Monitoring and control program for the offshore dumping sites

"Application of ecosystem principles for the location and management of offshore dumping sites in SE Baltic Region (ECODUMP)”

Grazyna Sapota[1], Sergej Suzdalev[2], Grazyna Dembska[1], Monika Michalek[1], Nerijus Blažauskas[2]

[1]Maritime Institute in Gdańsk, Poland

[2]Klaipėda University Marine Science and Technology Centre, Lithuania

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1. Introduction

This document constitutes a part of the project "Application of ecosystem principles for the location and management of offshore dumping sites in SE Baltic Region (ECODUMP)".

Recent years have ushered in a trend of increasing interest and concern in the management of the offshore disposal sites for the relocation of dredged material. Monitoring of the dredged material disposal sites at sea forms one of the several interacting components of an overall dredged material management framework, which also includes disposal site designation, project evaluation, regulatory permitting, compliance and implementation. As part of the dredged material site designation process, a prospective monitoring plan is used in reaching decisions on site location and size. One goal of site designation is to select a site with the least potential for adverse environmental effects, thus minimizing monitoring requirements. Too much monitoring is a waste of time and money. Too little monitoring allows for undetected environmental effects and provides inadequate information for managing a site.

In-deep analysis of the existing offshore dumping sites monitoring approaches in the south-eastern part of the Baltic Sea (see ECODUMP report *"Existing legislative requirements for the location of dumping sites, dumping practices and monitoring approaches within BSR"*) has shown no uniformity in the available monitoring strategies. Systemic observations of marine environment at the existing offshore dumping sites are carried in Lithuania and partly in the Russian territorial waters of the south-eastern Baltic Sea. There is no regular monitoring of the offshore dumping sites in Poland.

This document recommends a joint approach to a monitoring program design, which emphasizes results that are useful to the decision making authorities, involved in the management process of dredged material disposal sites. The paper focuses on dredged material, which is suitable for the offshore disposal according to the legislative requirements existing in the countries along the Baltic Sea.

The monitoring approach described in this document may be applicable both for the dispersive and non-dispersive offshore dumping sites. Non-dispersive sites are chosen with the intention that most or all of the disposal material remains where it is placed, thus having only limited areal impact. Dispersive sites are chosen with the intent that transport and dilution of the disposed material will occur, but that this transport will not occur at a rate detrimental to the marine environment outside the designated disposal site.

2. Monitoring as a component of dredged material assessment

Disposal of dredged material, which is widely regulated by number of international conventions (see ECODUMP report *"Existing legislative requirements for the location of dumping sites, dumping practices and monitoring approaches within BSR"*) forms a part of Dredged material assessment framework (DMAF) (Fig. 1).

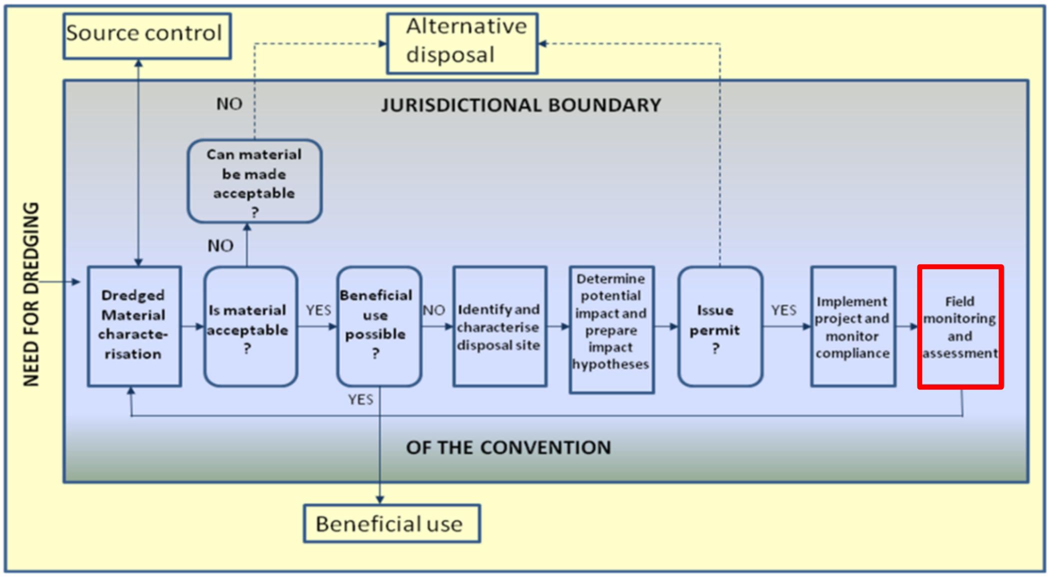

Fig. 1. Structure of Dredged Material Assessment Framework (DMAF)

Each component of the DMAF is integral to the overall management objectives, as it either provides background information for subsequent components or generates information that can be used in order to modify the approach taken in the future. Because of the interactive and supporting roles of the various components, the development of field monitoring and assessment programs must be based on the contributions and conclusions each brings to the framework, particularly the identification and characterization of the disposal site and evaluation of disposal options components. In particular, field monitoring should be used as a powerful management tool to provide specific evidence that can be used in order to support or modify other components of the framework.

Monitoring in relation to disposal of dredged material is often 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.

3. Objectives of the monitoring program

The main objective of the monitoring program of the dumping site is to determine whether the storage and management of the dumping site, including depositing process/method, should be amended to avoid unreasonable deterioration of the marine environment or risk to human health. It is important to document whether impacts defined as unacceptable are occurring, or whether conditions that will lead to an unacceptable impact are developing. A monitoring program should provide the site manager with clearly interpretable information about whether a threshold of adverse condition has been reached or is likely, so that decisions about continued or modified site use can be made.

Identification of the appropriate monitoring objectives for the particular offshore dumping site requires detailed analysis of the available site designation documents (e.g. Environmental Impact Assessment Studies), which were elaborated earlier to guide the decision on site selection. Such documents usually describe the impacts expected to occur as a result of the disposal site use, identified sensitive resources in the nearby areas as well as insignificant issues.

4. Monitoring program

In order to approach the monitoring program in a resource-effective manner, it is essential that the program should have clearly defined objectives, that the measurements made can meet those objectives, and that the results be reviewed at regular intervals in relation to those objectives. The monitoring scheme should then be continued, reviewed or even terminated, as appropriate.

Monitoring programs should be flexible, cost effective, and based on scientifically sound procedures and methods to meet site-specific monitoring needs. A monitoring program should have the ability to detect environmental change and assist in determining regulatory and permit compliance. The program should be designed to provide the following:

- Information indicating whether the disposal activities are occurring in compliance with the permit and site restrictions;
- Information indicating the short-term and long-term fate of materials disposed of in the marine environment;
- Information concerning the short-term and long-term environmental impacts of the disposal.

Monitoring programs should be structured to address specific questions (null hypotheses) and measure the conditions of key indicators and endpoints, particularly those identified during site designation, or major project-specific issues that arise.

The level of effort devoted to monitoring should be related to the magnitude and types of concerns. In some cases there may be little or no need to conduct monitoring. Such situations may include sites that have been used historically with no problems, sites where the disposal sediments are similar to the natural sediments (e.g., sand on sand, mud on mud), sites that are used infrequently, or sites that receive only small volumes of material. In other situations, monitoring requirements range from a need for only physical monitoring to consideration of a large suite of physical, chemical, and biological investigations.

The monitoring program should be based on an overall assessment of what is known about the site environment, the past use of the site, and amenities in or near the site that need to be protected. The development of the monitoring program should include an assessment of:

- environmental information collected at or near the site describing its condition in the past and/or present;
- characteristics of materials already dumped at the site and characteristics of materials that may potentially be dumped at the site in the future;
- special management conditions used at the site that could affect the environmental effects or fate of dumped material.

The consortium of the ECODUMP initiative proposed following 4-step systematic approach for the successful design of a monitoring program:

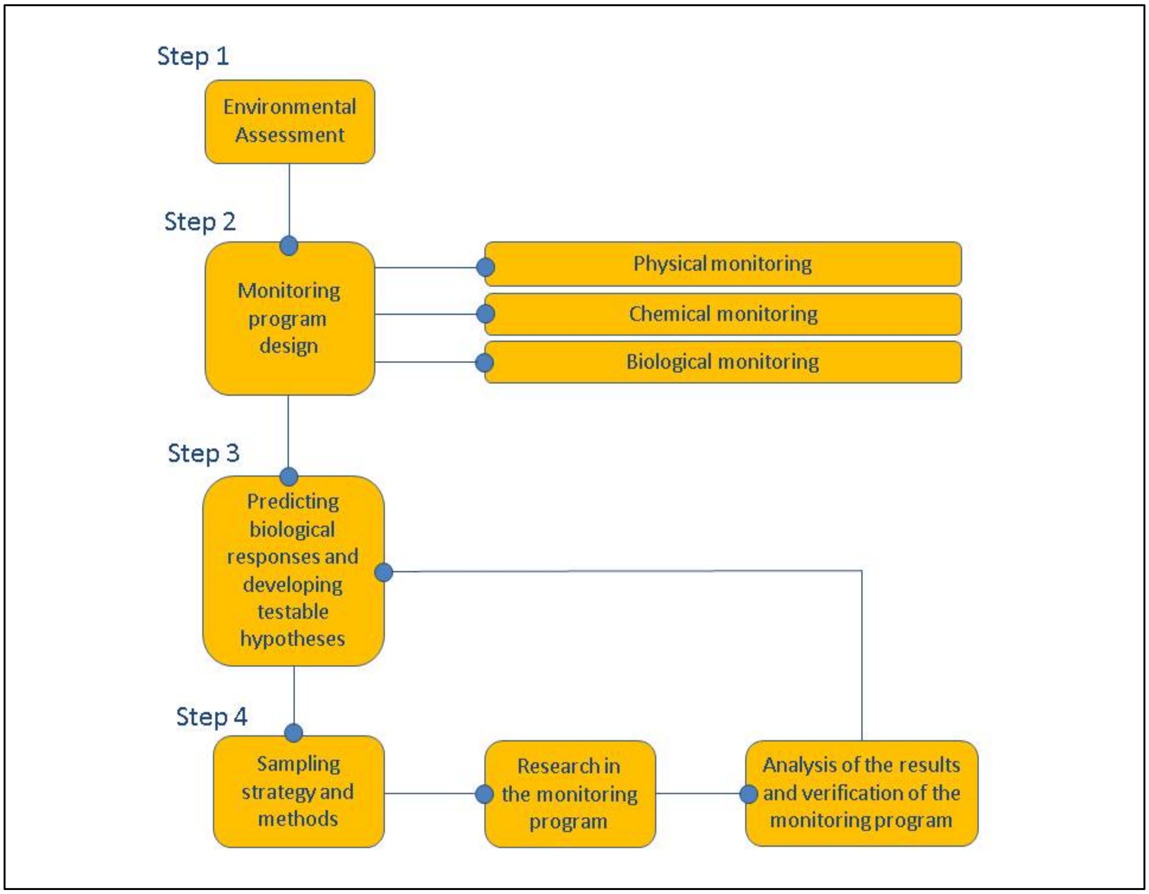

Fig. 2. Systematic approach for the development of monitoring program

Due to the specific nature of each dumping site the monitoring programs may not be exactly the same. Monitoring range and respective components will vary depending on the characteristics and location of dumping site, and type of deposited sediments.

4.1. Step 1: Environmental assessment

Clear monitoring objectives for the particular offshore dumping site can be identified on the basis of site designation documents (usually EIA studies). Available EIA studies developed for the site of interest generally describe the impacts expected to occur as a result of site use, identify sensitive environmental resources in the adjacent areas as well as the issues judged to be insignificant. Where appropriate, the monitoring program should be used to verify the impact predictions and support assumptions that led to site selection.

As a consequence of the site designation/selection process, it is also reasonable to expect that monitoring of the disposal site is a minimal requirement. Usually, the final designation results in the choice of a site that has limited potential for impact (located away from sensitive habitats, spawning areas, etc.) and therefore requires only limited monitoring.

4.2. Step 2: Monitoring program design

The monitoring program should be designed to observe the physical, chemical and biological impact of the offshore disposal activities. This requires precise designation of most relevant physical, chemical, and biological parameters of concern.

Physical/chemical effects

Generally include those associated with sediment characteristics as well as spatial distribution of the material after the disposal. These factors represent both short- and long-term direct effects to the biota (e.g., resulting from changes in grain size and bottom topography). Alterations in water quality are generally short-lived, and while concerns over them may be justified during the disposal, they are generally not considered as part of a long-term monitoring program.

Biological effects

Naturally related to the mentioned physical/chemical alterations and must be considered as consequences of these changes. Immediate short-term effects include burial of benthic communities, which acts to reset the successional sequence of community development, and alterations of sediment type, which can affect the type of community that will recolonize the area.

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

The expected consequences of disposal (targets) could be described in terms of habitats, processes, species, communities and uses affected. The precise nature of the change, response, or interference (effect) predicted could then be described. The target and the effect together could be described (quantified) in sufficient detail so that there would be no doubt as to the parameters to be measured during post-operational monitoring. In the latter context, it might be essential to determine "where" and "when" the impacts can be expected.

Because disposal site management depends on proper monitoring to determine site status, successful monitoring programs must integrate physical, chemical and biological data into interpretable results that can be used by a site manager to make decisions about site use. Ideally, monitoring as it applies to management of the offshore dredged material disposal sites should consist of repeated observations or measurements, which determine if site conditions conform to an "already stated standard” (Moriarty 1983).

Physical monitoring

Physical monitoring relates to the collection of geological information that is relevant to determining the area of deposition, delineating the disposal site boundaries; studying the accumulation of dredged material within the area of deposition; documenting evidence of sediment transport from the disposal site.

Potential physical impacts:

- mounding (appearance of new relief forms);
- transport of the dumped material out of the disposal site to undesirable locations (shellfish beds, beaches, navigation channels, etc.);
- effects of disposal mounds on hydrodynamic processes, such as wave refraction or currents.

Where it is considered that effects will be largely physical, monitoring is usually based on remote methods such as:

- side-scan surveys (to identify changes in the character of the seabed);
- bathymetric surveys (echo-sounding) (to identify areas of dredged sediment accumulation)

Both methods additionally require taking a certain amount of surface sediment samples for the establishment of ground-truth.

Table 1. Basic range of physical monitoring

Purpose	Component	Parameters of monitoring	Monitoring tools
Identify changes in the character of the seabed and areas of sediment accumulation	Sea bottom topography	• Depth • Sediment distribution • Sediment composition	• Echo-sounding • Side-scan sonar • Sediment sampling (grab samplers)
Measure the driving forces for sediment transport (climatic and hydrodynamic) and tracking the possible dispersal of disposed dredged material	Water	• Current velocity and direction • Waving • Total suspended sediment (TSS) concentrations • Temperature • Salinity • Transparency	• CTD probes • Secchi disk

Chemical monitoring

Chemical measurements are of major importance when a contaminated (but not exceeding national quality standards) dredged material is deposited. Analysis of chemical components is necessary to ensure that unacceptable accumulation of these components does not occur. It also can be useful to trace the dispersion of the dredged spoil and assess any minor accumulation of material not detected by bathymetric surveys.

It is recommended that the choice of contaminants to be monitored should depend primarily on the ultimate purposes of monitoring as well as contamination patterns of sediments to be dredged. Most often chemical analyses include following trace metals, as indicators of anthropogenic contamination: cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn). In addition the concentrations of organic chemicals of concern can be determined if there are known sources of contamination or historic inputs. Based upon local information on sources of contamination the list of substances to be analysed may include: polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), tributyltin compounds (TBT), polychlorinated dibenzodioxins/polychlorinated dibenzofurans (dioxins), total petroleum hydrocarbons (TPHs), organochlorine pesticides, etc.

There is no need to monitor regularly for all contaminants at all sites. The results obtained during the pre-investment stage can be helpful in defining the background (reference) values of particular chemical substances, which can be used in further monitoring studies.

Table 2. Basic range of chemical monitoring

Purpose	Component	Parameters	Monitoring tools
Identify contamination	Water	• pH, O_2, PO_4^{3-}, P (total), NH_4^{3+}, N (total), NO_2^-, NO_3^-, oxygen demand • Heavy metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn) • Organic chemicals (list of chemicals site specific)	• Water sampling (bathometer) • Standard laboratory analyses
	Bottom sediments	• Grain size composition • Heavy metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn) • Organic chemicals (list of chemicals site specific)	• Sediment sampling (grab samplers) • Standard laboratory analyses

Biological monitoring

The effect of dredged material disposal from a biological perspective usually involves monitoring for impacts to specific resources (e.g., hard clams) or general changes in community structure and function. However, biological changes will also reflect responses to either physical or chemical alterations. Deposition of dredged material contributes to the increase the turbidity and decrease in transparency of water, which has an impact on pelagic organisms: phytoplankton, zooplankton and fish and birds feeding in the water column. These disturbances have short-term character. During these studies, phytoplankton and zooplankton may be omitted due to high seasonal and spatial variability.

In the first instance, macrozoobenthos is recommended to undergo monitoring research because contaminated sediments may have an adverse impact on the habitat of these organisms. Where either physical or chemical effects at the seabed are expected, it will be necessary to examine the benthic community structure in areas where dredged material disperses. In the case of chemical effects, it may also be necessary to examine the chemical quality of the biota (including macrozoobethos and fish).

When it comes to birds and mammals monitoring, the specific scope of monitoring is closely associated with the location of a dumping site. If the results of other monitoring programs or researches are not available, the observation of both birds and mammals should be included to the monitoring program.

Table 3. Basic range of biological monitoring

Purpose	Component	Parameters	Monitoring tools
Assessment of biotic elements	Macrozoobenthos and invasive species	• Taxonomic composition • Abundance • Biomass	• Grab samplers • Dredge
	Fish	• Taxonomic composition • Abundance • Morphometric traits, size and age of specimens • Spawning grounds (if there are no available data from the study area)	• Net • Trawl • Analysis of sediment spreading • Video investigations
	Birds*	• Taxonomic composition • Abundance (if there are no available data from the study area)	• Observation
	Mammals**	• Taxonomic composition • Abundance (if there are no available data from the study area)	• Observation
Chemical pollution***	Bivalves	• Heavy metals content (Pb, Cd, Cu, Hg, Zn) in soft tissue • Persistent organic pollutants in soft tissue	• Standard laboratory analyses
	Fish	• Heavy metals content (Pb, Cd, Cu, Hg, Zn) in muscle and liver • Persistent organic pollutants in muscle and liver	• Standard laboratory analyses
Health state***	Bivalves	• Histopathological tests, MN, NOR	• Dredge • Standard laboratory analyses

*Monitoring of birds is only recommended if there are well-known areas of their wintering in close vicinity to the disposal site

** Monitoring of mammals is only recommended if there are well-known migration routes in close vicinity to the disposal site

*** Relevant if considerable chemical contamination of water/sediments were identified in frame of chemical monitoring

4.3. Step 3: Predicting biological responses and developing testable hypotheses

This aspect of program development requires:

- quantitative estimates of alteration of each physical/chemical parameter of concern;
- best available information on the levels of response of target resources to these alterations;
- identification of critical threshold levels;
- application of threshold levels to develop criteria for a management decision.

Detailed review on the physical/chemical alterations, occurring around the dredging and disposal operations as well as available information concerning the effects of these alterations on fishes and shellfishes is available in Lunz and LaSalle (1986).

Specific information is needed on the range of a parameter within which a particular organism is capable of normal behavior. The upper limit of the range may be used as a threshold level at which a decision to alter operations must be made. The following example illustrates the process of defining a critical threshold and developing a testable hypothesis:

A species of mussel known to occur in the vicinity of the project area is known to be tolerant (exhibiting normal feeding behavior) of total suspended sediment (TSS) concentrations up to 500 mg/l, above which it responds by valve closure for periods of up to 6 to 10 hours without undue harm. Levels of TSS during a disposal event are expected to be as high as 500 mg/l at the surface and 1,000 to 2,000 mg/l near the bottom within 500 m of the disposal site for up to 1 hour after each disposal event. Disposal events will occur about 10 to 12 hours apart. Given this information and the concern about mussels in the immediate vicinity of the disposal site, a monitoring effort might include periodic (e.g., every fifth disposal event) measurement of TSS concentrations 1 hour after an event to determine if site conditions do result in rapid settling of material and a return to ambient conditions (within 500 mg/l) for a reasonable period of time between disposal events (to allow mussels periods of time to feed normally).

An example of a tiered approach to this issue would include specific conditions that would trigger more extensive monitoring of the situation, if warranted. For example, as long as levels of TSS return to less than 500 mg/l within 1 hour after every fifth disposal event, no further action is taken. If, however, the concentration of TSS exceeds 500 mg/l after 1 hour, a second measurement is taken after 2 hours to assess the situation. If, after the second measurement, TSS concentrations remain above 500 mg/l, the next disposal event is delayed for a period of time to allow TSS concentrations to return to ambient conditions for a period of a few hours. Note the use of specific TSS concentrations and time periods as critical threshold levels and the switch to more frequent sampling if the first threshold level is exceeded.

4.4. Step 4: Sampling strategy and methods

The ways in which data are gathered (sampling methods) and analysed (statistical methods) will determine their usefulness in drawing conclusions about the given study. Considerations of sample size (areal coverage or volume), number of samples and frequency of sampling, while important for statistical reasons, are often limited by constraints of handling and processing. Processing of benthic samples, including sorting and taxonomic identification is very time consuming, thereby limiting the number of samples that can be reasonably taken and processed from both a cost and scheduling perspective. Similar considerations are necessary with most types of samples, either physical or biological.

In determining the spatial extent should take into account the size of the area designated for depositing, mobility of deposited material and water movements that will determine the direction and scope of sediment transport. This can cause potential limitation of sampling. Note, however, that the distribution and number of sampling stations should be sufficiently representative to verify a research hypothesis, and to detect environmental changes.

The frequency of survey will depend on a number of factors. Where a disposal operation has been going on for several years, should also take advantage of existing data.

Table 4. Sampling strategy in physical, chemical and biological monitoring

Type of monitoring	Sampling stations	Component	Frequency	Tool/method
Physical monitoring	**Echo-sounding profiles** covering the dumping area by equal intervals **Sediment sampling stations** (evenly distributed along the whole area and outside the immediate area of impact)	**Sea bottom topography and sediment spreading**	**Once a year**	**Echo-sounder** **Side-scan sonar** **Grab samplers**
	Sediment sampling stations (along the perimeter of dumping area and in the central part)	**Type of surface sediments**	**Twice a year**	**Grab samplers** **Standard lab analysis (grain size)**
	Water sampling stations (along the perimeter of dumping area and in the central part)	**Hidrological parameters (surface and bottom of the water column)**	**Each season (four times per year)**	**Bathometers** **CTD probes, etc.**
Chemical monitoring	**Sediment sampling stations** (along the perimeter of dumping area and in the central part)	**Chemical composition of surface sediments**	**Twice a year**	**Grab samplers** **Standard lab analysis (chemistry)**
	Water sampling stations (along the perimeter of dumping area and in the central part)	**Hidrochemical parameters (surface and bottom of the water column)**	**Each season (four times per year)**	**Bathometers** **CTD probes, etc.** **Standard laboratory analyses (chemistry)**
Biological monitoring	**Sediment sampling stations** (evenly distributed along the whole area and outside the immediate area of impact)	**Macro-zoobenthos and invasive species**	**Once a year**	**Grab samplers**
	Selected profiles	**Bivalves**	**Once a year** (in parallel with the collection of macrozoobenthos samples)	**Dredge**
	Designated transects (number of trawls representative for the area of dumping site)	**Fish**	**Once a year** (5-10 organisms per species with similar size and/or weight)	**Net** **Trawl**

Temporal sampling frequency is highly dependent on the anticipated level of impact and the temporal physical and biological site variability.

The results of monitoring (or other related research) should be reviewed at regular intervals in relation to the objectives and can provide a basis to:

- modify or terminate the field monitoring program;

- modify or revoke the permit;
- redefine or close the dumping site;
- modify the basis on which applications to dump wastes are assessed.

Summary

Monitoring program is usually specific to a particular place, but should be also flexible, cost-effective and based on scientific methods. Monitoring program should detect environmental changes and to assess compliance with the conditions specified in the permit for storage. Monitoring program of a dumping site should be one of many elements within the integrated management of dredged material.

References

Environmental Quality Standard Directive 2008/105/EC.

Fredette T.J., Nelson D.A., Clausner J.E., Anders F.J. 1990. “Guidelines for physical and biological monitoring of aquatic dredged material disposal sites”, Technical Report D-90-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Guidance document for the development of site management plans for ocean dredged material disposal sites (US Environmental Protection Agency, US Army Corps of Engineers), 1996.

HELCOM Guidelines for the Disposal of Dredged Material at Sea, 2007.

Lunz, J. D., and LaSalle, M. W. 1986. "Physicochemical Alterations of the Environment Associated w4.th Hydraulic Cutterhead Dredging," Entrainment-of ftiters. American Malacological Bulletin, Special Edition No. 3, pp 31-40.

Marine Strategy Framework Directive 2008/56/EC

Moriarty, F. 1983. Ecotoxicology. Academic Press, New York.

OSPAR Guidelines for the Management of Dredged Material, 2009.

QA/QC Directive 2009/90/EC.

Specific Guidelines for Assessment of Dredged Material (LC), 2000.

Water Framework Directive 2000/60/EC.