain size analysis (laser or sieving methods) or exceptionally on the basis of visual determination (*i.e.* clay/silt/sand/gravel/boulder).

Evaluation of the physical characteristics of sediments for disposal is necessary to determine potential impacts and the need for subsequent chemical and/or biological testing (cf. Technical Annex I for further guidance).

## Chemical characterisation

5.5 Sufficient information for chemical characterisation may be available from existing sources. In such cases new measurements may not be required of the potential impact of similar material in the vicinity, provided that this information is still reliable and has been obtained within the last 5 years. Details of the substances recommended to be determined are listed in Technical Annex I.

5.6 Considerations for additional chemical characterisation of dredged material are as follows:

- a. major geochemical characteristics of the sediment including redox status;
- b. potential routes by which contaminants could reasonably have been introduced to the sediments;
- c. industrial and municipal waste discharges (past and present);
- d. probability of contamination from agricultural and urban surface runoff;
- e. spills of contaminants in the area to be dredged;
- f. source and prior use of dredged materials (e.g., beach nourishment); and
- g. natural deposits of minerals and other natural substances.

5.7 Further information may also be useful in interpreting the results of chemical testing (cf. Technical Annex I).

## Biological characterisation

5.8 If the potential impacts of the dredged material to be dumped cannot be adequately assessed on the basis of the chemical and physical characterisation and available biological information, biological testing should be conducted. Further detailed guidance on biological testing is provided in Technical Annex I.

5.9 Biological tests should incorporate species that are considered appropriately sensitive and representative and should determine, where appropriate.

- a. acute toxicity;
- b. chronic toxicity;
- c. the potential for bioaccumulation; and
- d. the potential for tainting.

5.10 Assessment of habitats communities and populations may be conducted in parallel with chemical and physical characterisation, e.g. triad approach. It is important to ascertain whether adequate scientific information exists on the characteristics and composition of the material to be dumped and on the potential impacts on marine life and human health.

## Action List

5.11 The Action List is used as a screening mechanism for assessing properties and constituents of dredged material with a set of criteria for specific substances. It should be used for dredged material management decisions, including the identification and development of source control measures as described in Section 6 below. The criteria should reflect experience gained relating to the potential effects on human health or the marine environment.

5.12 Action List levels should be developed on a national or regional basis and might be set on the basis of concentration limits, biological responses, environmental quality standards, flux considerations or other reference values. They should be derived from studies of sediments that have similar geochemical properties to those from the ones to be dredged and/or to those of the receiving system. Thus, depending upon natural

variation in sediment geochemistry, it may be necessary to develop individual sets of criteria for each area in which dredging or disposal is conducted. With a view to evaluating the possibilities for harmonising or consolidating the criteria referred to above, Contracting Parties are requested to inform the OSPAR Commission of the criteria adopted or revisions, as well as the scientific basis for the development and refinement of these criteria.

5.13 An Action List may include an upper and lower level giving these possible actions:

- a. material which contains specified contaminants or which causes e.g. biological responses, in excess of the relevant upper levels should generally be considered unsuitable for disposal at sea;
- b. material of intermediate quality, below the upper level but exceeding the lower level, should require more detailed assessment before suitability for disposal at sea can be determined ; and
- c. material which contains contaminants below the relevant lower levels should generally be considered of little environmental concern for disposal at sea.

5.14 Action levels should be established at least for determinants on the Primary List in Technical Annex I.

5.15 If, as an option of least detriment, dredged material is disposed of at sea when one or more criteria exceed the upper level, a Contracting Party should:

- a. where appropriate, identify and develop source control measures with a view to meeting the criteria - see paragraphs 6.1 - 6.2 below;
- b. utilise disposal management techniques, including the use of containment or treatment methods, to mitigate the impact of the dumping operation on the marine environment see paragraphs 8.3 - 8.4 below; and
- c. report the fact to the Secretariat, including the reason for permitting the disposal, in accordance with the format for the Annual Reporting on Dumping Operations at Sea.

## **6. Contaminant source evaluation and control**

6.1 Contamination of estuarine and coastal marine sediments both as a consequence of historical and present day inputs presents a continuing problem for the management of dredged material. High priority should be given to the identification of sources, reduction and prevention of further contamination of sediments and should address both point and diffuse sources. Successful implementation of prevention strategies will require collaboration among local, regional and national agencies with responsibility for the control of point and diffuse sources of contamination.

6.2 In developing and implementing the source control strategy, appropriate agencies should take into account:

- a. the continuing need for dredging;
- b. the hazards posed by contaminants and the relative contributions of the individual sources to these hazards;
- c. existing source control programmes and other regulations or legal requirements;
- d. the criteria for best available techniques (BAT) and best environmental practice (BEP) as defined in Appendix 1 of the 1992 OSPAR Convention, *inter alia*, as regards the technical and economic feasibility;
- e. the evaluation of the effectiveness of measures taken; and
- f. consequences of not implementing contaminant reduction.

6.3 In cases where there has been historical contamination or where control measures are not fully effective in reducing contamination to acceptable levels, disposal management techniques, including the use of containment or treatment methods may be required - see paragraphs 8.3 - 8.4 below.

## 7. Dredged material sampling

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

7.1 Dredged material that is not exempted under paragraph 5.3 will require analysis and testing (cf. Technical Annex I) to obtain sufficient information for permitting purposes. Judgement and knowledge of local conditions will be essential when deciding what information is relevant to any particular operation.

7.2 A survey of the area to be dredged should be carried out. The distribution and depth of sampling should reflect the size and depth of the area to be dredged, the amount to be dredged and the expected variability in the horizontal and vertical distribution of contaminants. Core samples should be taken where the depth of dredging and expected vertical distribution of contaminants suggest that this is warranted. In other circumstances, grab sampling will usually be sufficient. Sampling from dumping vessels or barges is not advisable for permitting purposes.

7.3 The following table gives an indication of the number of separate sampling stations required to obtain representative results, assuming a reasonably uniform sediment in the area to be dredged:

<u>Amount dredged (m<sup>3</sup>)</u>	<u>Number of Stations</u>
Up to 25 000	3
25 000 - 100 000	4 – 6
100 000 - 500 000	7 – 15
500 000 - 2 000 000	16 – 30
>2 000 000	extra 10 per million m <sup>3</sup>

The number of sample stations can also be determined on the basis of the area to be dredged. Contracting Parties are encouraged to use the Guidelines for the Sampling and Analysis of Dredged Material Intended for Disposal at Sea (IMO, 2005).

7.4 Normally, the samples from each sampling station and different depths in the sediment should be analysed separately. However, if the sediment is clearly homogenous with respect to sediment texture, it may be possible to analyse composite samples from two or more adjacent sampling stations at a time, providing there are no distinctly different contaminant concentrations in different sub samples and care is taken to ensure that the results allow derivation of valid mean contaminant values. The original individual samples should, however, be retained until the permitting procedure has been completed, in case further analyses are necessary.

### Frequency of sampling

7.5 If the results of the analyses indicate that the material is essentially 'clean' (*i.e.* below lower action level), sampling in the same area need not be repeated more frequently than once every 3 years, provided that there is no indication that the quality of the material has deteriorated.

7.6 It may be possible, following assessment of the results of an initial survey, to reduce either the number of sampling stations or the number of determinants and still provide sufficient information for permitting purposes. If a reduced sampling programme does not confirm the earlier analyses, the full survey should be repeated. If the list of determinants is reduced, further analysis of the complete list of determinants is advisable every 5 years.

7.7 In areas where there is a tendency for sediments to exhibit high levels of contamination, analysis of all the relevant determinants should be frequent and linked to the permit renewal procedure.

## 8. Evaluation of disposal options

8.1 The results of the physical/chemical/biological characterisation will indicate whether the dredged material, in principle, is suitable for disposal at sea. Where sea disposal is identified as an acceptable option, it is nonetheless important, recognising the potential value of dredged material as a resource, to consider the availability of beneficial uses.

### Beneficial uses and alternative disposal options

8.2 There is a wide variety of beneficial uses depending on the physical and chemical characteristics of the material. Generally, a characterisation carried out in accordance with these guidelines will be sufficient to match a material to possible uses such as:

- a. Engineered uses - land creation and improvement, beach nourishment, offshore berms, capping material and fill;
- b. Agricultural and product uses - aquaculture, construction material, liners; and
- c. Environmental enhancement - restoration and establishment of wetlands, terrestrial habitats, nesting islands, and fisheries.

The technical aspects of beneficial uses are well-established and described in the literature - see the references section.

### Options for material for which criteria exceed the upper level

8.3 Where the characteristics of the dredged material are such that normal sea disposal would not meet the requirements of the 1992 OSPAR Convention, treatment or other management options should be considered. These options can be used to reduce or control impacts to a level that will not constitute an unacceptable risk to human health, or harm living resources, damage amenities or interfere with legitimate uses of the sea.

8.4 Treatment, such as separation of contaminated fractions, may make the material suitable for a beneficial use and should be considered before opting for sea disposal. Disposal management techniques to reduce or control impacts may include e.g. placement on or burial in the sea floor followed by clean sediment capping, or methods of containing dredged material in a stable manner. Advice on dealing with contaminated dredged material is available from PIANC (see references).

8.5 A permit to dump dredged material shall be refused if the permitting authority determines that appropriate opportunities exist to reuse, recycle or treat the material without undue risks to human health or the environment or disproportionate costs. The practical availability of other means of disposal should be considered in the light of a comparative risk assessment involving both dumping and the alternatives.

## 9. Sea disposal site selection

9.1 The selection of a site for sea disposal involves considerations of an environmental nature and also economic and operational feasibility. Site selection should try to ensure that the disposal of dredged material does not interfere with, or devalue, legitimate commercial and economic uses of the marine environment nor produce undesirable effects on vulnerable marine ecosystems or species and habitats on the OSPAR List of Threatened and/or Declining Species and Habitats (Reference number 2008-6).

9.2 For the evaluation of a sea disposal site information should be obtained and assessed on the following, as appropriate:

- a. the physical, chemical and biological characteristics of the seabed (e.g., topography, sediment dynamics and transport, redox status, benthic biota);
- b. the physical, chemical and biological characteristics of the water column (e.g., hydrodynamics, dissolved oxygen, pelagic species); and



- c. proximity to:
- (i) areas of natural beauty or significant cultural or historical importance;.
  - (ii) areas of specific scientific or biological importance (e.g. Marine Protected Areas);
  - (iii) recreational areas;
  - (iv) subsistence, commercial and sport fishing areas;
  - (v) spawning, recruitment and nursery areas;
  - (vi) migration routes of marine organisms;
  - (vii) shipping lanes;
  - (viii) military exercise zones;
  - (ix) past munitions disposal sites;
  - (x) engineering uses of the sea such as undersea cables, pipelines, wind farms
  - (xi) areas of mineral resources (e.g. sand and gravel extraction areas).

Such information can be obtained from existing sources, complemented by field work where necessary.

9.3 The information on the characteristics of the sea disposal site referred to above is required to determine the probable fate and effects of the dumped material. The physical conditions in the vicinity of the sea disposal site will determine the transport and fate of the dredged material. The physico-chemical conditions can be used to assess the mobility and bioavailability of the chemical constituents of the material. The nature and distribution of the biological community and the proximity of the site of sea disposal to marine resources and amenities will, in turn, define the nature of the effects that are to be expected. Careful evaluation will allow determination of environmental processes that may dominate the transport of material away from the sea disposal site. The influence of these processes may be reduced through the imposition of permit conditions.

9.4 In some cases, dumping can augment existing effects attributable to inputs of contaminants to coastal areas through land runoff and discharge, from the atmosphere, resource exploitation and maritime transport. These existing stresses on biological communities should be considered as part of the assessment of potential impacts caused by dumping. The proposed method of dumping and potential future uses of resources and amenities in the marine receiving area should also be taken into account.

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

9.6 The use of open-sea sites at distant off-shore locations is seldom an environmentally desirable solution to the prevention of marine pollution by contaminated dredged material.

9.7 The dredged material which is acceptable for sea disposal and the sediments at the disposal site, or in case of a dispersive disposal site of the receiving area, should be of similar characteristics as far as possible.

## **10. Assessment of potential effects**

### **Disposal sites**

10.1 Assessment of potential effects should lead to a concise statement of the expected consequences of the disposal option (*i.e.* the Impact Hypothesis). Its purpose is to provide a basis for deciding whether to approve or reject the proposed disposal option and for defining environmental monitoring requirements.

10.2 This assessment should integrate information on the characteristics of the dredged material and the proposed disposal site conditions. It should comprise a summary of the potential effects on human health, living resources, amenities and other legitimate uses of the sea and should define the nature, temporal and spatial scales and duration of expected impacts based on reasonably pessimistic assumptions.

10.3 In order to develop the 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 be helpful to develop sediment transport, hydrodynamic and other models, to determine possible effects of disposal.

10.4 For a retentive site, where the material deposited will remain within the vicinity of the site, the assessment should delineate the area that will be substantially altered by the presence of the deposited material and what the severity of these alterations might be. At the extreme, this may include an assumption that the immediate receiving area is entirely smothered. In such a case, the likely timescale of recovery or re-colonisation should be projected after disposal operations have been completed as well as the likelihood that re-colonisation will be similar to, or different from, the existing benthic community structure. The assessment should specify the likelihood and scale of residual impacts outside the primary zone.

10.5 In the case of a dispersive site, the assessment should include a definition of the area likely to be altered in the shorter term by the proposed disposal operation (i.e., the near-field) and the severity of associated changes in that immediate receiving environment. It should also specify the likely extent of long-term transport of material from this area and what this flux represents in relation to existing transport fluxes in the area, thereby permitting a statement regarding the likely scale and severity of effects in the long-term and far-field.

10.6 If applicable, the "Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the Assessment of the Effects of Certain Public and Private Projects on the Environment" of the European Community, which requires environmental impact assessments in case of capital dredging operations (and optionally to maintenance dredging) should be taken into account when assessing potential impacts of dredged material disposal. Where applicable, the EU-Habitats Directive (92/43/EEC) may require an appropriate assessment and the EU-Landfill (99/31/EC) and Water Framework Directives (2000/60/EC) may have implications for dredging and disposal operations. Additionally Directive 2008/56/EC Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive) specifies the disposal of dredged material as a possible pressure with regard to physical loss or damage which needs to be considered when assessing the status of the marine environment.

10.7 The Convention on Biological Diversity has produced guidance on biodiversity issues in relation to Environmental Impact Assessment that should be taken into account, when appropriate.

### **Nature of the impact**

10.8 All dredged materials have a significant physical impact at the point of disposal. This impact includes covering of the seabed and local increases in suspended solids levels. Physical impact may also result from the subsequent transport, particularly of the finer fractions, by wave and tidal action and residual current movements.

10.9 Biological consequences of these physical impacts include smothering of benthic organisms in the dumping area and potentially in the surrounding area. In comparatively rare circumstances, the physical impacts can also interfere with the migration of fish (e.g. the impact of high levels of turbidity on salmonids in estuarine areas) or crustaceans (e.g. if deposition occurs in the coastal migration path of crabs).

10.10 The toxicological and bioaccumulation effects of dredged material constituents should be assessed. Disposal of sediments with low levels of contamination is not devoid of environmental risk and requires consideration of the fate and effects of dredged material and its constituents. Substances in dredged material may undergo physical, chemical and biochemical changes when entering the marine environment and these changes should be considered in the light of the eventual fate and potential effects of the material. It should also be taken into account that disposal at sea of certain substances may disrupt the sensory capabilities of the fish and may mask natural characteristics of sea water or tributary streams, thus confusing migratory species which e.g. fail to find spawning grounds or food.

10.11 In relatively enclosed waters, such as some estuarine, archipelagic and fjordic situations, sediments with a high chemical or biological oxygen demand (e.g. organic carbon-rich) could adversely affect the oxygen regime of the receiving environment while sediments with high levels of nutrients could significantly affect the nutrient flux.

10.12 An important consequence of the physical presence of dredged material disposal activities is interference with fishery activities and in some instances with navigation and recreation. These problems can be aggravated if the sediment characteristics of the dredged material are very dissimilar to that of the ambient sediment or if the dredged material is contaminated with bulky harbour debris such as wooden beams, scrap metal, pieces of cable etc.

10.13 Particular attention should be given to dredged material containing significant amounts of oil or other 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 lead to interference with protected species and habitats, fishing, shipping, amenities or other beneficial uses of the marine environment.

## **11. Permit or regulation by other means**

11.1 If sea disposal is the selected option, then a permit or regulation by other means (which is in compliance with these guidelines) authorising sea disposal must be issued in advance. In granting a permit, the immediate impact of dredged material occurring within the boundaries of the disposal site such as alterations to the local, physical, chemical and biological environment is accepted by the permitting or supervising authority. Notwithstanding these consequences, the conditions under which a permit for sea disposal is issued should be such that environmental change beyond the boundaries of the disposal site are as far below the limits of allowable environmental change as practicable. The disposal operation should be permitted subject to conditions which further ensure that environmental disturbance and detriment are minimised and benefits maximised.

11.2 The permit is an important tool for managing sea disposal of dredged material and will contain the terms and conditions under which sea disposal may take place as well as provide a framework for assessing and ensuring compliance.

11.3 Permit conditions should be drafted in plain and unambiguous language and will be designed to ensure that:

- a. only those materials which have been characterised and found acceptable for sea disposal, based on the impact assessment, are dumped;
- b. the material is disposed of at the selected disposal site;
- c. any necessary disposal management techniques identified during the impact analysis are carried out; and
- d. any monitoring requirements are fulfilled and the results reported to the permitting or supervising authority.

### **Management of the disposal operation**

11.4 Where appropriate, disposal vessels should be equipped with accurate positioning systems and the activity of the vessels may be reported to the permitting or supervising authority. Disposal vessels and operations should be inspected regularly to ensure that the conditions of the disposal permit are being complied with and that the crew are aware of their 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 disposal is taking place at the specified disposal site.

11.5 This section deals with management techniques to minimise the physical effects of dredged material disposal. The key to management lies in careful site selection and an assessment of the potential for conflict with other interests and activities. In addition, appropriate methods of dredging and of disposal should be chosen in order to minimise the environmental effects. Guidance is given in Technical Annex III.

11.6 In most cases, blanketing of a comparatively small area of seabed is considered to be an acceptable environmental consequence of disposal. To avoid excessive degradation of the seabed as a whole, the number of sites should be limited as far as possible and each site should be used to the maximum extent that will not interfere with navigation.

11.7 Effects can be minimised by ensuring that, as far as possible, the dredged material and the sediments in the receiving area are similar. Locally, impacts may also be reduced if the deposition area is subject to natural physical disturbance. In areas where natural dispersion is low or unlikely to be significant and where reasonably clean, finer-grained dredged material is concerned, it may be appropriate to use a deliberately dispersive disposal strategy to prevent or reduce blanketing, particularly of a smaller site.

11.8 The rate of deposition of dredged material can be an important consideration since it will often have a strong influence on the impacts at the disposal site. It may therefore need to be controlled to ensure that the environmental management objectives for the site are not exceeded.

11.9 The infilling of depressions, deliberate capping or other contained methods of disposal of dredged material deposits may be appropriate in certain circumstances to avoid interference with fishing or other legitimate activities.

11.10 Temporal restrictions on dumping activities may be appropriate such as tidal and/or seasonal restrictions to prevent interference with e.g. nature protection, anthropogenic uses, migration, spawning or seasonal fishing activity.

## 12. Monitoring

12.1 Monitoring in relation to disposal of dredged material is defined as measurements of compliance with permit requirements and of the condition and changes in condition of the receiving area to assess the Impact Hypothesis upon which the issue of a disposal permit was approved.

12.2 The effects of dredged material disposal are likely to be similar in many areas, and it would be very difficult to justify (on scientific or economic grounds) monitoring all sites, particularly those receiving small quantities of dredged material. 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) to obtain a better understanding of processes and effects.

12.3 It may usually be assumed that suitable specifications of existing (pre-disposal) conditions in the receiving area are already contained in the application for disposal

12.4 The impact Hypothesis forms the basis for defining the monitoring programme. The measurement programme should be designed to ascertain that changes in the receiving environment are within those predicted. In designing a monitoring programme the following questions must be answered:

- a. what testable hypotheses can be derived from the Impact Hypothesis?
- b. what measurements (e.g. type, location, frequency, performance requirements) are required to test these hypotheses?
- c. what should be the temporal and spatial scale of measurements?
- d. how should the data be managed and interpreted?

12.5 The permitting or supervising authority is encouraged to take account of relevant research information in the design and modification of monitoring programmes. Measurements should be designed to determine two things:

- a. whether the zone of impact differs from that projected; and

- b. whether the extent of change protected outside the zone of impact is within the scale predicted.

The first of these questions 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 the acquisition of measurements that provide information on the extent of change that occurs outside the zone of impact after the disposal operation. Frequently, this latter suite of measurements will only be able to be based on a null hypothesis - that no significant change can be detected.

## **Feedback**

12.6 Information gained from field monitoring, (or other related research studies) can be used to:

- a. modify or terminate the field monitoring programme;
- b. modify or revoke the permit; and
- c. refine the basis on which applications to dump dredged material at sea are assessed.

12.7 Concise statements of monitoring activities should be prepared. Reports should detail the measurements made, results obtained and how these data relate to the monitoring objectives. The frequency of reporting will depend upon the scale of disposal activity and the intensity of monitoring.

## **13. Reporting**

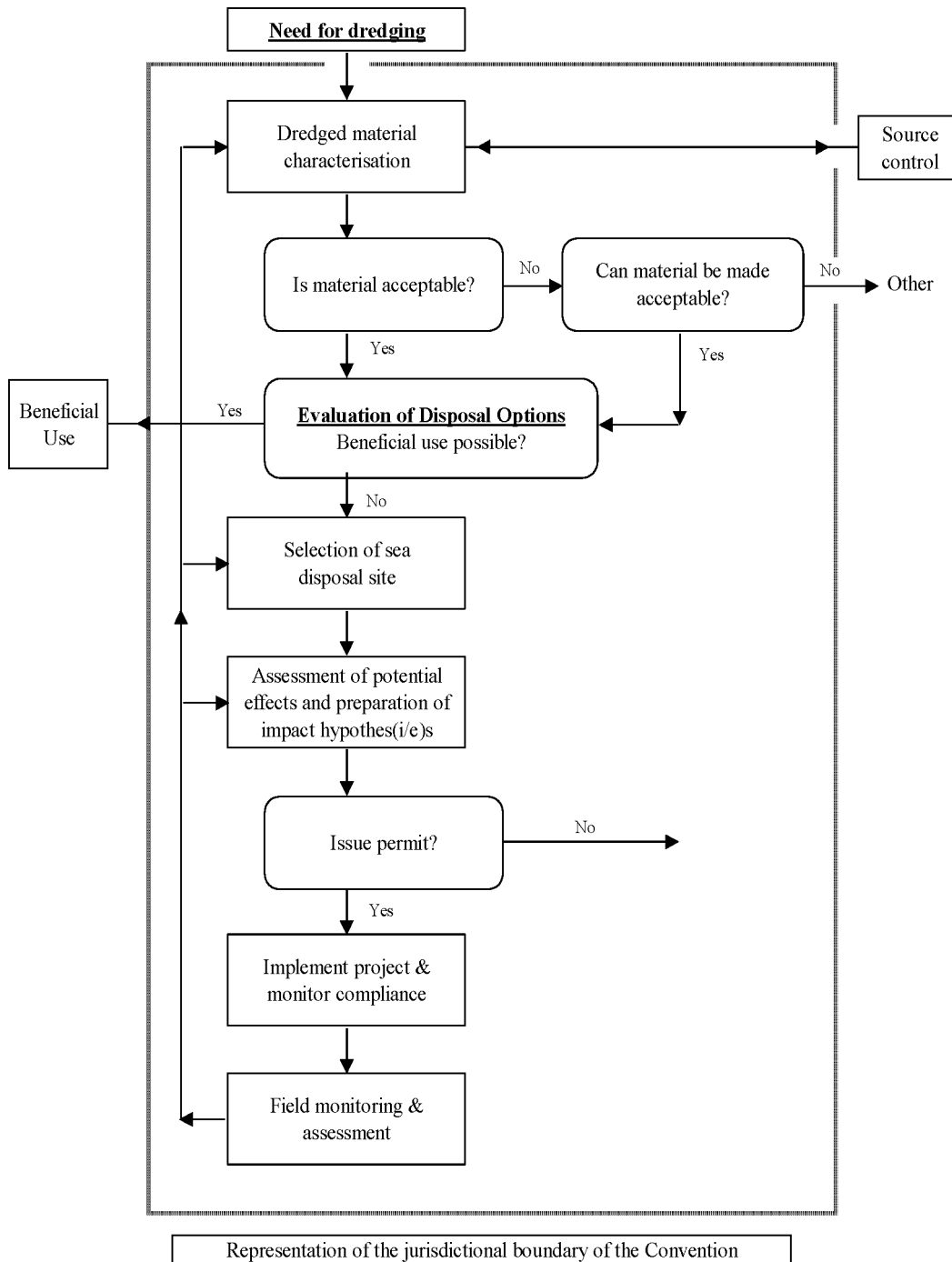
13.1 Reporting of permits issued and amounts of dredged material, dumped together with the associated contaminants, is required according to the 1992 OSPAR Convention - see paragraph 3.4 above. The characterisation process is designed to provide information for permitting purposes. However, it will also provide some information on the contribution of dredged material to total inputs and, at the present time, it is considered the only approach available for this purpose. It is assumed that materials exempted from analysis represent insignificant inputs of contaminants and therefore it is not necessary to calculate or report contaminant loads. See paragraph 3.4 for the basis of this reporting requirement.

13.2 Together with contaminant data, information on the methods of determination and on quality assurance of analyses of dumped material should be provided as requested in the Reporting Format (Agreement 2009/3).

13.3 Contracting Parties should also inform the Secretariat of their monitoring activities and submit reports when they are available.

**Figure 1**

**Steps to be considered in assessing permits application for sea disposal**



## **Background information and supplementary literature to the OSPAR Guidelines for the Management of Dredged Material**

CBD, 2006. Guidelines on biodiversity - inclusive Environmental Impact Assessment (EIA). <http://www.cbd.int/decisions/?dec=VIII/28>

IMO, 2005. Sampling of Dredged Material. Guidelines for the sampling and analysis of dredged material intended for disposal at sea. IMO publication I537E.

EPA/CE, 1992. Evaluating Environmental Effects of Dredged Material Management Alternatives - A Technical Framework, EPA 842-B-92-008.

International Association of Dredging Companies (IADC)/Central Dredging Association (CEDA), 1997. Environmental Aspects of Dredging, Guide 2a: Conventions, Codes and Conditions: Marine Disposal.

International Association of Dredging Companies (IADC)/Central Dredging Association (CEDA), 1997. Environmental Aspects of Dredging. Guide 3 (Investigation, Interpretation and Impact). ISBN 90-75254-08-3.

International Association of Dredging Companies (IADC)/Central Dredging Association (CEDA), 1998. Environmental Aspects of Dredging, Guide 4: Machines, Methods and Mitigation.

International Association of Dredging Companies (IADC)/Central Dredging Association (CEDA), 1999. Environmental Aspects of Dredging, Guide 5: Reuse, Recycle or Relocate.

PIANC, 1992. Beneficial Uses of Dredged Material: A Practical Guide, Report of Working Group No. 19.

PIANC, 1996. Handling and Treatment of Contaminated Dredged Material from Ports and Inland Waterways, Report of Working Group No. 17 of the Permanent Technical Committee 1 - Supplement to PIANC Bulletin No. 89.

PIANC, 1997. Dredged Material Management Guide. Special Report of the Permanent Environmental Commission – Supplement to Bulletin no.96.

PIANC, 1998. Handling and Treatment of Contaminated Dredged material from Ports and Inland Waterways, Vol. 2., Report of Working Group No. 17 of the Permanent Technical Committee 1.

PIANC, 1999. Management of Aquatic Disposal of Dredged Material. Report of ENVICOM Working Group 1 of the Permanent Environmental Commission.

## Analytical Requirements for Dredged Material Assessment

1. This Technical Annex covers the analytical requirements necessary to implement paragraphs 5.5 - 5.10 of the OSPAR Guidelines for the Management of Dredged Material.
2. A tiered approach to testing is recommended. At each tier it will be necessary to determine whether sufficient information exists to allow a management decision to be taken or whether further testing is required.
3. As a preliminary to the tiered testing scheme, information required under section 5.4 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 5.3 of the Guidelines, then the material will not require further testing. However, if all or part of the dredged material is being considered for beneficial uses, then it will usually be necessary, in order to evaluate these uses, to determine at least some of the physical properties of the material indicated in Tier I.
4. The sequence of tiers is as follows:
  - assessment of physical properties
  - assessment of chemical properties
  - assessment of biological properties and effects

A pool of supplementary information, determined by local circumstances may be used to augment each tier (cf. section 5.6 of the Guidelines).

5. At each stage of the assessment procedure account must be taken of the method of analysis. Analysis should be carried out on the whole sediment (< 2mm) or in a fine-grained fraction. If analysis is carried out in a fine-grained fraction, the results should be appropriately converted to whole sediment (< 2 mm) concentrations for establishing total loads of the dredged material. Additional information (e.g. as regards storage and pre-treatment of samples, analytical procedures, analytical quality assurance) can be obtained in the JAMP Guidelines for Monitoring Contaminants in Sediments.
6. The physical composition of samples, and therefore the chemical and biological properties, can be strongly influenced by the choice of sampling sites, the method of sampling and sampling handling. These possible influences should be taken into account when evaluating data.

### Tier I: Physical properties

Physical analyses are important because they help to indicate how the sediment may behave during dredging and disposal operations and indicate the need for subsequent chemical and/or biological testing. It is strongly recommended that the following determinations be carried out:

Determinant	Indicating
<ul style="list-style-type: none"> <li>• grain size analysis (by laser or sieving methods)</li> <li>• percent solids (dry matter)</li> </ul>	<ul style="list-style-type: none"> <li>• Cohesiveness, settling velocity/resuspension potential, contaminant accumulation potential</li> </ul>
<ul style="list-style-type: none"> <li>• density/specific gravity</li> </ul>	<ul style="list-style-type: none"> <li>• Consolidation of placed material, volume <i>in situ</i> vs. after deposit</li> </ul>
<ul style="list-style-type: none"> <li>• organic matter (as total organic carbon)</li> </ul>	<ul style="list-style-type: none"> <li>• Potential accumulation of organic associated contaminants</li> </ul>



When dredged material is being considered for beneficial uses, it will also usually be necessary to have available details of the engineering properties of the material e.g. permeability, settling characteristics, plasticity and mineralogy.

## **Tier II: Chemical properties**

### **Primary List**

The following trace metals should be determined in all cases:

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

The following organic/organo-metallic compounds should be determined:

Polychlorinated biphenyl (PCB) congeners - IUPAC nos 28, 52, 101, 118, 138, 153 and 180 (ICES 7).

Polycyclic aromatic hydrocarbons (PAHs).  $\Sigma$ PAH9 is the sum of the following PAHs: anthracene; benzo[a]anthracene; benzo[ghi]perylene; benzo[a]pyrene; chrysene; fluoranthene; indeno[1,2,3-cd]pyrene; pyrene; phenanthrene.

Tri-Butyl tin (TBT) compounds and their degradation products

Arsenic (As).

As a minimum requirement, national action levels should be established for the primary list above.

However, the determination of PCBs, PAHs and Tri-Butyl tin compounds and its degradation products will not be necessary in circumstances where the sediments are very unlikely to be contaminated with these substances. The relevant circumstances are:

- a) sufficient information from previous investigations indicating the absence of contamination is available (cf. §§ 7.5 - 7.7 in the OSPAR Guidelines for the Management of dredged Material); or
- b) - there are no known significant sources (point or diffuse) of contamination or historic inputs; and  
- the sediments have very low amounts of fine material ; and/or  
- the content of total organic carbon is low.

### **Secondary List**

Based upon local information of sources of contamination (point sources or diffuse sources) or historic inputs, other determinants may require analysis, for instance:

Other chlorobiphenyls <sup>3</sup>	organophosphorus pesticides	petroleum hydrocarbons
Organochlorine pesticides	other organotin compounds	Polychlorinated dibenzodioxins (PCDDs)/polychlorinated dibenzofurans (PCDFs)
	other anti-fouling agents	

In deciding which individual organic contaminants to determine, reference should be made to existing priority substance lists, such as those prepared by OSPAR<sup>4</sup> and the EU<sup>3</sup>

### **Normalisation**

It is recommended that normalised values of contaminants should be used to enable a more reliable comparison of contaminant concentrations in dredged material with those in sediments at disposal or reference sites, as well as with action levels. The normalisation procedure (see Technical Annex II) used within a regulatory authority should be consistent to ensure effective comparisons.

Therefore in order to be in the position to anticipate the effects of contaminants adsorbed on sediment particles on deposit or filter feeders it is important to have information on the contaminant concentration of the relevant fine fraction (*e.g.* less than 63 µm or 20 µm).

### **Analytical Techniques**

Reference should be made to the Technical Annexes of the JAMP monitoring guidelines (Agreement 2002/16) and ISO/EN methods for recommended analytical techniques.

## **Tier III: Biological properties and effects**

In a significant number of cases the physical and chemical properties described above do not provide a direct measure of the biological impact. Moreover, they do not adequately identify all physical disturbances and all sediment-associated constituents present in the dredged material. If the potential impacts of the dredged material to be dumped cannot be adequately assessed on the basis of the chemical and physical characterisation, biological measurements should be carried out.

The selection of an appropriate suite of biological test methods will depend on the particular questions addressed, the level of contamination at the dredging site and the degree to which the available methods have been standardised and validated.

To enable the assessment of the test results, an assessment strategy should be developed with regard to granting a permit authorising disposal at sea. The extrapolation of test results on individual species to a higher level of biological organisation (population, community) is still very difficult and requires good knowledge of assemblages that typically occur at the sites of interest.

<sup>3</sup> Decision No. 2455/2001/EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC The daughter directive to WFD on chemical compounds: Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequent repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

<sup>4</sup> OSPAR List of Chemicals for Priority Action (Up-date 2007); Reference Number: 2004-12

## 1. Toxicity bioassays:

- The primary purpose of toxicity bioassays is to provide direct measures of the effects of all sediment constituents acting together, taking into account their bioavailability. For ranking and classifying the acute toxicity of harbour sediment prior to maintenance dredging, short-term bioassays may often suffice as screening tools.
- To evaluate the effects of the dredged material, acute bioassays can be performed with pore water, an 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);
- 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 portion of the test species life cycle may provide a more accurate prediction of potential impact of dredging operations. However, standard test procedures are still under development;

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 concentration and pH should therefore be determined during the bioassay.

- 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) or PIANC (2006).

## 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 experiment:

In order to investigate long-term effects, experiments with dredged material in mesocosms can be performed, for instance to study the effects of PAHs in flatfish pathology. Because of the costs and time involved these experiments are not applicable in the process of authorising permits but are useful in cases where the extrapolation of laboratory testing to field condition is complicated or 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 permitting decisions.

## 5. Other biological properties:

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

## Supplementary information

The need for further information will be determined by local circumstance 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 contaminant data (e.g. aluminium, lithium, scandium – cf. Technical Annex II). Consideration should also be given to chemical or biochemical changes that contaminants may undergo when disposed of at sea.

## Literature References related to Technical Annex I

ASTM, 1994. Standard guide for collection, storage, characterisation and manipulation of sediment for toxicological testing. American Society for Testing and Material, Annual Book of Standards. Vol. 11.04, E1391-96.

EPA/CE, 1991. Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual EPA-503/8-91/001. US-EPA Office of Water (WH-556F).

EPA/CE, 1998. Evaluation of Dredged Material Proposed for discharge in Waters of the US. Testing Manual (Draft): Inland Testing Manual EPA – 823-B-98-004.

EPA, Office of Water, 2001. Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual EPA-823-F-01-023.

International Association of Dredging Companies (IADC)/Central Dredging Association (CEDA), 1997. Environmental Aspects of Dredging. Guide 3 (Investigation, Interpretation and Impact). ISBN 90-75254-08-3.

International Maritime Organization (IMO) 2003. Waste Assessment Guidance - Selection and analysis of physical and chemical parameters for the assessment of dredged material quality, Report of the Scientific Group of the LONDON Convention.

IOC - UNEP - IMO, 2000. Global Investigation of Pollution in the Marine Environment (GIPME 2000): Guidance on Assessment of Sediment Quality, Pub. No. 439/00.

Gustavson, K. and Wangberg, S.A.,1995. Tolerance induction and succession in microalgae communities exposed to copper and atrazine. *Aquatic Toxicology*. 32: 283-302.

HELCOM, 1997. Manual for Marine Monitoring in the Cooperative Monitoring in the Baltic Marine Environment (COMBINE Programme) of HELCOM. Part C - Programme for Monitoring of Eutrophication and its Effects. Annex C-4: Directives for sampling and analysis of hydrographic, chemical and biological variables. Annex C-8: Soft bottom macrozoobenthos.

Murk *et al.*, 1996. Chemical-activated luciferase gene expression (CALUX): a novel in vitro bioassay for Ah receptor active compounds in sediments and pore water. *Fund. & Applied Tox.* 33: 149-160.

OSPAR, 1997 (available from the OSPAR website):

JAMP Eutrophication Monitoring Guidelines: Benthos - Technical Annex 1 (Hard-bottom macrophytobenthos and hard-bottom macrozoobenthos) - Technical Annex 2 (Soft-bottom macrozoobenthos)

OSPAR, 2002

JAMP Guidelines for Monitoring Contaminants in Sediments (Agreement 2002-16)

PIANC 2006 Biological assessment guidance for dredged material, EnviCom report of WG 8 Rees, H.L., C. Heip, M. Vincx and M.M. Parker, 1991. Benthic communities: use in monitoring point-source discharges. ICES Techniques in Marine Environmental Sciences No. 16.

Rumohr, H.,1990. Soft-bottom macrofauna: collection and treatment of samples. ICES Techniques in Marine Environmental Sciences No. 8.

# Normalisation of Contaminants Concentrations in Sediments

This annex provides guidance on the application of methods to normalise contaminant concentrations in sediments

## 1. Introduction

Normalisation is defined here as a procedure to correct contaminant concentrations for the influence of the natural variability in sediment composition (grain size, organic matter and mineralogy). Most natural and anthropogenic substances (metals and organic contaminants) show a much higher affinity to fine particulate matter compared to the coarse fraction. Constituents such as organic matter and clay minerals contribute to the affinity to contaminants in this fine material.

Fine material (inorganic and organic) and associated contaminants are preferentially deposited in areas of low hydrodynamic energy, while in areas of higher energy, fine particulate matter is mixed with coarser sediment particles which are generally not able to bind contaminants. This dilution effect will cause lower and variable contaminant concentrations in the resulting sediment. Obviously, grain size is one of the most important factors controlling the distribution of natural and anthropogenic components in 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 variable granulometry and texture within individual areas, among areas or over time.

When analysing whole sediment (*i.e.* < 2mm fraction) for spatial distribution surveys, the resulting maps give a direct reflection of the sea bed sediments. However, in areas with varying grain size distributions, a map of contaminant concentrations will be closely related to the distribution of fine grained sediments, and any effects of other sources of contaminants, for example anthropogenic sources, will be at least partly obscured by grain size differences. Also in temporal trend monitoring, differences in grain size distribution can obscure trends. If samples used for a spatial survey consist predominantly of fine material, the influence of grain size distribution is of minor importance and may probably be neglected.

## 2. Normalisation procedures

Two different approaches to correct for variable sediment compositions are widely used:

- a. Normalisation can be performed by relating the contaminant concentration with components of the sediment that represents its affinity for contaminants, *i.e.* binding capacity. Such co-factors are called **normalisers** (cf. section 4). Normalisation can be performed by simple contaminant/normaliser ratios or linear regression. Another procedure takes into account that the coarse sediment fraction contains natural metal concentrations in the crystal structure before the normalisation is performed (see section 5). Combinations of co-factors, possibly identified from multiple regression analysis, can be used as normalisers.
- b. Isolation of the fine fraction by sieving (e.g. <20 µm, <63 µm) can be regarded as a physical normalisation to reduce the differences in sediment granulometric compositions and is applicable to both metals and organic contaminants (Ackermann et al. 1983; Klamer et al.

---

<sup>5</sup> Technical Annex 5 - Normalisation of contaminant concentrations in sediments - to the JAMP Guidelines for monitoring contaminants in sediments

1990). Consequently the coarse particles, which usually do not bind anthropogenic contaminants and dilute their concentrations, are removed from the sample. Then, contaminant concentrations measured in these fine fractions can be directly compared. Subsequently, the differences in sediment composition due to geochemical nature remaining after sieving can be further corrected for by the use of co-factors. Thus, sieving is a first powerful step in normalisation.

### 3. Limitations of normalisation

Clearly, normalisation procedures may not apply equally well to all elements at all sites; especially important in this respect are elements that participate in diagenetic reactions. In cases where there is a lack of full understanding of the geochemical processes operating care should be taken when normalising for grain size differences. These processes can create important natural enrichment of metals at the sediment surface, as a result of the surficial recycling of oxihydroxides or deeper in the sediment as the result of co-precipitation of the metals with sulphides (cf., e.g., Gobeil et al. 1997), which cannot be accounted for by normalisation.

There is no evidence that normalised data are more appropriate for ecotoxicological interpretation than non-normalised data. However, the matter deserves further investigation.

### 4. Normalisation with co-factors

- a. The binding capacity of the sediments can be related to the content of fines (primary factor) in the sediments. Normalisation can be achieved by calculating the concentration of a contaminant with respect to a specific **grain-size fraction** such as <2 µm (clay), <20 µm or <63 µm.
- b. As the content of fines is represented by the contents of major elements of the clay fraction such as **aluminium** (Windom et al. 1989) or an appropriate trace element enriched in that fraction such as **lithium** (Loring 1991), these can also be used as co-factor (secondary). Both, aluminium and lithium behave conservatively, as they are not significantly affected by, for instance, the early diagenetic processes and strong redox effects frequently observed in sediments. Problems may occur in when the sediment is derived from glacial erosion of igneous rocks, with significant amounts of aluminium present in feldspar minerals contributing to the coarse fraction. In such cases, lithium may be preferable (Loring 1991).
- c. Organic matter, usually represented by organic carbon, is the most common co-factor for organic contaminants due to their strong affinity to this sediment component. Trace metals can be normalised using the organic carbon content (Cato 1977 ) but would require further explanation due to the non-conservative nature of organic matter.

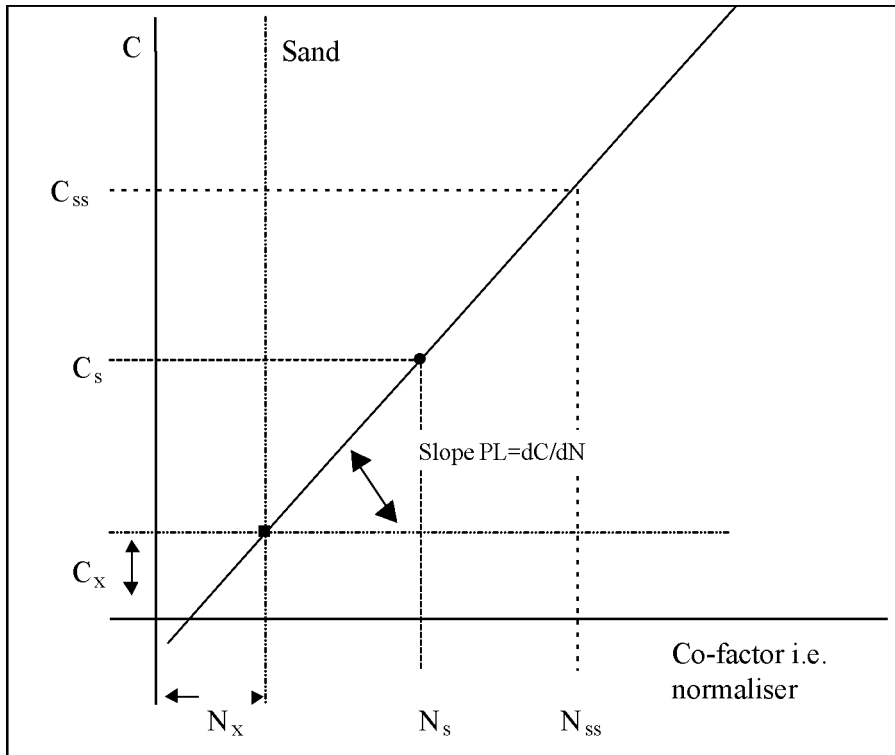


Figure 1: Relation between the contaminant C and the cofactor N (see text).

## 5. Theory

The general model for normalisation taking into account the possible presence of contaminants and cofactors in the coarse material is given in figure 1 (Smedes et al.1997).  $C_x$  and  $N_x$  represent the co-factor and the contaminant contents, respectively, in pure sand. These “intercepts” can be estimated from samples without fines and organic material. The line of regression between the contaminant and co-factor will originate from that point. That means that regression lines of sample sets with a different pollution level and consequently different slopes will have this point in common (i.e. pivot point). When this pivot point is known only one sample is required to estimate the slope. This allows determination of the contaminant content for any agreed (preselected) co-factor content ( $N_{ss}$ ) by interpolation or extrapolation. The slope for a sample with a contaminant content  $C_s$  and a co-factor content of  $N_s$  can be expressed as follows:

$$PL = \frac{dC}{dN} = \frac{C_s - C_x}{N_s - N_x} \dots\dots\dots(1)$$

The extrapolation to an agreed co-factor content,  $N_{ss}$ , follows the same slope:

$$PL = \frac{dC}{dN} = \frac{C_s - C_x}{N_s - N_x} = \frac{C_{ss} - C_x}{N_{ss} - N_x} \dots\dots\dots(2)$$

Rewriting gives the contaminant content,  $C_{ss}$ , that is normalised to  $N_{ss}$ :

$$C_{ss} = (C_s - C_x) \frac{N_{ss} - N_x}{N_s - N_x} + C_x \dots\dots\dots(3)$$

Results of different samples normalised to the agreed  $N_{ss}$  can be compared directly.

Normalisation by this model can be applied with different cofactors. Here primary and secondary cofactors can be distinguished. A primary cofactor like clay or organic carbon is not present in the coarse fraction and

consequently has no intercept ( $N_x=0$ ). Al and Li are present in the coarse fraction and therefore are considered to be secondary cofactors. Provided  $N_x$  and  $C_x$  are known, the model allows recalculation of total samples to a co-factor content usually found in sieved fractions, either  $<20$  or  $<63\mu\text{m}$ . However such an extrapolation for a coarse grained sample will be associated with a large error due to the uncertainty of the intercepts and the analysed parameters. For a more fine grained sample, the uncertainty of the normalised result is much lower than for normalisation of a sieved fraction to the agreed cofactor content and will result in a more accurate result. The model presented also applies to the normalisation of organic contaminants using organic carbon but in that case the intercepts  $N_x$  and  $C_x$  will not differ significantly from zero.

Principally, the result allows comparison of data of total and sieved samples, irrespective the sieving diameter but the error has to be taken into account. Through propagation of errors the standard error of the result can be calculated from the analytical variation and the natural variation of the intercept  $N_x$ . Results can therefore always be reported with a standard deviation.

## 6. Considerations on co-factors

The **clay mineral content** is the most important cofactor for trace metals. In the model above the  $N_x$  will be zero for clay and only the intercept due to the content of the trace metal in the coarse fraction ( $C_x$ ) has to be taken into account. However, current intercomparison exercises do not include this parameter. Presently other parameters such as aluminium or lithium are used to represent the clay content.

The **aluminium** content in the sandy fraction may vary from area to area. For some areas aluminium contents in the sandy fractions are found at the same level as found in the fines (Loring, 1991) and therefore the intercept  $N_x$  becomes very high. In equation (3) this implies that the denominator is the result of subtracting two large numbers, that is the normaliser content in the sample ( $N_s$ ) and the normaliser content in only sand ( $N_x$ ). Consequently, due to their individual uncertainties, the result has an extremely high error. Obviously, normalisation with low intercepts is more accurate. Much lower intercepts are found if partial digestion methods are used that digest the clay minerals, but not the coarse minerals. Using partial digestion, the spatial variability of the results of aluminium analyses in the sandy fraction has been found to be much smaller than with total methods. Although normalising concentrations of contaminants in fine grained material will always give more accurate results, an error calculation will identify whether using coarse samples (and total methods, e.g. HF, X-ray fluorescence) allows the requirements of the program to be met.

For most areas the **lithium** content in the sandy fraction is much lower than in the fine fraction. In addition, results from partial digestion and total methods do not differ significantly. There is only little spatial variability of the lithium content in the sandy fraction. Generally, compared to aluminium, more accurate normalised data can be expected using lithium.

As for clay, no intercept ( $N_x$ ) applies for organic matter, which is usually represented by **organic carbon**. Organic matter also occurs in the coarse fraction but is even then a cofactor that contributes to the affinity for contaminants, whereas the aluminium in the coarse fraction does not. Furthermore, organic matter in a sample is not always well defined as it can be composed of material with different properties. The most variable properties will be found in the organic matter present in the coarse fraction, i.e. that not associated with the fines. In **fine sediments** or in the sieved fine fractions the majority of the organic matter is associated with the mineral particles and it is assumed to be of more constant composition than in the total sample. In addition, the nature of the organic matter may show spatial variation. For samples with low organic carbon content close to the detection limit, normalisation using this cofactor suffers from a large relative error. This results from the detection limit and the insufficient homogeneity that cannot be improved due to the limited intake mass for analysis.

For further interpretation of data the **proportion of fines** determined by sieving can be useful. Provided, there are no significant amounts of organic matter in coarse fractions, the proportion can be used as



normaliser. The error in the determination of fines has to be taken into account and will be relatively high for coarse samples.

## **7. Considerations on contaminants**

Almost all trace metals, except mercury and in general also cadmium, are present in the coarse mineral matrix of samples. The metal concentrations show a spatial variability depending on the origin of the sandy material. In sandy sediments, partial digestion techniques result in lower values than are obtained from total digestion techniques. This implies that partial digestion results in lower intercepts (pivot point is closer to the zero). However, the partial digestion must be strong enough so the clay will be totally digested (as is the case with HF digestion techniques), and the measured aluminium content remains representative for the clay. It was demonstrated that analyses of fine material gave similar results for several trace elements using both total and strong partial methods (Smedes et al. 2000, QUASH/QUASIMEME intercalibrations).

In general, correlations of organic contaminants with organic carbon have no significant intercept. Obviously a normalised result from a coarse sample will show a large error as due to the dilution by sand the concentrations are often close or even below the detection limit. Presently, organic carbon is usually applied for normalisation of PAHs. It should be recognised that due to the possible presence of undefined material, for example soot or ash, elevated PAH concentrations may occur in specific fractions that might have limited environmental significance. Although this needs further investigation, existing results indicate that PAH concentrations in the sieved fractions are not affected significantly.

## **8. Isolation of fine fractions for analyses**

### *The Sample preparation*

Samples must be sieved at 2 mm as soon as possible after sampling to remove large detritus and benthic organisms. Otherwise during further sample handling like storage, freezing or ultrasonic treatment, biotic material will deteriorate and become part of the sediment sample. Until the final sieving procedure that isolates the fines, the sample can be stored at 4°C for about a week and up to 3 months when frozen at –20°C, although direct wet sieving is preferred. For prolonged storage freeze-drying of samples can be considered. In this case contamination and losses of contaminants during freeze-drying have to be checked. Air-drying is not appropriate due to high contamination risks. Besides, samples may be difficult to be disaggregate and mineral structures may be affected.

### *Requirements for Sieving*

A wet sieving procedure is required to isolate the fine-grained fractions (<63 µm or <20 µm). Wet sieving re-suspends fine particles that would otherwise remain attached to coarser particles in the sample. Sediments should be agitated during sieving to prevent to disaggregate agglomerates of fines and to prevent clogging of the mesh. Freeze-dried samples need to be re-suspended using ultrasonic treatment. Seawater, preferably from the sampling site, should be used for sieving as it reduces the risk of physico-chemical changes in the sample i.e. losses through leaching or contamination. Furthermore seawater assists the settling of fine particles after the sieving. If water from the sampling site is not available, then seawater of an unpolluted site, diluted with deionised water to the required salinity, can be used. The amount of water used for sieving should be kept to a minimum and be reused for sieving subsequent batches.

To minimise or prevent contamination it is recommended to use large sample amounts of sediment for sieving. No significant contaminant losses or contamination was detected when at least 25 g of fine fraction is isolated. (QUASH).

### *Methodology*

Both automated and manual methods are available for sieving. A video presentation of these methods can be provided by the QUASH Project (QUASH 1999).

- The automatic sieving method pumps seawater over a sieve that is clamped on a vibrating table (Klamer et al. 1990). The water passing the sieve is lead to a flow-through centrifuge that retains the sieved particles and the effluent of the centrifuge is returned to the sieve by a peristaltic pump. Large sample amounts, up to 500 g, can be handled easily.
- The second method is a manual system sieving small portions 20-60 g using an 8-cm sieve in a glass beaker placed in an ultrasonic bath (Ackermann et al. 1983). Particles are isolated from the water passing the sieve by batch wise centrifugation. The water can be reused for a subsequent batch of sediment. In case of sandy samples, when large amounts of sediments have to be sieved, removal of the coarse material by a pre-sieving over e.g. 200- $\mu$ m mesh can facilitate the sieving process.

Isolated fine fractions have to be homogenised thoroughly, preferably by a ball mill, as centrifugation produces inhomogeneous samples due to differences in settling speed of different grain-size fractions.

## 9. Recommendations

1. For both temporal trend and spatial monitoring, it would be ideal to analyse samples with equal composition. This could be confirmed by determination of co-factors Al, Li, OC and parameters of the grain size distribution (e.g. clay content, proportion <20 $\mu$ m, proportion <63 $\mu$ m). However, this situation will not always occur, particularly in the case of spatial surveys.
2. New temporal trend programs should be carried out by the analysis of fine sediments or a fine-grained fraction, isolated by sieving. Existing temporal trend programs could be continued using existing procedures, provided that assessment of the data indicates that the statistical power of the programs is adequate for the overall objectives.
3. Contaminant concentrations in whole sediments can be subjected to normalisation using co-factors for organic matter, clay minerals etc., taking into account the presence of both co-factors and target contaminants in the mineral structure of the sand fraction of the sediment. Taking into account these non-zero intercepts of regressions of contaminant concentrations with co-factors, normalisation to preselected co-factor content will reduce the variance arising from different grain sizes. Normalised values for sandy sediments will have greater uncertainties than for muddy sediments. The propagated error of the variables used for normalisation may be unacceptable high for sandy sediments, if both contaminant and co-factor concentrations are low, particularly when approaching detection limits. In that case, in order to draw reliable maps, alternative procedures, such as sieving, need to be used to minimise the impact of this error structure.
4. Variance arising from grain size differences can be reduced in a direct way by separation of a fine fraction from the whole sediment. Spatial distribution surveys of the concentrations of contaminants in separated fine fractions can be used to prepare maps which will be much less influenced by grain size differences than maps of whole sediment analyses. There will still be some residual variance arising from differences in the composition (mineralogy and organic carbon content) of the sediments.
5. The natural variance of sample composition will be smaller in the fraction <20  $\mu$ m than in the fraction <63  $\mu$ m. Therefore, the fraction <20  $\mu$ m should be preferred over the fraction <63  $\mu$ m. However, separation of the fraction <20  $\mu$ m can be considerably more laborious than the separation of the fraction <63  $\mu$ m and might be an obstacle to its wide application. For this practical reason, the fraction <63  $\mu$ m is an acceptable compromise for both temporal trend and coordinated large scale spatial surveys.
6. The preferred approach for preparing maps of the spatial distribution of contaminants in sediment consists of two steps: analyses of contaminants in fine sediments or in the fraction <63  $\mu$ m, followed by normalisation of analytical results using co-factors (see section 4). Current scientific knowledge indicates that this procedure minimises the variances arising from differences in grain size, mineralogy and organic matter content. Application of this two-tiered approach to fractions <20  $\mu$ m gives results that can be directly compared to results found by normalisation of concentrations measured in fractions <63  $\mu$ m. This approach

should give consistent and comparable data sets over the ICES/OSPAR area. Maps of contaminant levels in fine sediments should be accompanied by maps of the co-factors in the whole sediments.

7. In order to clarify aspects of data interpretation, analytical data for field samples should be accompanied by information on limits of detection and long term precision. In order to contribute to environmental assessment, data for field samples should include the grain size distribution, as a minimum the proportion of the analysed fraction in the original whole sediment.

## 10. References

Ackermann, F., Bergmann, H., and Schleichert, U. (1983) Monitoring of heavy metals in coastal and estuarine sediments - A question of grain-size: <20 µm versus <60 µm. *Environmental Technology Letters*, 4: 317-328.

Cato, I. (1977): Recent sedimentological and geochemical conditions and pollution problems in two marine areas in south-western Sweden. *Striae* 6, 158 pp. Uppsala.

Gobeil, C., MacDonald, R. W. & Sundby, B. (1997): Diagenetic separation of cadmium and manganese in suboxic continental margin sediments. *Geochim. Cosmochim. Acta* 61, 4647-4654.

Klamer, J. C., Hegeman, W. J. M. & Smedes, F. (1990): Comparison of grain size correction procedures for organic micropollutants and heavy metals in marine sediments. *Hydrobiologia* 208, 213-220.

Loring, D. H. (1991): Normalization of heavy-metal data from estuarine and coastal sediments. *ICES J. mar. Sci.* 48, 101-115.

QUASH (1999) Sediment Sieving Techniques, QUASH Project Office, FRS Marine Laboratory, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, Scotland

Smedes, F. (1997) Grainsize Correction Procedures, Report of the ICES Working Group on Marine Sediments in Relation to Pollution. ICES CM 1997/Env:4, Ref. E, Annex 6.

Smedes, F., Lourens, J., and Wezel, van A. (1997) "Zand, Slib en Zeven, Standardisation of contaminant contents in marine sediments, Report RIKZ-96.043 (Dutch), ISSN 0927-3980, RIKZ, PO Box 20907, 2500 EX, The Hague.

Smedes, F. Davies, I.M., Wells, D., Allan, A., Besada, V. (2000): Quality Assurance of Sampling and Sample Handling (QUASH) - Interlaboratory study on sieving and normalisation of geographically different sediments; QUASH round 5 (sponsored by the EU Standards, Measurements and Testing Programme)

Windom, H. L., et al. (1989): Natural trace metal concentrations in estuarine and coastal marine sediments of the southeastern United States. *Environ. Sci. Technol.* 23, 314-320.

## Appendix

### Testing normalisation methods

As normalisation should correct for sediment composition, a criterion for an adequate normaliser is that after normalisation of equally polluted sediment samples with different grain size distributions, the results should not differ significantly. However, sample sets to test normalisation approaches for this criterion are scarce. An alternative approach is to take one sample and to produce subsamples with varying grain size distributions (Smedes 1997, Smedes et al. 1997, Smedes et al. 2000). Both the fine and coarse subsamples are analysed for contaminants and potential normalisers. In this way a higher variability for the normaliser concentrations, i.e. a worst case than ever will occur in nature, can be obtained which provides a sensitive test for the usefulness of potential normalisers.



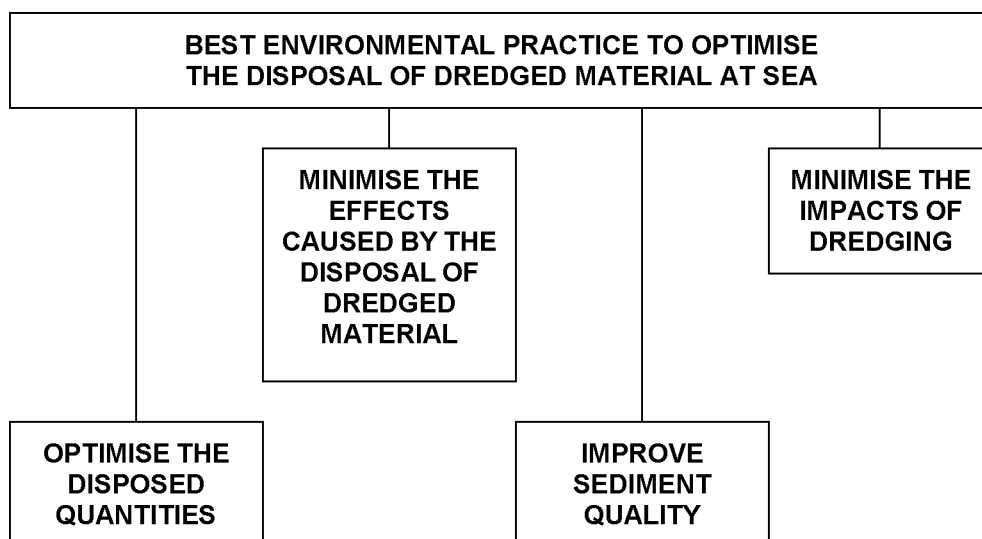
# Best Environmental Practice (BEP)

## Introduction

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' are requirements resulting from Annex V to the OSPAR Convention (see § 3.5 of the OSPAR Guidelines for the Management of Dredged Material), and, in addition, are very relevant to the prevention of pollution of the marine environment resulting from the disposal of dredged materials. Descriptions of BEP in relation to these activities are given at Appendices I and II.

