Biodiversity Series

Environmental Impacts to marine species and habitats of dredging for navigational purposes

OSPAR Commission

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The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

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Executive Summary

Annex V to the OSPAR Convention requires that Contracting Parties take measures to protect the maritime area against the adverse effects of human activities. It is recognised that removal of sediments may have adverse impacts on marine species and habitats. Impacts may be due to physical or chemical changes in the environment at the dredging site. The extent of such impacts depends on the characteristics and the sensitivity of the area dredged, and of the dredging technique applied.

This background document assesses the need for additional OSPAR measures to control the effects of dredging activities on species and habitats. It includes a concise summary of knowledge available on dredging techniques with a special view on their environmental impacts and a brief description of the most important impacts, including references (in Appendix 1) which provide more detailed information.Based on the experience of Contracting Parties, gaps of knowledge and the need for further investigations and the development of techniques or approaches to investigate, assess and minimise impacts due to dredging for navigational purposes are identified. Furthermore, gaps in regulations and guidance are pointed out.

This background document mainly aims at the assessment of the need for additional OSPAR measures to control the effects of dredging activities on species and habitats.

Récapitulatif

L'annexe 5 à la Convention OSPAR porte que les Parties contractantes prennent des mesures afin de protéger la zone maritime contre les effets préjudiciables des activités de l'homme. Il est reconnu que l'enlèvement des sédiments peut avoir des influences préjudiciables sur les espèces et les habitats marins. Les impacts peuvent être dus aux bouleversements physiques ou chimiques de l'environnement des lieux du dragage. L'ampleur de ces impacts dépend des caractéristiques et de la sensibilité de la zone draguée ainsi que de la technique de dragage employée.

Dans le présent document de fond, l'on juge de la nécessité de mesures OSPAR complémentaires qui viseraient à combattre les effets que les opérations de dragage ont sur les espèces et les habitats. Il comprend un résumé concis des connaissances que l'on a des techniques de dragage, tout en insistant sur leurs impacts environnementaux ; il comprend de plus une brève description des impacts les plus importants, avec des renvois bibliographiques (en appendice 1) qui donnent des renseignements plus approfondis. Sur la base de l'expérience acquise par les Parties contractantes, les lacunes des connaissances et la nécessité de poursuivre les études et de développer des techniques ou des stratégies d'étude, d'appréciation et de minimisation des impacts dus au dragage d'entretien des voies de navigation sont déterminées. De plus, les lacunes de la réglementation et des lignes directrices sont mises en évidence.

Le présent document de fond a principalement pour but de juger de la nécessité de mesures OSPAR complémentaires visant à combattre les effets que les opérations de dragage ont sur les espèces et les habitats.

1. Introduction

Annex V to the OSPAR Convention requires that Contracting Parties take measures to protect the maritime area against the adverse effects of human activities.

Dredging is essential to maintain navigation in ports, harbours and navigation channels as well as for the development of such facilities. It is recognised that removal of sediments may have adverse impacts on marine species and habitats. Impacts may be due to physical or chemical changes in the environment at the dredging site. The extent of such impacts depends on the characteristics and the sensitivity of the area dredged, and of the dredging technique applied.

The OSPAR Guidelines for the Management of Dredged Material which cover issues related to the disposal of dredged material, encourage Contracting Parties to exercise control over both, dredging and disposal operations in order to minimise the impacts. Technical Annex III to the Guidelines include guidance on how to minimise the effects on the environment of dredging operations. However, these guidelines do not commit Contracting Parties to control dredging operations.

The background document includes a concise summary of knowledge available on dredging techniques with a special view on their environmental impacts and a brief description of the most important impacts, including references (in Appendix 1) which provide more detailed information.

Based on the experience of Contracting Parties, gaps of knowledge and the need for further investigations and the development of techniques or approaches to investigate, assess and minimise impacts due to dredging for navigational purposes are identified. Furthermore, gaps in regulations and guidance are pointed out.

This background document mainly aims at the assessment of the need for additional OSPAR measures to control the effects of dredging activities on species and habitats.

2. Different types of dredging techniques with a view on environmental impacts

The issue of impacts of dredging and dumping of dredged material to species and their habitats has been discussed at several meetings of OSPAR Working Groups on sea-based activities (SEBA), on impact in the marine environment (IMPACT) and on the use of and impact on the seabed (SEABED). Available information (*inter alia* received from Contracting Parties through the Questionnaires and available from other literature) has been compiled and summarised in Appendix 1.

In the report of Romke van der Veen (1993) a very detailed survey of dredging methods, a qualitative assessment of their effectiveness in environmental terms and their applications, as well as detailed recommendations for improving existing and developing new dredging methods are given. In this report, 31 dredging techniques (mechanical, hydraulic, mechanical/hydraulic) are assessed. Each of the techniques was scored on the basis of:

- safety of the operating crew;
- the dredging accuracy (selectivity) both
  - vertically, and
  - horizontally;
- dispersion beyond the area to be cleaned, both during and after dredging;
- mixing of clean and polluted soil;
- spillage during and after dredging;
- dilution during dredging.

The assessment presents the differences in the environmental effectiveness of dredging techniques. Of the existing methods, purely mechanical approaches such as grab cranes and digger buckets have the lowest ranking, although they result in higher concentrations of solids in the material dredged than hydraulic techniques. Mechanical/hydraulic systems such as auger dredgers and disc cutter dredgers perform best. In the category of mechanical shovelling and scooping methods, the amphibious grab dredger and the watermaster with digger bucket were considered to be the least appropriate techniques to dredge contaminated sediments, as they produce holes in the sea/river bed, are not suitable for removing thin layers, and lead to dispersal of sediments. The scraper dredger and the enclosed bucket conveyor are the most environmentally effective mechanical techniques. Also a bucket dredger can still be quite appropriate for dredging contaminated sediments.

The most appropriate hydraulic dredgers to remove contaminated sediments are the silt box with a positive displacement pump and the Pneuma silt suction system. According to the assessment, the trailing dredger is the least suitable technique for contaminated sediment dredging, as it causes dispersal of sediments and mixing with surrounding sediments. Furthermore, the method cannot be used to remove thin layers. According to the ranking, the water injection technique is not as critical as the trailing dredger for removing contaminated sediments, however is still ranked low.

Generally, the highest scores were assigned to the combined mechanical/hydraulic techniques and these can be considered to be most effective in dredging contaminated soils. However, the cutter dredger and the chain silt slicer cause relatively high spillage and dispersal of sediments and thus are less appropriate.

Most dredging methods were developed for capital dredging and maintenance dredging of channels and harbours. Remediation of contaminated beds imposes different requirements on the dredging techniques. These requirements largely concern the complete removal of sediment layers, which are often thin, without increasing the turbidity of the water in the area. During remediation dredging the main threats to the environment occur during excavation, i.e. breaking the cohesion of the soil and forming breaches or trenches, and the vertical transport of the soil through the water. Increased turbidity of the water during maintenance dredging due to excavation and raising material to the surface will not have any adverse effects, particularly if there is no current. However, when contaminated beds are remediated a mopping up pass will be required.

Combined mechanical/hydraulic techniques are recommended for the removal of relatively thin layers of sediment (approx. 0,5 m). The selection from the techniques with high ratings, such as the auger dredger with shield, disc cutter suction dredger with screens, shovelling suction silt plough, conventional auger suction dredger and cutter suction dredger with Otter head is determined, in part, by the site conditions. These include: size of the harbour or canal, water depth, currents, slopes and the presence of any large wastes. Conventional maintenance dredging methods can be used for the removal of thick layers of polluted sediment, as long as there is no dispersal beyond the affected area. Some general operating precautions, such as avoiding hopper overflow will suffice. One of the techniques identified above could then be used to remove the spillage.

In document SEBA 99/12/Info.1, and to some extent in document SEBA 99/12/1, both presented at SEBA 99, an overview of knowledge on hydrodynamic dredging techniques (presented by CEDA and Germany) is given. For maintenance of some harbours and sedimentation areas lying parallel to the navigation channel, silty sediments are removed by water injection dredging. Sediments are resuspended by the injection of water with low pressure and subsequently are transported as a density flow or by natural currents occurring at the dredging site. The application of the water injection procedure is restricted to areas, where no harmful oxygen depletion and remobilisation of contaminants is to be expected. Mechanical agitation dredging is only applied in small harbour areas or other small sedimentation areas that are difficult to access. Hydrodynamic dredging [c.f. SEBA 99/12/Info.1-E] results in an increase of turbidity. In case of water injection dredging the increase of turbidity usually has its maximum close to the bottom. Depending on the material dredged, oxygen depletion may occur. However, it is generally limited to the direct surrounding of the dredging site and in tidal waters, no enduring impact was observed [Netzband, 1999]. If sediments are contaminated, remobilisation of contaminants can occur and contaminants associated with the fines can be spread with limited control of the transport.

As natural events may also result in resuspension of sediments and increased turbidity, the assessment of impacts requires consideration of natural as well as dredging conditions. Hydrodynamic dredging can only be undertaken under suitable circumstances. First of all, the material to be removed needs to be susceptible to transport by the water column. Secondly, the water needs to flow in the direction where the transported material is intended to go to and where it does not interfere with other interests. In general, promising areas for application may be:

- Areas with high natural sediment concentrations;
- Areas with erodable material;
- Areas with a potentially high current velocity, either natural or artificial;
- Areas in the vicinity of deep troughs;
- Areas with material of low level of contamination.

Some of the limitations (mentioned in Hydrodynamic dredging: Principles, effects and methods – SEBA 99/12/Info.1) are:

- Restricted control of the destination of agitated material: sedimentation at undesired places such as shipping lanes and harbours should be avoided.
- In the case of contaminated material, dredging will spread the pollution, which is not desirable. Some forms of hydrodynamic dredging are in many of these cases less advisable, as effects might be more serious.
- Substances, which consume oxygen, nutrients and harmful materials, bonded to the sediments, can relatively easily be released into the water and thus reduce its oxygen content or cause an increase in the concentration of nutrients or harmful materials.
- A relative enrichment of the coarse fraction ('armouring') will occur in the dredged area, which will make the area less susceptible to erosion, also making future hydrodynamic dredging operations more difficult. Then normal dredging techniques can be applied.
- The effectiveness is difficult to measure directly because the density transition zone between the solid sea/river bed and the water column prevents accurate acoustic surveys being carried out. However, with measurement of other parameters, like turbidity or nautical bottom, results can be analysed.
- The sometimes occurring visual effect of clouding or colouring of the surface water by hydrodynamic dredging, especially when raising material to the water surface, is not always allowed or desired. This clouding does not necessarily lead to environmental damages.

The potential environmental impact must be evaluated in relation to the natural situation. The natural sediment concentrations in the water, especially under storm conditions or high (river) transport situations, are frequently similar to or even larger than that which is attained by hydrodynamic dredging. In assessing the environmental impact of hydrodynamic dredging, the total quantity of material brought into suspension should be considered, in conjunction with sediment concentrations and duration of the works. Also, natural seasonal variations could make hydrodynamic dredging (and even normal dredging) more acceptable in one season than in another. Even tidal variations, in-going or out-going current, can make a considerable difference. Therefore proper planning of any type of dredging works is essential.

More details on environmental effects of water injection dredging and other types of hydrodynamic dredging, including sidecast dredging, are described in SEBA 99/12/Info.1-E.

3. The most important impacts

The potential (negative) impacts of (conventional) dredging activities on species and their habitats can, arbitrarily, be described as:

- Substrate removal and thus habitat and species removal (recolonisation or recovery of disturbed areas may be possible);
- Alteration of bottom topography and hydrography, and thus destroying of local habitats and the risk of direct physical/mechanical stress to the species present;
- Alteration of sediment composition, i.e. of substrate characteristics in the surrounding of the dredging site, resulting in a change of the nature and diversity of benthic communities, e.g. decline of individual density, species abundances or biomass;
- Local resuspension of sediments and increase of turbidity.

Dredging generally causes to some extent an increase of turbidity that may be regarded as indicator for potential ecological impacts, as resuspension of sediments may give rise to various adverse effects on the environment. These include:

- Spread of sediments and associated contaminants in the surroundings of the dredging site;
- Transport of sediments, particularly of finer fractions, and possibly adsorbed contaminants from the dredging area to other (possibly more sensitive) areas, there resulting possibly in an increase of contaminant concentrations;
- Release of nutrients, increase in eutrophication;

- Introduction of new species;
- Consumption of oxygen, generally limited to the direct surroundings of the dredging site. In tidal waters, no enduring impact is to be expected;
- Impact on pelagic and benthic organisms (e.g. decrease of primary production due to reduced transparency of the water column, smothering) may occur, but is less important at the dredging site than at the disposal site;
- Mixing of interstitial water with sea water, turbidity plumes and resuspension may change the physical/chemical equilibria, with a potential to release contaminants into the water phase (remobilisation), especially in suspensions of anoxic silty sediments, to enhance the bioavailability and ecotoxicological risk of the already present (background) contaminants (e.g. heavy metals), and to chemical or biochemical changes of contaminants;
- Bioaccumulation.

Hydrodynamic and sidecast dredging activities are using the principle of deliberate (re)suspension of the fine fraction of sediment from the sea/river bed with the aim of removing this material from the dredging area using natural processes for transportation. Some of the potential impacts described above (and in SEBA 99/12/Info.1) are:

- In the case of contaminated material, hydrodynamic dredging will spread the pollution, which is not desirable. If sediments are contaminated, remobilisation of contaminants can occur and contaminants associated with the fines can be spread with limited control of the transport.
- Substances, which consume oxygen, nutrients and harmful materials, bonded to the sediments, can relatively easily be released into the water and thus reduce its oxygen content or cause an increase in the concentration of nutrients or harmful materials.
- A relative enrichment of the coarse fraction ('armouring') will occur in the dredged area, which will make the area less susceptible to erosion, also making future hydrodynamic dredging operations more difficult.
- The sometimes occurring visual effect of clouding or colouring of the surface water by hydrodynamic dredging, especially when raising material to the water surface, is not always allowed or desired. This clouding does not necessarily lead to environmental damages.

4. Gaps in knowledge and need for techniques to minimise, to investigate and to assess environmental impacts

Although, information on impacts of many dredging techniques exists, there is still a need for information on impacts caused by some dredging techniques, such as agitation and water injection dredging, silt wing, hydro digger.

Contracting Parties stated a need to improve or develop bioassays and their assessment. In addition, guidance for habitat mapping, approaches to predict sediment transport and to verify model predictions should be further developed. Furthermore, an approach to distinguish impacts of dredging and natural variability or impacts from other human activities should be developed. However, most of these issues also apply to and may be even more important for disposal sites, and therefore should be dealt with under the revision of the OSPAR Guidelines for the Management of Dredged Material.

Modelling of turbidity during dredging is already under development in the project TASS (Turbidity Assessment Software System) under the lead of the Netherlands.

Although cumulative effects at the dredging site are to be expected, they were not specifically studied. However, no need for further investigations was stated. This may be due to the fact that sites where maintenance dredging is carried out frequently, usually are not of high ecological value.

In order to minimise impacts of dredging, techniques for selective dredging should be further developed. Furthermore, techniques to minimise turbidity generated by dredging, should be improved.

5. Existing regulations for and measures taken to control environmental impacts of dredging operations

No specific OSPAR measures to control impacts of dredging operations exist. However, the OSPAR Guidelines for the Management of Dredged Material (Reference Number: 1998-20) encourage Contracting Parties to exercise control over dredging operations in order to minimise the impacts. The Technical Annex III to the Guidelines includes guidance on how to minimise the effects of dredging operations on the environment. However, Contracting Parties are not obliged to control dredging operations.

Council Directive 97/11/EC of 3 March 1997 amending Council Directive 85/337/EWG of the European Community requires environmental impact assessments in case of capital dredging operations.

All Contracting Parties which responded to the questionnaire regulate dredging activities by national laws and recommendations. However, only a few Contracting Parties report that environmental impact assessments are required for each maintenance dredging project. Generally, impact assessments are carried out in special cases with a high risk of environmental impacts, e.g. in sensitive or highly contaminated areas.

Almost in all Contracting Parties, regulatory authorities/agencies impose restrictions in cases where negative environmental impacts due to dredging were observed or are expected. Restrictions include e.g. use of protective or mitigating measures in order to minimise effects of dredging, such as silt screens or sealed grabs. Furthermore, temporal or seasonal restrictions for dredging are imposed. A potential stop of a dredging operation is not common practice, and was reported by one Contracting Party only.

It should be kept in mind that controlled application of available techniques rather than applying mitigating measures might be sufficient to minimise environmental impacts of dredging.

6. Gaps in regulations and guidance

At present, guidance on how to optimise dredging and to minimise impacts of dredging operations as given at Technical Annex III of the OSPAR Guidelines for the Management of Dredged Material is regarded as sufficient, this all the more since dredging operations are very complex processes depending on local conditions for which detailed guidance cannot be provided in general terms. However, a compilation of basic information on dredging activities actually carried out with different techniques is regarded as important. Existing guidance should be updated according to the development of techniques.

Regulations and guidance for the assessment of environmental impacts due to relocation of dredged material by agitation dredging or other related methods do not exist. Contracting Parties had no common position with regard to the need of measures to control the effects resulting from the use of these techniques. One Contracting Party did not and some Contracting Parties see a requirement for additional measures, whereas others did not take a firm position on this issue. SEABED 2002 agreed that it seemed that there was no need for additional measures to exercise control on the relocation of dredged material set off by hydrodynamic and sidecast dredging. This issue would be dealt with under the revision of the OSPAR Guidelines for the Management of Dredged Material.

7. Identification of further actions required

The outcome of SedNet (European Sediment Research Network) and of the TASS project should be followed, and if appropriate, considered in further development of guidance.

Exchange of knowledge should be improved. It could minimise the efforts for further developments. A compilation of dredging activities actually carried out with different techniques could be a first step of exchange of knowledge. Furthermore, in order to deal with a potential lack of understanding between regulating authorities and contractors, an 'independent expert group' could be established under OSPAR, which can be consulted by parties involved in dredging activities.

In addition to the assessment of impacts on marine species and habitats, also impacts on fisheries resources (spawning/nursery grounds), on commercial fisheries and shell fisheries and on other uses of the sea should be considered.

More generally, the replies of France and Germany to the questionnaire indicate the need for regulations aiming at the reduction of contaminants at their sources. However, such regulations probably will result from the implementation of the EU water framework directive.

8. Need for additional OSPAR measures to control the effects of dredging activities on species and habitats

One Contracting Party proposed that a measure aiming at the control of turbidity during dredging operations should be adopted. All other Contracting Parties and CEDA did not propose specific additional measures to control dredging operations and the related impacts.

In most cases, existing EU and national regulations will be sufficient to minimise adverse effects on marine species and habitats of dredging. Controlled application of techniques available may already reduce impacts sufficiently.

Control can be implemented properly only if the impact of dredging techniques to the environment is well understood, and there is still a need for further research. In addition, approaches to assess impacts need to be improved.

General measures to control impacts of dredging might be inadequate, as case and site specific impacts require an approach which is site specific and takes into consideration the dredging technique applied.

Concluding, there was no consensus for the need to develop additional OSPAR measures to exercise specifically control on the effects of dredging operations on marine species and habitats.

Appendix 1: Bibliography of literature available on dredging and disposal techniques with a special view on their environmental impacts

1. Contaminated Sediment Remediation - Dredging Polluted Bed Materials - A Study of Environmentally effective Dredging Methods - Romke van der Veen (1993)

The study consists of several parts. In order to assess and rank techniques by environmental effectiveness and practicability the factors relevant to these aspects were identified. Firstly, the definition of sediments to be remediated was considered, this covered the following aspects of locations requiring remediation:

- environment;
- size;
- soil type;
- water flow/currents;
- contaminants;
- accessibility;
- soil investigations required.

The dredging process was then considered in greater detail and in consultation with the client three conditions were selected which the techniques have to fulfil when removing polluted sediment:

- precise separation between the polluted soil and its environment: i.e. the volume of clean soil removed should be minimised;
- no loss or escape of polluted soil to clean or cleaner sediment or the surrounding water;
- preferably, the *in situ* density of the soil should be maintained.

These conditions were then developed into quality criteria to be fulfilled by the dredging process:

- safety of the operating crew;
- the dredging accuracy (selectivity) both
  - vertically, and
  - horizontally;
- dispersion beyond the area to be cleaned, both during and after dredging;
- mixing of clean and polluted soil;
- spillage during and after dredging;
- dilution during dredging.

The various dredging methods are also described. This fairly theoretical study is followed by a list and short descriptions of the techniques used or proposed by contractors in the Netherlands for the remediation of polluted sediment (i.e. the known techniques). Some developments in other countries, particularly the United States and Japan are also discussed.

The techniques to be assessed were divided into three groups, based on their operating principles: mechanical, hydraulic and combined mechanical/hydraulic techniques. This classification facilitates the assessment which is based on a comparison of the techniques. Given the wide range of techniques and the diversity of locations to be cleaned up, all with different conditions, a classification by application also had to be used.

Once this method had been applied to known techniques it was determined to what extent obvious improvements could be made and whether completely new methods would meet the quality criteria to a greater extent. This resulted in some 16 new, unknown techniques. These techniques were also classified by environmental effectiveness and potential applications.

Results

Preparation

The accuracy of the soil investigations is one of the factors which determines the accuracy to which polluted sites can be cleaned up by dredging. The dredging accuracy determines the total volume of soil to be removed and thus the costs of further processing or storage. The volume of dredged material to be processed or stored will always be greater than the volume of soil *in situ*. A factor two is not uncommon, particularly if thin layers of only about 50 cm have to be removed.

Dredging

The aspects of the dredging process which are mostly likely to affect the environment are soil removal (excavation) and the vertical transport of the dredged material to the surface of the water. Mechanical/hydraulic methods are inherently more environmentally effective than purely mechanical or hydraulic methods. Mechanical/hydraulic methods are used in dredgers which remove the soil mechanically, by cutting or scooping it up, and then transport the dredged material hydraulically using pumps and pipes. Mechanical digging generally leads to less disturbance than hydraulic methods and suspends less soil in the water. Hydraulic transport is carried out in enclosed systems, thus the dredged material does not come into contact with the surrounding water.

Assessment of environmental effectiveness

The assessment of the environmental effectiveness of the methods was based on the quality criteria defined earlier, which were assigned weighting factors. The report is based on a prioritisation, which resulted in a selection of techniques leading to the best results when removing polluted soil. Safety and accuracy were given high priority, the mixture concentration a low priority. This assessment resulted in a ranking. The assessment demonstrates that the environmental effectiveness of dredging methods does indeed vary. Of the existing methods, purely mechanical approaches such as grab cranes and digger buckets have the lowest ranking. Mechanical/hydraulic systems such as auger dredgers and disc cutter dredgers perform best. Even better results are to be expected if auger suction dredgers and disc cutter dredgers are fitted with environmental protection features such as screens around the suction head and process controls.

Further to this ranking another four assessments were undertaken based on different priorities. However, the leading group always included the same dredging methods. It may therefore be assumed that these methods perform best on most criteria.

Applications

The assessment of the potential applications of the dredging methods on the basis of the various aspects relating to remediation sites listed above was not based on a weighting system. Instead, this assessment was based on the experience of the author. It would have been impossible and unproductive to rank the methods by their suitability for various areas as these methods can often be used for a wide range of applications or may be modified to suit. Each technique was assessed and ranked by its environmental effectiveness. The scope of application was also identified. The size of the dredging location was the most important criterion. Grab cranes may be used in shallow docks and watercourses with many jetties, obstacles and large objects. The mechanical/hydraulic methods referred to earlier can be used in larger and unrestricted areas.

Improvements and developments

The proposed improved dredging methods and new developments were also included in the assessment of environmental effectiveness and applications. This indicated that improvements may indeed lead to better results. Examples include the improved vacuum cleaner mouth and the improved plough suction dredger. New developments may also result in high environmental effectiveness. For example the use of covers combined with sludge pumping. However, the practicability of such methods has yet to be determined.

Conclusion

This study indicated that there is a number of dredging methods for the environmentally effective removal of thick and thin layers of polluted sediment. However, the environment will always be affected to some extent, quite apart from similar external disturbances such as shipping.

New methods will have to be developed if any environmental impact has to be avoided in the event that the dispersal of certain pollutants may have particularly serious consequences, e.g. when radioactive waste or highly toxic materials have accumulated in hot spots.

2. Environmental effects of dredging/dumping of dredged material – Germany (SEBA 98/9/5)

Dredging generally causes to some extent an increase of turbidity that may be regarded as indicator for potential ecological impacts, as resuspension of sediments may give rise to various adverse effects on the environment. These include transport of sediments and possibly adsorbed contaminants from the dredging area to other areas, release of nutrients, consumption of oxygen, remobilisation of contaminants and decrease of primary production due to reduced transparency of the water column. Impact on benthic organisms (e.g. smothering) may occur, but is less important at the dredging site than at the disposal site. A study carried out in The Netherlands confirms that turbiditiy is reduced shortly after the dredging operation ceased [Pennekamp et al., 1996].

Volume and density of the material dredged is of significance for potential environmental effects at the disposal site.

The compilation being prepared in Germany will describe and assess the techniques with respect to their

- risk of increasing turbidity due to excavation and losses during transport;
- ability to dredge selectively and accurately sediments in horizontal and vertical directions in order to minimise the volume to be dredged and disposed of and to facilitate, if necessary, the separate dredging of contaminated and uncontaminated material;
- need of additional water to loosen sediments.

It also includes measures to mitigate environmental impacts, as e.g. silt screens or the shielding of excavation tools.

Mechanical techniques can dredge the sediment in almost in-situ density. Most of them cause quite low turbidity during the excavation procedure. However, additional losses of material occur during the vertical transport from the bottom to the barge or scow. The turbidity plume extends throughout the entire water column. The use of watertight grabs can reduce the loss of material. The methods can work quite selectively.

Hydraulic techniques usually need the addition of water to dredge the sediment. Thus mixture concentrations are low and turbidity due to the loosening of material occur. As dredged material is transported through pipelines, no further losses of material occur. In new techniques, water can be recirculated, resulting in less resuspension of sediment. Selective uptake by pure hydraulic dredging usually is poor.

When operating a trailing suction hopper dredger with overflow, turbidity increases due to suspended particles in the overflow water. Suspended solid concentrations depend on the type of sediments dredged. Concentrations were observed that are about 3 times [Pennekamp et al., 1996] and up to 16 times [Canada Environment, 1994 and quotations therein] higher compared to operation without overflow. In particular, fine grained material having high adsorption capacity for contaminants, is removed with the overflow and thus the potential of dispersing sediment-associated contaminants is quite high.

Resuspension rates are generally higher with mechanical dredgers than with hydraulic ones operating without overflow, if the material to be dredged is fine and non-cohesive. In cohesive sediment however, mechanical dredging causes lower suspended matter concentrations, as pure hydraulic dredgers usually require water jets to loosen the material and thus generating large turbidity plumes.

Combined mechanical/hydraulic techniques are less sensitive to turbidity, as material is loosened by mechanical means and no loss of the material is to be expected during transport through the water column. Furthermore, concentrations of the material dredged are between those of mechanical and hydraulic methods. With some of these techniques selective dredging is possible.

Hydraulic agitation dredging that applies the injection of water to loosen sediments, results in a resuspension of material and thus in increased turbidity. Suspended sediment concentrations that are elevated compared to those of mechanical dredging and non-overflow conditions had been observed [Canada Environment 1994] at different depths with a maximum at the bottom. Similar high concentrations of suspended particles at the bottom had been measured during dredging with a mechanical bottom leveller. However, concentrations decreased more distinct with distance from the bottom than with the water injection dredger. Both methods have the advantage that sediments are not transported by technical equipment but either by density currents or by natural currents at the dredging site. As mainly the fines are transported, the potential for dispersing contaminants adsorbed to the fines, increases. More detailed information from field studies on the effects of water injection dredging in the tidal Elbe will be available in 1999 [Strom- und Hafenbau, in prep.].

Sidecast dredging is defined as uptake of dredged material with a suction dredger and direct disposal, i.e. without storage, via a pipeline or by jetting. In Germany, this technique is not applied, however in the USA. Information on its application by Contracting Parties is scarce. No investigations into the effects were available for this overview. However, a strong increase in turbidity is to be expected. The effects should be comparable to those of conventional pipeline discharge, except that the "disposal site" always is just the waterbody adjacent to the dredging site.

Furthermore, special techniques, e.g. pneumatic dredgers, had been developed, which only cause a small increase of turbidity.

To assess the extent of the effects on the environment, not only the environmental aspects of the dredging techniques but the local circumstances in and around the dredging area have to be considered also, including the type of sediment, i.e. its sensitivity to resuspension and the hydrodynamic conditions of the water (e.g. current velocity, water depth).

3. The Use of Agitation Dredging, Water Injection Dredging and Sidecasting in the UK – Results of a Survey of Ports in England and Wales - United Kingdom (DUMP 00/4/Info.2)

Abstract

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) carries out a diverse range of scientific research, advice and monitoring into aspects of the marine environment. The Regulatory Assessments Team work within CEFAS to provide expert scientific advice to the Ministry of Agriculture, Fisheries and Food on the impacts of the disposal of dredged material at sea. Disposal of material at sea in the UK, is regulated by the Food and Environment Protection Act (FEPA) Part II 1985. The day-to-day provision of advice is informed by research and monitoring programmes. Presently, dredging methods that involve relocation of sediment by means other than physical removal and deposition elsewhere are not regulated under FEPA. This paper presents the results of a recent review into the use of hydrodynamic dredging techniques in England and Wales.

A questionnaire was sent to 250 ports, harbours and marinas in the study area. The response was encouraging, with 42% of consultees submitting completed questionnaires. The responses were both geographically widespread, and representative of the study area. More than a quarter of respondents claimed to employ hydrodynamic dredging techniques. However, only 11% of respondents use these techniques as their sole method of dredging. All but one of these ports are situated on the south coast of England. The Review also queried which conventional dredging methods were employed, what consultations were undertaken, and the environmental impacts of these activities. Several site visits provided a practical aspect to the review and allow the presentation of case studies.

Main conclusions

Hydrodynamic dredging techniques are used both alone and in conjunction with conventional dredging techniques at a number of ports and harbours throughout England and Wales.

Most ports or harbours which use hydrodynamic techniques as their sole method of dredging move relatively small quantities of sediment, typically <5000 wet tonnes per annum, but up to 30 000 wet tonnes per annum can be moved in some cases.

Chemical and physical impacts associated with the use of hydrodynamic dredging techniques are seldom fully evaluated. There appears to be little if any requirement for such assessments under existing legislative controls.

Potentially adverse environmental impacts can occur from the use of hydrodynamic techniques. A site-specific assessment should be made to ensure that measures are taken to minimise such impacts. Key factors are the environmental sensitivity of the site, the quantity and nature of the dredged sediment and the hydrodynamic regime.

When used in conjunction with conventional dredging from which sea disposal of the material has been licensed, additional adverse impacts from hydrodynamic dredging are likely to be minimal.

A few ports may take advantage of the lack of legislative control of hydrodynamic dredging techniques and employ them if refused a licence to dispose of dredged material at sea. If the licence has been refused because of high contamination of the sediment there is a strong likelihood of adverse environmental consequences resulting from the operation.

4. Techniques Applied by Contracting Parties for Dredging, and their Environmental Effects - Germany (SEBA 99/12/1-E)

Techniques applied in Germany for dredging in OSPAR waters

The bulk of material dredged in OSPAR waters is removed by trailing suction hopper dredgers. However, depending on the dredging site and the material to be dredged, further techniques are applied at several dredging sites.

In order to optimise the actual need for dredging and to minimise the amounts dredged, the sea/river bed is surveyed frequently. Generally, all dredging processes are controlled and monitored automatically. Monitoring often includes the position of suction heads.

For disposal on land, dredged material is usually transported by pipelines. Aquatic disposal is carried out through bottom doors, bottom valves or split hulls.

Dredging of cohesive sediments

Undisturbed consolidated soils from capital dredging are removed mainly by bucketline dredgers or, if soils can be rendered pumpable, with stationary suction dredgers with rotating cutting heads (cutters). Occasionally, silt screens are employed. The dredged material is transported to barges or through discharge pipelines onto land. Cutters equipped with discharge pipelines onto land are also used for dredged material for beneficial use.

Dredgings for hydraulic engineering, e.g. construction or enlargement of navigation channels, harbours or harbour channels; construction or reinforcement of dykes, jetties, barriers, training dykes are mainly carried out with stationary suction dredgers equipped with a cutting head and submerged dredge-pumps. Submerged pumps, e.g. a centrifugal pump can transport sediment/water mixtures of high density (40 - 50 % solids of volume conveyed) at any water depth.

For the removal of small volumes of dredged material, for example from piers, locks or small water bodies, often pontoon-based cable operated grab dredgers or hydraulic backhoe dredgers are used.

Dredging of non-cohesive sediments

The large amounts of sand and silt from capital or maintenance projects in navigation channels and most harbours are commonly dredged with trailing suction hopper dredgers equipped with one or two drag suction heads. In order to increase efficiency, loosening of cohesive sediments can be supported by using drag heads with toothed edges or by water jets at the suction head. When dredging sand, suction hopper dredgers are operated with overflow to increase efficiency.

Specially equipped trailing suction hopper dredgers allow improvements of the dredging procedure and reduction of environmental effects. Suction heads often can be positioned at a given depth resulting in a higher vertical accuracy. In order to increase the density of the conveyed sediment/water suspension when dredging silt, some dredgers are equipped with degassing installations and submerged dredge pumps. This equipment is planned to become standard for dredging silt. In one harbour, experience has been gained with recirculation of low-density suspensions from the hopper to the drag head to avoid uptake of surrounding water and to optimise the density of dredged material in the hopper. No increase of turbidity at the suction head had been observed when recirculating these suspensions [WURPTS ET AL., 1996].

Hydrodynamic dredging

For maintenance of some harbours and sedimentation areas lying parallel to the navigation channel, silty sediments are removed by water injection dredging. Sediments are resuspended by the injection of water with low pressure and subsequently are transported as a density flow or by natural currents occurring at the dredging site. The application of the water injection procedure is restricted to areas, where no harmful oxygen depletion and remobilisation of contaminants is to be expected.

Mechanical agitation dredging is only applied in small harbour areas or other small sedimentation areas that are difficult to access.

Hydrodynamic dredging [c.f. SEBA 99/12/Info.1-E] results in an increase of turbidity. In case of water injection dredging the increase of turbidity usually has its maximum close to the bottom. Depending on the material dredged, oxygen depletion may occur. However, it is generally limited to the direct surrounding of the dredging site and in tidal waters, no enduring impact was observed [Netzband, 1999]. If sediments are contaminated, remobilisation of contaminants can occur and contaminants associated with the fines can be spread with limited control of the transport.

As natural events may also result in resuspension of sediments and increased turbidity, the assessment of impacts requires consideration of natural as well as dredging conditions. More details on environmental effects of water injection dredging and other types of hydrodynamic dredging, including sidecast dredging, are described in SEBA 99/12/Info.1-E.

The water injection technique is also applied in one harbour to keep suspended particulate matter in suspension and to avoid sedimentation. Thus a navigable depth is maintained without removing settled particles. The high-density layer of suspended matter remains in the harbour and furthermore, avoids further input of particulate matter from the river to the harbour [Woltering, 1996].

Further dredging techniques and developments

Non-cohesive soils or soils that can be rendered non-cohesive can be loosened with bucket wheels.

Highly contaminated sediments are dredged with sealed grabs or dippers that minimise resuspension of sediments. The use of further environmentally effective dredging techniques is considered on a case by case basis.

A new technique (AMOB) to increase efficiency for dredging silt, is being tested in the estuaries of the rivers Elbe and Ems. A valve restricts the uptake of dredged material into the hopper to sediment/water mixtures of a density of $\geq 1{,}14\ t/m^3$ whereas low density mixtures remain in the water body. Thus, the increased efficiency should not cause enhanced turbidity compared to the conventional hopper dredging. Results of tests with regard to the environmental effects still are not available.

Conclusions

A large variety of dredging techniques are available for the removal of aquatic sediments. However, maintenance dredging of recent sediments, which usually are not highly contaminated, is mainly carried out with trailing suction hopper dredgers. For dredging contaminated sediments, this technique is considered the least environmentally effective method.

Among other techniques, water injection dredging is also applied for small projects. Depending on the consistency and the contamination of dredged material as well as the local conditions and dredging requirements, further techniques are applied. Particularly for removing contaminated sediments, several dredging techniques are available that minimise environmental effects, e.g. spread of resuspended sediments in the water phase or dilution of sediments with water.

The ranking with regard to the environmentally effectiveness provided by the Netherlands may offer indications for the selection of an appropriate dredging technique for contaminated sediments.

Like conventional dredging techniques, all types of hydrodynamic dredging, including sidecast and agitation dredging affects the environment and should in future be regulated by the OSPAR Convention.

The assessment of the environmental impact of an actual dredging project always requires the consideration of the local circumstances, as other uses of the waters as well as natural conditions and events may also have comparable effects.

5. Environmental Effects Of Dredging Operations - United Kingdom (SEBA 99/12/2)

In 1998 a questionnaire was sent to 250 ports in England and Wales. The response was encouraging with 42% of ports submitting completed questionnaires. In addition, the responses were geographically widespread which enabled an understanding of dredging practice throughout the study area and were for disposal quantities varying from 1 000 tonnes to >19 000 000 tonnes.

The response to the questionnaire suggests that ports on the south coast require relatively little dredging compared to those on the East and West coasts. The survey found that silt was the common surface sediment in ports, although on the south and west coasts, sediments also consisted of fine sands and shingle. The material found at depth was variable according to location and included silt, stiff clay, gravel, boulder clay and rock.

What Dredging Techniques are Used/Applied?

The most popular conventional dredging method employed by ports is the trailer suction dredger; closely followed by backhoe and grab dredgers. None of the responding ports employ a dipper or bucket ladder dredger and only a small number make use of a cutter suction dredger.

A quarter (27%) of respondents claimed to use 'novel' dredging techniques with the plough/bed leveller being the most popular. The ports employing these techniques are located on most sections of the coast.

How were these Techniques Used/Applied?

CONVENTIONAL TECHNIQUES

There were three main reasons given for the choice of dredging plant employed:

- Water depth - Backhoe and grab dredgers are limited to shallow waters while trailer suction dredgers can remove material from deeper water.
- Accessibility of area - Trailer dredgers are used to dredge large areas, they require enough space to complete a turning circle. For restricted areas, backhoe and grab dredgers are most suitable.
- Availability of contractor/vessels - The dredging operation needs to be timed to coincide with the availability of the contractor. Smaller ports tend to use local contractors to minimise costs.

The majority of responding ports (55%) employed a contractor to carry out the dredging process against 20% of ports owning vessels. A small number (9%) of ports own a vessel for daily upkeep, whilst employing a contractor for large-scale maintenance campaigns.

NOVEL

‘Novel dredging techniques’ are defined for the purposes of this paper as those techniques that do not require a disposal licence. The main uses of the bed leveller are to move material from inaccessible areas into the path of the main dredging plant and to level the peaks and troughs caused by trailer suction dredgers. Most ports found it difficult to define the quantities of material involved. Two ports both redistribute significant quantities of material, >50 000 tonnes pa, using bed levellers in addition to licensed dredging.

Nearly all the ports that use 'novel' techniques as their only means of dredging are located on the south coast of England and the quantities involved are small, <5000 tonnes pa. Ports suggested that the major limitation of 'novel' techniques is a loss in effectiveness with increased quantities of material. Only one area that employs only 'novel' techniques redistributes significantly larger quantities of materials, >30 000 tonnes pa. Several ports admitted to redistributing sediment by vessel propeller agitation.

Two-thirds of respondents commented on the comparison of conventional and 'novel' dredging techniques. They felt that 'novel' techniques were less successful as a lone method of dredging but very useful when used in conjunction with conventional methods. For small ports, 'novel' dredging was the only cost effective way of maintaining water depths.

A comment made by many ports was that 'novel' dredging techniques can be successful. The level of success depends on the operation and the many variables associated with a port (area, geography, topography, material, currents etc.).

What effects of these dredging techniques had been observed?

Nearly all the responding ports stated that there were no noticeable environmental effects associated with, or following dredging. Only 15 ports admitted that turbidity increased during dredging. The type of dredger used can effect the extent to which turbidity increases.

Encouragingly, 80% of respondent stated that they would perform environmental impact studies and consultation prior to commencing dredging using 'novel' techniques. The scale of the studies would depend upon the scale of the proposed dredging activity, as an environmental assessment can be costly, and an incentive for using 'novel' methods is their relatively low cost.

There is little UK information about the environmental effects of ‘novel’ dredging techniques. While these techniques remain outside the national controls applied to dumping, the licensing authority gives informal advice on a case by case basis when contacted by ports or operators.

6. Hydrodynamic Dredging: Principles, Effects and Methods - CEDA (SEBA 99/12/Info.1-E)

Hydrodynamic dredging is used in the development and maintenance of harbours and waterways. It is a useful addition to conventional methods of relocating dredged material to a physically distant location. Hydrodynamic dredging methods include the so-called “agitation dredging” and the “water injection” methods. Their application requires special conditions. These processes mainly use the natural currents in waterways for transporting sediment. Once mobilised, possibilities for control of the sediment are limited. However, due to their low cost and ease of use these processes represent a very interesting alternative to conventional methods. Results from various investigations carried out throughout the world are now available, so that it is possible to predict the ecological effects of such processes.

Hydrodynamic dredging and hydrodynamic effects during regular dredging have some specific uses and also some specific disadvantages or limitations.

Some of the specific advantages are in general:

- Hydrodynamic dredging is a low cost dredging method. Nature takes care, for free, of the horizontal transportation of the dredged material. Relatively simple equipment is used, with low investment and with low operating costs.
- Hydrodynamic dredging is a simple and flexible method, especially for maintenance dredging. Mobilisation of equipment can be easy, allowing works to be scheduled and executed in an effective way.
- In estuaries, hydrodynamic dredging may have a low impact on the sometimes-vulnerable sediment balance, whereas normal dredging with distant disposal of the dredged material might be more harmful.
- With dredged material staying below water no oxygen is added to the material. Chemical and biological changes are, thus, reduced to a minimum.

Some of the limitations are:

- Restricted control of the destination of agitated material: sedimentation at undesired places such as shipping lanes and harbours should be avoided.
- In the case of contaminated material, dredging will spread the pollution, which will normally not be desirable. Some forms of hydrodynamic dredging are in many of these cases less advisable, as effects might be more serious.
- Substances, which consume oxygen, nutrients and harmful materials, bonded to the sediments, can relatively easily be released into the water and thus reduce its oxygen content or cause an increase in the concentration of nutrients or harmful materials.
- A relative enrichment of the coarse fraction (‘armouring’) will occur in the dredged area, which will make the area less susceptible to erosion, also making future hydrodynamic dredging operations more difficult. Then normal dredging techniques can be applied.
- The effectiveness is difficult to measure directly because the density transition zone between hard bottom and water prevents accurate acoustic surveys being carried out. However, with measurement of other parameters, like turbidity or nautical bottom, results can be analysed.
- The sometimes occurring visual effect of clouding or colouring of the surface water by hydrodynamic dredging, especially when raising material to the water surface, is not always allowed or desired. This clouding does not necessarily lead to environmental damages.

The potential environmental impact must be evaluated in relation to the natural situation. The natural sediment concentrations in the water, especially under storm conditions or high (river) transport situations, are frequently similar to or even larger than that which is attained by hydrodynamic dredging. In assessing the environmental impact of hydrodynamic dredging, the total quantity of material brought into suspension should be considered, in conjunction with sediment concentrations and duration of the works. Also, natural seasonal variations could make hydrodynamic dredging (and even normal dredging) more acceptable in one season than in another. Even tidal variations, in-going or out-going current, can make a considerable difference. Therefore proper planning of any type of dredging works is essential.

7. Water Injection Dredging. Results of a Literature Review and of Measurements in the Port of Hamburg and the Elbe Estuary

R. Meyer-Nehls, G. Gönnert, H. Christiansen, H. Rahlf, Ergebnisse aus dem Baggergut-untersuchungsprogramm, Heft 8 (2000), ISSN 0177-1191

Abstract

Hamburg harbour is situated about 100 km from the North Sea at the upper end of the tidally influenced Elbe River. Solids are being transported from upstream as well as from downstream with the tide from the North Sea and lead to more or less heavy siltation. Each year about 2 Mio. m³ of sediments have to be dredged in order to secure water depths for vessel traffic in the harbour.

Relocation of dredged material is possible if the contamination of dredged material is below given environmental standards and is not restricted by environmental windows. About 400 000 m³ are dredged annually by water injection dredging (WID). This is an especially interesting technology for a harbour administration because of its low costs. No transport of dredged material with ships or barges is necessary. Therefore, a quick and flexible operation is possible. The technology finds its limitations in local morphologic and hydrodynamic conditions. Nevertheless, it can be applied almost everywhere.

Various international investigations are concerned with the efficacy and ecological effects of WID in tidal waters. The report contains the summary of a literature study on this, and also the results of investigations carried out in Hamburg and in the Elbe Estuary at the Rhinplatte.

8. Machines, methods and mitigation

[Jos Smits]. - The Hague : International Association of Dredging Companies (IADC) and Central Dredging Association (CEDA), 1998. - 80 p. : ill. (Environmental aspects of dredging ; 4). With ref. ISBN 9075254091

Abstract

This guide

- describes three types of dredging projects: capital, maintenance and remedial;
- defines the characteristics and the positive and negative impact;
- explains the phases of a dredging project: disintegration of the in-situ material; raising of the dredged material to the surface; horizontal transport and placement of further treatment;
- describes standard dredging equipment and the new types of dredgers especially developed for low-impact projects;
- gives attention to the different possible methods of transport and disposal of dredged sediments, with emphasis on the techniques and equipment that mitigate environmental impacts;
- considers monitoring and control of the dredging process in terms of compliance, verification of the assessments, and the acquisition of know-how in order to improve the assessment of future projects.