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Agenda item 4: Common methodologies and techniques for the assessment and monitoring of adverse impacts of dumping activities

Common methodologies and techniques for the assessment and monitoring of adverse impacts of dumping activities

UNEP/MAP
Athens, 2021

Note by the Secretariat

The Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea (hereinafter as Dumping Protocol) was adopted by the Contracting Parties to the Barcelona Convention on 16 February 1976 and amended on 10 June 1995.

UNEP/MAP-MED POL Programme organized on 9-10 October 2019, the Regional Meeting on Best Practices on Enforcement and Compliance for Industrial Sectors in Athens, Greece. The Meeting recommended identifying and reinforcing implementation of techniques for monitoring of dumping activities such as surveys based on dumping permits, and compliance monitoring for verification of permitting conditions.

The 21st Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols, held in Naples (Italy), on 2-5 December 2019, mandated the Secretariat to work in, *inter alia*, two principal directions: (i) initiate the process for updating the Annex to the Dumping Protocol; and (ii) facilitate aspects related to the implementation of the Dumping Protocol by sharing best practices on Dumping Protocol Guidelines implementation at regional, sub-regional, national levels. In concurrence with its mandate, as well as with activities under the bilateral Cooperation Agreement signed on 9 October 2019, with the International Maritime Organization (IMO) which hosts the Secretariat for the London Convention/London Protocol (LC/LP), UNEP/MAP MEDPOL developed two documents titled "Compendium of Best Practices on Implementation of Dumping Protocol (UNEP/MAP WG.487/4)" [1] and, the present document titled "Common methodologies and techniques for the assessment and monitoring of adverse impacts of dumping activities." These two documents are complementary to each other; whereas the latter is intended to bring together all relevant available methodologies and techniques that can be used by the Contracting Parties for implementation of the Dumping Protocol with a particular focus on (i) **monitoring of dredging operations** from harbours, ports, navigation channels and infrastructure projects such as cables and pipelines, and (ii) **monitoring of disposal sites** of dredged material at sea.

This document endeavours to present a set of **common methodologies and techniques** that will facilitate reporting by the Contracting Parties of compatible and comparable data on their monitoring activities; hence, further expediting their reporting obligations to the Barcelona Convention. It also builds on the Guidelines on Management of Dredged Material pertinent to **monitoring of disposal sites** and links the IMAP Guidance/Monitoring Protocol(s), where appropriate, to map the common methodologies which will ensure the unity and uniformity with regards to monitoring data. Accordingly, this additional data generated from monitoring of dredging and dumping operations can be also linked in the future and where possible with, and used for, assessment tools under UNEP/MAP in the Mediterranean.

The Joint Meeting with IMO-LC/LP on Regional Meeting on Best Practices on Implementation, Compliance and Enforcement related to Dumping Protocol is expected to discuss and approve this document, as well as recommend case studies on the national and regional levels which constitute Best Available Techniques pertaining to monitoring activities. This document will be presented to the Meeting of the MED POL Focal Points scheduled in May 2021 for their consideration and approval.

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[1] UNEP/MAP WG.487/3

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List of Abbreviations / Acronyms

AIS	Automatic Identification System
BAT	Best Available Techniques
BEP	Best Environmental Practice
COP	Conference of the Parties
EIA	Environmental Impact Assessment
ECHA	European Chemicals Agency
EPA	Environmental Protection Agency
EU	European Union
GESAMP	Joint Group of Experts on Scientific Aspects of Marine Environmental Protection
GES	Good Environmental Status
IMAP	Integrated Monitoring and Assessment Programme
LBS Protocol	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities
LC-LP	London Convention and Protocol
LSPC	List of Substances of Possible Concern
MAP	Mediterranean Action Plan
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean Sea
MSFD	Marine Strategy Framework Directive
RSC	Regional Seas Conventions
UNEP	United Nations Environment Programme

Objective of the document

1. The objective of this document is to bring together a set of common methodologies and techniques that can be used by the Contracting Parties relating to both **monitoring of dredging operations** from harbours, ports, navigation channels and infrastructure projects such as outfalls, cables and pipelines, as well as **monitoring of the disposal sites** of dredged material at sea. This document also provides for compatible and comparable reporting of data by the Contracting Parties with regard to their monitoring activities pertinent to the Dumping Protocol; thus, further expediting their reporting obligations to the Barcelona Convention in accordance with its Article 12. Additionally, this document elaborates on two main issues of increasing significance and importance: underwater noise and marine litter.

Scope of the document

2. The scope of this document covers all aspects relating to monitoring operations involving both the dredging of material from harbours, ports, navigation channels and infrastructure projects such as outfalls, cables and pipelines, as well as the disposal of dredged material at sea.

Methodology for preparation of this document

3. The information presented in this document is derived primarily from consideration of guidance documents prepared by UNEP/MAP-MEDPOL, namely the updated Guidelines on Management of Dredged Materials[2] and the Guidelines for the Dumping of Inert Uncontaminated Geological Materials[3]; as well as the London Convention/London Protocol (LC/LP); the OSPAR Convention; HELCOM and other related national guidance documents from Canada; the United States; and the United Kingdom (see section 2 below).

1. Introduction

1.1 Monitoring in General

4. A very good explanation of marine monitoring in general is found in a book published by the National Research Council of the United States in 1990. This is still considered one of the best descriptions of marine monitoring and its role in environmental management; even though it was published 30 years ago. It can be freely downloaded from the link to the document in the references list. The book states that there are generally three types of marine-related monitoring:

i. Compliance monitoring – to ensure that activities are carried out in accordance with regulations and permit requirements;

ii. Model verification – to check the validity of assumptions and predictions used as a basis for sampling design or permitting i.e., the **"impact hypothesis"**; and

iii. Surveillance monitoring – to identify and quantify longer-term environmental changes (trends) as possible consequences of human activities.

5. Compliance and model verification monitoring are implicitly tied to specific management actions, whereas surveillance monitoring is for purposes of studying trends (spatial and temporal) in marine environmental quality. Each type of monitoring has different objectives although they often, but not always, use the same techniques/methodologies.

6. Monitoring of dredged material disposal (or other disposal activities in the marine environment) involves both compliance monitoring and model verification monitoring, whereas IMAP is an example of surveillance monitoring. Thus, the OSPAR Convention's monitoring programme (CEMP) does not cover the monitoring of disposal sites for dredged material, although it does cover

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[2] UNEP(DEPI)/MED IG.23/15
[3] UNEP(DEC)/MED WG.270/11

the trends in dumping activities and inputs from them and the two different monitoring programmes will often use the same techniques/methodologies. The same also applies to HELCOM.

1.2 The UNEP/MAP Dredged Material Guidelines and the UNEP/MAP Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast

7. Paragraph 144 of the UNEP/MAP Dredged Material Guidelines states:

> *"Whenever possible, the monitoring programme should be aligned with the current MEDPOL monitoring programmes for the Ecological Objectives 5, 8, 9, and 10, in line with the Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria set out in Decision IG.22/7 of COP 19."*

8. For monitoring of dredging:

- Ecological Objective 5 on Eutrophication and associated Common Indicators 13 and 14 would appear unlikely to be relevant in most cases.
- Ecological Objectives 8 on Coastal Ecosystems and Landscapes and associated Common Indicators 16 and 25 would also appear unlikely to be relevant in most cases since any potential issue should have been resolved in the permit approval process.
- Ecological Objective 7 on Hydrography and associated Common Indicator 15 would also appear unlikely to be relevant in most cases since any potential issues should have been resolved in the permit approval process.
- Ecological Objective 9 on Contaminants and the associated Common Indicators 17, 18 and 20would be relevant.
- Ecological Objective 11 on Underwater Noise and associated Common Indicators 26 and 27 would be relevant.

9. For monitoring dredged material disposal sites:

- Ecological Objective 5 on Eutrophication and associated Common Indicators 13 and 14 would only appear to be relevant in those circumstances where eutrophication is an issue in, and in the vicinity of, the location of disposal sites.
- Ecological Objective 8 on Coastal Ecosystems and Landscapes and associated Common Indicators 16 and 25 would appear unlikely to be relevant provided disposal sites are selected appropriately.
- Ecological Objectives 9 on Contaminants and the associated Common Indicators 17, 18 and 20 will always be relevant.
- Ecological Objective 10 on Marine Litter and associated Common Indicator 23 will be relevant.
- Ecological Objective 11 on marine noise and associated Common Indicators 26 and 27 were not mentioned in paragraph 144 of the UNEP/MAP Dredged Material Guidelines but is unlikely to be relevant for monitoring of disposal sites – see document UNEP/MED WG 487/4, section 4.1.4.

10. Standard UNEP/MAP Monitoring Guidelines/Protocols for sediment properties and sediment and water chemistry and the assessment of benthos etc., are in place for the IMAP and will be used, where applicable, in the monitoring of dredging and dredged material disposal sites. However, there are number of sediment and water features not covered by these IMAP Monitoring Guidelines/Protocols but are covered in this document – see below in section 5.

11. So, in conclusion, it is necessary to consider Ecological Objectives 5 on Eutrophication, 9 on Contaminants, 10 on Underwater Noise and 11 on Marine Litter when undertaking monitoring of dredging and dredged material disposal.

1.3 Factors for Monitoring of Dredging Activities

12. The necessity for field monitoring of dredging operations will depend on the outcome of the assessment of potential effects of dredging and any impact hypotheses that might result from that assessment. Many dredging operations take place without any monitoring being required. The main marine environmental concerns that may require monitoring are most commonly:

a) Turbidity due to sediment put into suspension in the water column;

b) Contaminants associated with the sediment put into suspension in the water column that may affect water quality and impact biota. This could include marine litter, particularly macro- and micro-plastics;

c) Dissolved oxygen that may be depressed by reaction with organic material in the suspended sediment and might impact on biota; and

d) Underwater noise.

1.4 Factors for Monitoring of Dredged Material Disposal Sites

13. Monitoring in relation to the Barcelona Convention Dumping Protocol is focused on the potential impacts on the marine environment in and around the dredged material disposal site. Impacts on the seabed and associated biota are usually the most important impacts due to the bulk nature of the material. However, water column impacts may be relevant in some cases. Best practices for such monitoring are referred to in section 5 of the Compendium of Best Practices for Implementation of Dumping Protocol (UNEP/MED WG 487/4).

14. The necessity for field monitoring of dredging operations will depend on the outcome of the assessment of potential effects of disposal and any impact hypotheses that might result from that assessment. The potential effects of dredged material disposal can be regarded as a set of bottom-up causes and primary effects, in which the physical system (both in the water column and on the bed) is altered and which in turn affect the health of the biological system. The eventual effects on the biological system and its anthropogenic uses can be regarded as a set of top-down responses, e.g., the effects on the higher levels of the ecological system (such as fishes, seabirds and marine mammals) as well as on fisheries and conservation objectives. Our knowledge of these effects and the linkages between the different responses can be regarded as a conceptual model which, by the nature of the system and the potential changes to dredging and marine disposal, is naturally very complex – see Figure 2.1 and Figure 2.2 in MEMG (2003).

15. The disposal of dredged material will have the potential to affect the water column, the bed conditions and their biota. Reductions in water clarity through an increased turbidity may in turn affect the primary production by the phytoplankton. The release of any materials contained within the dredged material, either as the water-soluble fraction or the release of particulate materials may result in a changed chemical environment, i.e., anoxic fine sediments liberated into the oxygenated water column may cause the release of pollutants previously sequestered due to the anoxic chemical conditions. Similarly, any organic matter in the sediment will create a water column oxygen demand. The deposited sediment will change the nature of the bed sediment if it is of a different particle size and it can have a smothering effect on the bed community as well as bringing new organisms to an area. Both of these features will affect the structure of the bed community and in turn the demersal and benthic fishes feeding on that bed community.

16. Where it is considered that effects will be largely physical, one component of monitoring may be based upon remote methods such as side-scan sonar to identify changes in the character of the

seabed and bathymetric techniques such as multibeam bathymetry to identify areas of dredged material accumulation. Both techniques may require some sediment sampling to establish "ground truth".

17. Where either physical or chemical effects at the seabed are expected, it will usually be necessary to assess the benthic community structure in areas around the disposal site where the dredged material may be transported. In the case of chemical effects, it may also be necessary to examine the chemical quality of the sediment and biota including fish and other seafood species.

18. In order to assess the impact, it will be necessary to compare the physical, chemical and biological quality of the affected areas with reference sites located away from dispersal pathways. Such areas can be identified during the early stages of the impact assessment.

19. The spatial extent of sampling will need to take into account the size of the area designated for dumping, the mobility of deposited material and water movements which will determine the direction and extent of sediment transport. Where dredging for pipelines, outfalls or cables are concerned, such operations will usually deposit dredged material in a narrow band parallel to the length of the structure. When trenches are excavated for pipelines, outfalls and cables, it is usual to use a significant part of the temporarily deposited material to refill the trench after the installation of the pipeline or outfall in order to protect them e.g., from fishing gear or anchors. Dredging for the installation of cables does not always involve excavating a trench as it is common to leave the cables on the seabed surface where they are not at risk of damage. In such cases, the dredging is done to provide a relatively flat surface for the cable by dredging to remove sand waves, mega-ripples and other unevenness of the seabed along the route of the cable.

20. The frequency of surveys will depend on a number of factors. Where a disposal 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 occasionally to check that effects are within those predicted or if changes are made to the operation such as the quantities or type of material, the method of deposit etc.

2. General

2.1 Guidance from Other Conventions for Monitoring of Disposal Sites

21. The London Convention/London Protocol (LC/LP), the OSPAR Convention, HELCOM and UNEP/MAP do not have a specific detailed guidance documents covering the common methodologies and techniques for assessing adverse effects of dredged material disposal sites at sea. They do each have some limited guidance within their dredged material guidelines.

22. The LC/LP has published detailed guidance for the sampling and analysis of dredged material intended for disposal at sea (IMO, 2005). OSPAR and HELCOM have a number of guidance documents on particular aspects of monitoring, not all of which will necessarily be relevant for the monitoring of dredged material disposal sites see Annex 1.

2.2 National Guidance

23. A number of countries around the world have prepared specific guidance documents for all or some aspects of the monitoring of dredged material disposal sites including Australia (Australian Government, 2009, 2012), Canada (Environment Canada, 1998a, 1998b), United Kingdom (MEMG (2003, Scottish Office, 1996) and USA (USEPA/USACE, 2004). In the answers to the questionnaire[4], only one country, Cyprus, referred to a national guidance document but it is likely that other Mediterranean countries do have such documents.

[4] As of 25 January 2021.

3. Deriving the Impact Hypothesis

24. Paragraphs 148-160 of the UNEP/MAP Dredged Material Guidelines provide general guidance on establishing and using an Impact Hypothesis for monitoring. The LC/LP Specific Guidelines for Assessment of Dredged Material (IMO, 2014) and the OSPAR Guidelines for the Management of Dredged Material at Sea (OSPAR, 2014)) have some additional information on the Impact Hypothesis that is useful to refer to. This OSPAR Guidelines cover additional detailed guidance on how to derive an Impact Hypothesis and specific testable hypotheses that field monitoring can confirm or deny.

25. During the preparation of an impact hypothesis, Contracting Parties to the Barcelona Convention should bear in mind that there are usually two types of disposal sites, i.e., retentive (accumulative) and dispersive5 and these will require a different impact hypothesis.

26. In the case of 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 should examine the severity of these alterations. The assessment should specify the likelihood and scale of residual impacts outside the primary zone where the bulk of the deposited material remains.

27. 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 deposit 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.

28. The Impact Hypothesis is derived from the predicted effects on the physical, chemical and biological characteristics of the areas in and around both the dredging site and the disposal site (paragraphs 148-149 of the UNEP/MAP Dredged Material Guidelines). While numerous potential effects can be envisaged, see Figures 2.1 and 2.2 of MEMG (2003), it is only those of potential significance (however defined) that require monitoring. It is then necessary to derive testable hypotheses for each of those potentially significant effects and to determine what measurements are required to test them. The primary consideration for impact hypotheses should be tailored to specific information such as site characteristics, site-specific species, local spatial and temporal scales of variable parameters and the permit terms and conditions. The measurements required for monitoring can be divided into (i) those within the zone of predicted impact and (ii) those outside, and should determine:

a) if the actual zone differs from that projected; and
b) if the extent of change projected outside the zone of impact is within the scale predicted.

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[5] However, there will be some disposal sites in between the two types e.g., weakly dispersive.

Impact hypotheses can be of three different types:

Type	Examples of Different Types of Hypotheses
Operational	Does the extent of dispersion from the disposal site exceed that predicted?
	Can the disposal site receive the required amount?
Environmental	Do suspended solids levels exceed critical levels for fish?
	Do the changes degrade the overall health/quality of the environment?
Effects on users/uses	Does the depth of accumulation of material at the disposal site cause concern for navigation?

29. Examples of specific impact hypotheses from Environment Canada (1998a) and MEMG (2003) are presented below:

Examples of Impact Hypotheses for Dredging

- Resuspension of fine material will be ephemeral, hence no observed impacts on adjacent sensitive sites i.e., no deposition of fine-grained material will be observed at adjacent sensitive sites.
- Restriction of dredging to outside of the salmon migration season will avoid impact with the salmon run i.e., dredging will not affect the numbers of salmon migrating up the river.

Examples of Impact Hypotheses for Disposal

- Disposal of dredged material will not result in:
  - a) transport of contaminated material from the disposal site,
  - b) subsequent increases in contaminant concentration in the sediments of the area reached by the transported material, and
  - c) consequent contaminant uptake by biota and ensuing effects on the biota.
- The deposited dredged material will not reach any protected habitat, through resuspension, erosion and sediment transport, in amounts sufficient to be of concern in relation to habitat destruction (taking into account the compatibility of the transported material with the sediments of the receiving environment). Resuspension, erosion and sediment transport of the deposited material will not affect any fishery.
- Disposal of dredged material will not result in contaminant uptake by harvested species and ensuing potential effects on human health.
- The deposited dredged material will not reach any sensitive areas, through resuspension, erosion and sediment transport, in amounts sufficient to be harmful to valued components of the sensitive area (taking into account the compatibility of the transported material with the sediments of the receiving environment).
- Containment of the majority of the deposited material within the disposal site would result in a measurable but acceptable decrease in water depths which would pose no hazard to shipping.
- The small size of the dredging operation limits seabed degradation to transient local effects.
- There will be no detectable deposition of mud film on amenity beaches.

4. Common Methodologies and Techniques for Assessing Adverse Effects of Dredging

30. As indicated in section 1.3, the main marine environmental concerns that may require monitoring are most commonly:

a) Turbidity due to sediment put into suspension in the water column;

b) Contaminants associated with the sediment put into suspension in the water column that may affect water quality and impact biota. This could include marine litter, particularly macro- and micro-plastics;

c) Dissolved oxygen that may be depressed by reaction with organic material in the suspended sediment and might impact on biota; and

d) Underwater noise.

4.1 Turbidity

31. Turbidity is a well-known issue for dredging and is very case specific in relation to the dredging technique and the local circumstances, as indicated in Compendium of Best Practices document (UNEP/MED WG 487/4). Techniques for testing of turbidity may include:

- Use of water displacement samplers at several depths, to give depth profile, then filtering water through filters to give weight of suspended solids;
- Optical instruments can measure turbidity by monitoring optical backscatter (OBS) or transmission. OBS instruments are more sensitive to fine sediments (14-170 μm) in suspension than acoustic instruments. They need calibration to give values of suspended sediment concentration. Continuous monitoring equipment for this is available and can be deployed from vessels or installed on buoys or fixed structures to ensure appropriate coverage around the dredging operation.
- Acoustic monitoring of turbidity may be achieved using instruments based upon acoustic backscatter. An increased concentration of suspended sediments leads to an increase in the backscattered acoustic energy. Acoustic instruments are more sensitive to coarse (75-250 μm) sediments in suspension. They also need calibration to give values of suspended sediment concentration. As for optical instruments, continuous monitoring equipment for this is available and can be deployed from vessels or installed on buoys or fixed structures to ensure appropriate coverage around the dredging operation.

32. As explained in the “Compendium of Best Practices” document (UNEP/MED WG 487/4), there do not appear to be any explicit BEPs for monitoring turbidity from dredging, but there are a number of publications that could be collectively considered to represent BEP. These are mainly published by the US Army Corps of Engineers that has produced many reports on monitoring and assessment of turbidity due to dredging operations including Borrowman (2006), Clarke and Wilber (2000), Francingues and Palermo (2005), Germano and Cary (2005), Johnson and Parchure (2000), Reine *et al.* (2002), Thackston and Palermo (2000), Tubman and Corson (2000), Wilber *et al.* (2005). Central Dredging Association (CEDA) has also produced a number of useful papers on turbidity related to dredging (CEDA, 2011a, 2020). Laboyrie *et al.* (2018) also provides useful guidance on the monitoring of turbidity due to dredging in section 8.3.3.

4.1.2 Contaminants

33. Where the level of chemical contaminants in sediments to be dredged raises concerns for potential adverse effects on water quality and biota, monitoring of those contaminants around the area being dredged may well be required. The best practices for such monitoring are well established in

relevant UNEP/MAP Monitoring Guidelines/Protocols. The dredging of contaminated sediments needs particular care and the publications by Bridges *et al*. (2008) and Palermo *et al*. (2008) provide the best information on this subject. In those circumstances, risk assessment of the dredging operations is critical and the publications by Moore *et al.* (1998), PIANC (2006b) and PIANC (2019) provide useful guidance.

34. Contamination arising from marine litter, including macro- and micro-plastics, could require monitoring if pre-dredge surveys indicate that dredging may put significant amounts of such material into suspension. UNEP/MAP has a monitoring protocol for floating micro-plastics (UNEP/MED WG.482/19) that would be appropriate for this purpose.

4.1.3 Dissolved oxygen

35. Where there are concerns about potential depression of dissolved oxygen levels due to dredging operations, monitoring may be necessary. Continuous monitoring equipment for this is available and can be deployed from vessels or installed on buoys or fixed structures to ensure appropriate coverage around the dredging operation. It can also be measured on discrete water samples using the technique in the 'Monitoring Guidelines/Protocols for Determination of Hydrographic Chemical Parameters', document UNEP/MED WG.482/7.

4.1.4 Underwater Noise

36. This is a relatively recent issue of concern which has gained more prominence recently. While there does not appear to be any existing BEP or guidance document for measuring underwater noise from dredging operations, there is a good practice guide for measuring underwater noise in general (Robinson *et al.*, 2014). Underwater noise is detected using hydrophones and these can be mounted on vessels, fixed structures or buoys as appropriate for each individual dredging operation (Robinson *et al.*, 2014).

37. In this regard, it is noted that PIANC EnviCom Working Group 226 is working on 'A Guide for Assessing and Managing Effects of Underwater Sounds from Navigation Infrastructure Activities' that should be useful to guide monitoring when it becomes available (https://www.pianc.org/uploads/files/EnviCom/ToR-new/ToR-EnviCom-WG-226-A-Guide-for-Assessing-and-Managing-Effects-of-Underwater-Sounds-from-Navigation-Infrastructure-Activities.pdf).

38. Moreover, the Convention on Biological Diversity (CBD) has a draft Technical Series report on 'Anthropogenic underwater noise: impacts on marine and coastal biodiversity and habitats, and mitigation and management measures' in preparation (https://www.cbd.int/doc/notifications/2020/cbd-ts-underwater-noise-peer-review-en.pdf). It is expected that this publication should provide some useful information in this domain.

39. In addition, there are a number of guidance documents on measuring underwater noise from dredging. The US Army Corps of Engineers has produced a number of publications on underwater noise generated by each of the main types of dredging equipment (Dickerson et al. 2001; McQueen *et al.*, 2019; Reine *et al.* 2012a, 2012b; 2014; Suedal *et al.*, 2019). CEDA and the World Organization of Dredging Associations (WODA) have produced general guidance about underwater noise from dredging (CEDA, 2011b; Thomsen *et al.*, 2013). Note that the underwater noise produced by dredging varies considerably between the different dredging techniques in both intensity and duration.

40. Finally, it should be mentioned that UNEP/MAP has developed two Common Indicators CI-25 and CI-27 under Ecological Objective 11 for underwater noise (UNEP/MED WG.467/5). However, neither of the factsheets for these two CIs mention underwater noise caused by dredging operations. Nevertheless, Common Indicators CI-25 and CI-27 will be useful for assessing underwater noise from dredging.

5. Common Methodologies and Techniques for Assessing Adverse Effects on Disposal Sites

5.1 Introduction

41. The range of common components and features that may be necessary[6] to be monitored at and in the vicinity of a dredged material disposal site can be organised into the categories as shown in Table 1 below (MEMG, 2003). As explained in the Compendium of Best Practices for implementation of the Dumping Protocol (UNEP/MED WG 487/4), it is recommended that the tiered approach to monitoring is adopted as best practice to address the impact hypotheses in a cost-effective and consistent fashion. This is described in Figure 2 below from Environment Canada (1998a):

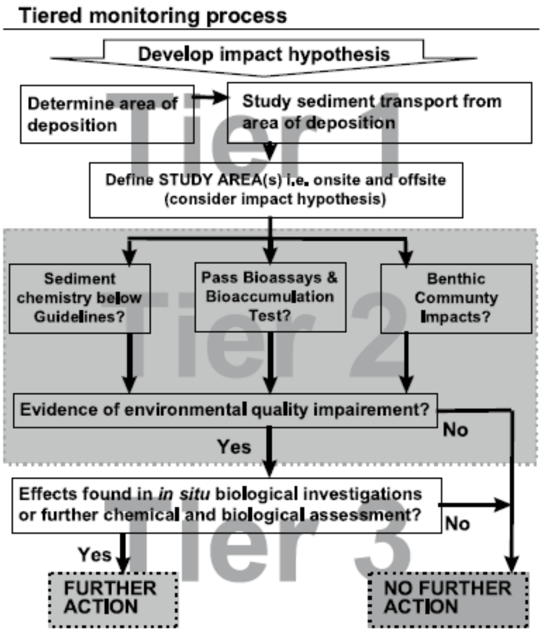

Figure 2 – Tiered Monitoring Process (Environment Canada, 1998a)

42. The tiered monitoring process is described by Environment Canada (1998a) as: “Physical monitoring (Tier 1) which defines the site boundaries. This is followed by concurrent chemical and biological assessments (Tier 2). The results of both Tiers 1 and 2 are used in making decisions on the need for further monitoring (Tier 3) and broadly address most impact hypotheses. At some sites, site-specific concerns will require different parameters or a different emphasis in monitoring resources allocation between tiers. However, it is expected that both Tier 1 and Tier 2, as well as, the core parameters[7] will be used at most sites, while Tier 3[8] will generally not be required.”

43. Note that the London Convention/London Protocol has developed guidance for low cost, low technology field monitoring for the assessment of the effects of disposal in marine waters of dredged material or inert, inorganic, geological material (IMO, 2016) that may be useful for some Parties. The objective of the guidance document is to provide practical information about using low technology and low-cost tools that are useful for monitoring of possible environmental impacts associated with marine disposal of either dredged material or inert, inorganic geological materials. The primary audiences for this guidance are countries that are in the early stages of developing waste assessment and monitoring actions in concert with permit programs for disposal of wastes and other matter into marine waters

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[6] Note that what needs to be measured in each case will depend on the impact hypothesis.
[7] Includes physical surveys, bathymetry, grain size, sediment chemistry, laboratory biological tests and benthic community surveys.
[8] Includes further chemical and biological assessment, onsite biological measurement and long-term stability assessment

which are consistent with the Dumping Protocol of Barcelona Convention. These guidelines could be considered BEP for such countries and are recommended for the interested Parties which may wish to follow.

Table 1 - The main environmental components and features relevant to monitoring dredged material disposal operations (MEMG, 2003)

Component	**Feature**
Hydrography:	Tidal excursion
	Wind-driven circulation
	Bed currents
	Short-term circulation
	Long-term circulation
	Sediment movement
Water Column:	Light penetration
	Turbidity/Suspended solids
	Contaminants in water/suspended solids
	Particulate organic carbon
Seabed – Physical:	Bathymetry Bed forms
	Sediment physical characteristics
	Marine litter including macro- and micro-plastics
Seabed – Chemistry:	Sediment chemistry – contaminants
	Sediment chemistry – organic carbon
	Sediment properties – pH, redox
Seabed – Biology:	Biotope
	Epibenthos
	Benthic infauna
Top Predators:	Fish
	Seabirds
	Mammals

44. The text below in sections 5.2 to 5.8 provide examples of the methodologies and techniques that can be used to monitor the main features relevant to disposal operations shown in Table 1. Where UNEP/MAP monitoring protocols exist, they are referenced under the relevant issue below. Further details about the methodologies and techniques can be found in the publications by Eleftheriou (2013), Environment Canada (1998a,1998b), IMO (2005), MEMG (2003), Scottish Office (1996) and Ware and Kenny (2011). Specific references have only been provided for those novel or new techniques as most of the techniques described are well-known oceanographic techniques and/or are covered in the references above. As sediment sampling is relevant for several features under ‘Seabed – Physical’, ‘Seabed – Chemistry’ and ‘Seabed – Biology’ below, this will be dealt with under section 6 below.

5.2 Hydrography

45. In the context of this report, hydrography is the science that measures and describes the physical features of bodies of water and this includes collecting information on tides, currents and sediment movement. This information should already be available for existing dredged material disposal sites as it would have been collected during the site selection process. However, in the case of

selecting a new dredged material disposal site, the following aspects and techniques can be used to provide information on hydrography.

5.2.1 Tidal excursion

46. The tidal excursion be measured with subsurface drogues, followed by boat with radar and DGPS position fixing and should be monitored per tide with spring and neap coverage. Also, navigational charts usually provide information about tidal speed and direction at a number of points (i.e., ‘Tidal Diamonds’ on Admiralty charts).

5.2.2 Wind-driven circulation

47. Surface drogues followed by boat with DGPS position fixing under several wind conditions. Also, Ocean Current Surface Radar (OSCR) and Acoustic-Doppler Current Profile (ADCP) Imaging can be used.

5.2.3 Bed currents

48. Bottom landers with recording current meters. Also, seabed drifters - deployment of plastic drifters, each tagged and with reward for recovery.

5.2.4 Short-term circulation

49. Direct-reading current meters (DRCM) or recording current meter (RCM), deployed over tidal cycles and under differing spring-neap conditions. They can be deployed in conjunction with other water parameter measurement devices (e.g., depth, temperature, salinity/conductivity, oxygen, turbidity) to define water masses. In addition, ADCPs can be used.

5.2.5 Long-term circulation

50. Recording current meter (RCM) deployed over a lunar cycle.

5.2.6 Sediment movement

51. Bottom landers deploying a range of optical sensors and water sampling equipment. Also, a variety of sediment tracers are in use e.g., fluorescent tracers.

5.3 Water Column

5.3.1 Light penetration

52. The simplest device is the Secchi disk that measures water transparency. UNEP/MAP has a relevant monitoring guidelines/protocols in UNEP/MED WG.482/6: Monitoring Guidelines/Protocols for Determination of Hydrographic Physical Parameters. Also, one can deploy underwater light meters to measure photosynthetically active radiation (PAR) penetration with depth.

5.3.2 Turbidity/Suspended solids

53. Techniques for this are the same as given in section 4.1 above for dredging

5.3.3 Contaminants in water/suspended solids

54. Water samples are collected using standard oceanographic samplers and filters to give suspended load and dissolved phase for analysis of inorganic or organic contaminants. UNEP/MAP has two relevant monitoring guidelines/protocols:

- WG. 482/15: Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Seawater for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants.

- WG. 482/16: Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Seawater for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants.

5.3.4 Particulate organic carbon

55. Water samples are filtered to collect particulate matter. Techniques that can be used include either percentage Loss-on-Ignition, CHN analyser or use wet oxidation technique followed by spectrophotometry or titration.

5.3.5 Underwater noise

56. As indicated above in section 1.2 above and in section 4.1.4 of the Compendium of Best Practices (document UNEP/MED WG 487/4), Ecological Objective 11 on underwater noise and Common Indicators 26 and 27 (UNEP/MED WG.467/5) are unlikely to be relevant for monitoring of disposal sites as underwater noise from general shipping is much more likely to be a significant source of underwater noise than disposal activities.

5.4 Seabed – Determination of physical characteristics

5.4.1 Bathymetry (i.e., the measurement of the depth of water in an area of the sea in order to produce a map of the seabed topography)

57. Techniques for bathymetry can include:

- Echo sounder and multibeam bathymetry to provide accurate recording of depth variations across disposal sites.

5.4.2 Bed forms (i.e., the shape of the seabed including sand waves, mega ripples, rock outcrops etc.)

58. Techniques for this can include:

- Photography to give presence of different ripple types, rock surfaces, crevices, sediment pockets in hard substratum.
- Side-scan sonar for sweep of area giving 2-dimensional interpretation.
- Bed-profiling, e.g., Sub-bottom profilers and RoxAnn (http://www.sonavision.co.uk/products.asp?cat_id=1), giving bed features (substratum types, bed forms, major changes of bed.

5.4.3 Sediment physical characteristics (i.e., sediment particle size, density, water content, permeability etc)

59. Techniques for this can include:

- A subjective assessment following grab or core sampling - skilled visual assessment into mud, muddy-sand, mud, etc.
- Detailed particle size analysis of samples taken by grab or core; granulometric analysis using sieving for the coarse fraction and laser granulometry (e.g., Malvern, Frisch), Coulter Counter, or pipette analysis for the finer fraction if <5% by weight.
- Geotechnical analyses for e.g., bulk density, liquid/plastic limits, consolidation, permeability and shear strength (Fitzpatrick and Long, 2007).
- Sediment Profile Imaging – This allows rapid data acquisition during field sampling and a

wide variety of physical and biological parameters can be measured from each image, including:

- Grain-size major mode and range (gravel, sand, silt, clay).
- Depth of the apparent Redox Potential Discontinuity (RPD).
- Calculation of the Organism-Sediment Index, allowing rapid identification and mapping of disturbance gradients in surveyed areas.
- Infaunal Successional Stage.
- Evidence of excess organic loading and high sediment oxygen demand.
- More details can be seen at: https://www.inspireenvironmental.com/2015/12/04/sediment-profile-imaging/#:~:text=Sediment%20Profile%20Imaging%20allows%20rapid%20data%20acquisition%20during,%28gravel%2C%20sand%2C%20silt%2C%20clay%29.%20Small-scale%20surface%20boundary%20roughness

5.4.4 Marine Litter Including Macro- and Micro-Plastics

60. There are a range of papers/reports on techniques for sampling, analysis and measurement for marine litter. The best developed techniques are for monitoring macro litter on beaches, as such guidelines have been developed over a long period of time., e.g., the OSPAR Guidelines for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (https://www.ospar.org/documents?v=7260). UNEP/MAP has Ecological Objective 10 related to marine litter and Common Indicator 23 ‘Trends in the amount of litter in the water column including microplastics and on the seafloor. Associated with that Common Indicator is a checklist for collecting data on seafloor marine litter (IMAP CI23).

61. Recently, Madricardo *et al*. (2020) have given an overview of the current state-of-the-art methods to address the issue of seafloor macro-litter pollution. The overview includes the following topics: the monitoring of macro-litter on the seafloor, the identification of possible litter accumulation hot spots on the seafloor through numerical models, and seafloor litter management approaches (from removal protocols to recycling processes). However, there do not appear to be any accepted best practice documents or widely accepted methodologies for monitoring marine litter on the seabed at present.

62. Regarding microplastics, the best guidance currently available is that proposed in GESAMP (2019) that has proposed guidelines including:

- Designing monitoring and assessment programmes
- Monitoring methods for shorelines
- Monitoring methods for the sea surface and water column
- Monitoring methods for seafloor
- Monitoring methods for marine biota
- Sampling processing for microplastics
- Methods for physical, chemical and biological characterisation of plastic litter

63. Note that OSPAR is in the process of developing an indicator for microplastics in sediment. There are many papers/reports about the techniques for sampling, analysis and measurement for marine microplastics in the literature but with the wide variety of techniques employed giving results that cannot be compared, it is inappropriate to refer to them here.

5.5 Seabed – Chemical Characteristics

5.5.1 Sediment chemistry – contaminants

64. Sampling by grab or core (non-contaminating material) then analysis by digestion and Atomic Absorption or Plasma-emission spectroscopy for metals; GCMS or HPLC for organic contaminants; petroleum hydrocarbons by extraction and gravimetry or GCMS. UNEP/MAP has two relevant monitoring guidelines/protocols:

- WG. 482/11: Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Sediment for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminant.
- WG 482/12: Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Sediment for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants.
- Sediment Profile Imaging can be used with Diffusive Gradient in Thin films (DGT) gels to give information on the profiles on contaminants in the top 20 cm of sediment (Birchenough et al. (2010). Also, there is the possibility of using passive sampler to assess the bioavailability of chemical contaminants in sediment e.g., Gilmore et al. (2020) and paper LC/SG 41/INF.7 'Laboratory, field, and analytical procedures for using passive sampling in the evaluation of contaminated sediments: user's manual' available through IMO Web Accounts.

5.5.2 Sediment chemistry – organic content

65. Sampling by core or grab to give undisturbed surface sediment then assess Loss-on-ignition (using muffle-furnace), direct measurement of carbon and nitrogen by CHN analyser or wet oxidation technique for carbon. Also, micro-Kjeldahl technique for nitrogen.

5.5.3 Sediment properties – Redox (Eh)

66. Platinum electrode measurements at depth in sediment in a grab or on a core sample to give Eh profile and depth of redox profile discontinuity level.

5.6 Seabed – Biological Characteristics

5.6.1 Biotope

67. A biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals.[9]

Techniques for this can include:

- Still and video photography using epibenthic sledge towed behind vessel or drop camera; calibrate area observed; record megabenthic organisms and any surface features (pockmarks, burrow entrances).
- Use of remote operated vehicle (ROV) from vessel to obtain precise nature of biological features; if necessary, ground-truth using core and grab sampling.
- Biotope mapping using combinations of multibeam bathymetry, sidescan sonar, sub-bottom

[9] Biotope is almost synonymous with the term habitat as defined in MSFD, Annex III, Table 1: "*Broad habitat types of the water column (pelagic) and seabed (benthic), or other habitat types, including their associated biological communities throughout the marine region or subregion"*

profiling and RoxAnn with ground truthing by core and grab analysis.

5.6.2 Epibenthos

68. Techniques for this can include:

- Still and video photography (as for biotope).
- Use of remote operated vehicle (ROV) (as for biotope).
- Towed epibenthic sledge, naturalists dredge or scallop dredge from vessel, with onboard analysis.
- Seabed towed gear, e.g., Agassiz or beam trawl with onboard analysis of large and common forms but laboratory analysis for more precise identification.

5.6.3 Benthic infauna

69. UNEP/MAP has a relevant monitoring guidelines/protocol for this issue in UNEP/MED WG.461/21: Update of Monitoring Protocols on Benthic Habitats: Guidelines for monitoring marine benthic habitats in Mediterranean.

70. Techniques for this can include:

- Use of grab or core samplers to provide fully quantitative samples; sieving on board and laboratory sorting and identification to give abundance, biomass and species richness per sample.
- Sediment profile imaging (SPI) to give photographs, and possible image analysis) of sediment type in relation to presence of organisms – see above.

5.6.4 Contaminants in biota

71. UNEP MAP has several monitoring protocols for this issue:

- UNEP/MED WG.482/13 Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Marine Biota for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants.
- UNEP/MED WG.482/14 Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Marine Biota for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants.
- UNEP/MED WG.482/17 Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Sea Food for IMAP Common Indicator 20: Heavy and Trace Elements and Organic Contaminants.
- UNEP/MED WG.482/18 Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Sea Food for IMAP Common Indicator 20: Heavy and Trace Elements and Organic Contaminants.

5.7 Top Predators

72. UNEP/MED WG.458/4: ‘Guidance on monitoring concerning the biodiversity and non-indigenous species’ covers cetaceans. Monk seals, sea birds and turtles.

5.7.1 Fish

73. Pelagic trawling of water column at risk; otter, beam or Agassiz trawling for demersal and benthic fishes; on-board analysis to give species, abundances, biomass and sizes of dominant species.

5.7.2 Seabirds

74. Aerial and shore photography, visual recording.

5.7.3 Mammals

75. Photography, visual recording

5.7.4 Reptiles (Turtles)

76. Photography, visual recording.

5.8. Novel techniques for Monitoring

77. A number of novel techniques for marine monitoring have and are becoming available due to new technologies being developed. In particular, the use of autonomous vehicles (drones) either underwater, on the sea surface or in the air are bringing new possibilities for marine monitoring. Powered Autonomous Underwater Vehicles (AUVs) have been in use for some time now that can carry out e.g., surveys of sidescan sonar, multibeam bathymetry and sub-bottom profiling. In addition, the use of underwater gliders and autonomous surface vehicles is becoming more common. Canada submitted a useful review of novel drones for marine monitoring to the LC/LP Scientific Groups meeting in 2019 (LC/SG 42/INF.11 available from IMO Wen Accounts). Also, see chapters 11-16 on in NOC (2020) for details of a variety of such devices.

6. Sampling of Seabed Sediments

78. Sampling of seabed sediments is necessary to enable both the analysis of sediment physical and chemical features and for the assessment of benthos. There are various aspects involved with sampling seabed sediments, including:

- Designing a sampling plan.
- The selection of the physical, chemical and biological parameters to be measured - derived from the impact hypotheses.
- Designing an analytical plan with appropriate Quality Assurance/Quality Control to ensure that the analysis and data meet the requirements for the assessment required.
- Field sampling of sediments with various devices. This is usually carried out using either grabs or cores and these are well covered in Mackie *et al*. (2007) (Grabs only), Eleftheriou (2013)
- Having appropriate sample containers and procedures for sample handling, transport and storage.

79. UNEP/MAP’s Monitoring Guidelines/Protocols in documents UNEP/MED WG.482/11 and UNEP/MED WG.482/13 cover sampling and sample preservation for sediments and marine biota respectively. In addition, there are several useful publications that cover all or some of the aspects above including those by Eleftheriou (2013), Environment Canada (1994), IMO (2005), MEMG (2003), Scottish Office (1996) and USEPA (2001). Where coarse-grained sediments are to be sampled (i.e., sands and gravels), the guidelines for benthic studies at marine aggregate extraction sites by Ware and Kenny (2011) are appropriate to use. In addition, a review of the tools used for marine monitoring

in the UK by Bean et al. (2017) includes some useful information about monitoring equipment and technology, data collection, and monitoring programmes including those for contaminants, eutrophication, non-indigenous species, hydrography, biodiversity, marine litter and marine noise.

7. Examples of Monitoring

80. Examples of national monitoring programmes are given in section 5 of MEMG (2003), Bolam et al. (2018), Environment Canada (2007) and USEPA (2017) and an individual port monitoring programme in Dublin Port Company (2020).

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Annex I
Additional Available Information for Monitoring

Additional available information for monitoring

OSPAR has a number of guidance documents on particular aspects of monitoring, not all of which will necessarily be relevant for the monitoring of dredged material disposal sites are presented below:

- CEMP Guidelines for the assessment of dumping and placement of waste or other matter at sea https://www.ospar.org/documents?d=37513
- CEMP Guidelines on Litter on the Seafloor https://www.ospar.org/documents?d=37515
- CEMP Guidelines for Monitoring and Assessment of loud, low and mid-frequency impulsive sound sources in the OSPAR Maritime Region https://www.ospar.org/documents?d=37516
- CEMP Guidelines for Monitoring Contaminants in Sediments (Agreement 2002-16). Revision 2018 http://www.ospar.org/documents?d=32743
- JAMP Guidelines for General Biological Effects Monitoring. Revised technical annexes 2007 (Agreement 2007-07) https://www.ospar.org/documents?d=32676
- JAMP Guidelines for Contaminant-Specific Biological Effects (Agreement 2008-09) https://www.ospar.org/documents?d=32799
- CEMP Guidelines for Monitoring Contaminants in Biota (Agreement 1999-02). Revision 2018 https://www.ospar.org/documents?d=32414
- CEMP Guidelines for coordinated monitoring for hazardous substances (Agreement 2016-04). Revised in 2018/19 https://www.ospar.org/convention/agreements?q=2016-04&t=&a=&s=

HELCOM has a number of detailed guidance documents that cover e.g.:

- measuring various contaminants in sediment, measuring turbidity in the water column and the biological material sampling and sample handling for the analysis of persistent organic pollutants (https://helcom.fi/action-areas/monitoring-and-assessment/monitoring-guidelines/);
- guidelines for monitoring seabed habitats, litter and underwater noise (https://helcom.fi/action-areas/monitoring-and-assessment/monitoring-manual/).