Treatment and Confined Disposal of Dredged Material

DGE

Dutch-German Exchange on dredged material

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- Part 2 -

Treatment and Confined Disposal of Dredged Material

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Contents

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- AKWA/RIKZ, Den Haag
- AKWA/BWD, Utrecht
- AKWA/DNZ, Rijswijk

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German delegation

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Federal Ministry of Transport, Building and Housing, Bonn

Federal Environmental Agency, Berlin

Federal Institute of Hydrology, Koblenz

Ministry of the Environment of Lower Saxony, Hannover

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The participating members of each authority are listed in Annex I.

DGE-Group at Polder Moder/Impoundment Iffezheim/Upper Rhine
13. June 2002

Meetings

December 1999:	Koblenz/D, hosted by the Federal Institute of Hydrology
June 2000:	Lelystad/NL, hosted by AKWA/RIZA
December 2000:	Bonn/D, hosted by the Federal Ministry for the Environment
June 2001:	Rotterdam/NL, hosted by the Port of Rotterdam
June 2002:	Rastatt/D, hosted by the Federal Ministry for the Environment

Abbreviations

CAD	=	Confined Aquatic Disposal
CEDA	=	Central Dredging Association (CEDA).
CDF	=	Confined Disposal Facility
CDM	=	Contaminated Dredged Material
DGE	=	Dutch German Exchange on Dredged Material
DM	=	Dredged Material
PAHs	=	Polycyclic Aromatic Hydrocarbons
TPH	=	Total Petroleum Hydrocarbons
METHA	=	Mechanische Trennanlage für Hafenschlick (Mechanic Treatment Plant for Harbour Sludge)
TBT	=	Tributyltin
WODA	=	World Dredging Association

1 General introduction

Economically and environmentally sound management and handling of dredged material is important both in The Netherlands and in Germany as huge amounts of dredged material emerge from maintenance, construction and remedial (clean-up) works within water systems. The national volumes of dredged material amount to about 35 and 50 Million m³/year, respectively.

A relatively small but significant part is contaminated, whereas the larger part is clean or only marginally contaminated. It is common practice to relocate the largest part of the dredged material in the water system in suitable locations. If relocation is undesirable or impossible for environmental, morphological or spatial reasons, alternative options are employed such as beneficial use, treatment and confined disposal. These options generally are more costly.

Against this background and because of the progressing European development the competent governmental authorities in The Netherlands and Germany have started a Dutch German Exchange on Dredged Material (DGE) in the year 1999. The status of DGE is informal.
DGE-participants acknowledge the international environmental policy on dredging as formulated by the World Dredging Association (WODA) and the Central Dredging Association (CEDA). This policy includes:

1. recognition that carefully designed and well executed dredging conducted in an environmentally sound manner contributes to a stronger economy;
2. conviction that dredging projects can be conceived, permitted, and implemented in a cost-effective and timely manner while meeting environmental goals and specific regulatory requirements;
3. commitment to the development and implementation of appropriate environmental safeguards and performance guidelines for construction, maintenance, mining and remedial dredging;
4. encouragement of beneficial use of dredged materials;
5. the need for open lines of communication among stakeholders, such as port interests, dredging contractors, regulatory agencies, other business interests, environmental interest groups, and the public, within any project;
6. encouragement of investment in and expeditious transfer of new technologies, and the development of new, more efficient techniques for improving the evaluation and safe handling of dredged material.

The main objective of the Dutch-German Exchange on Management of Dredged Material (DGE) is to increase understanding of management, both on policy (national) and practical (project) level, of dredged material by exchanging experiences and knowledge. In addition, DGE seeks to contribute to EU-wide for that deal, directly or indirectly, with management of dredged material – in particular the Sediment Network (SedNet).

From this perspective the DGE covers different aspects of dredged material management like legislation, treatment, chemistry, ecotoxicology, dredging technology etc. The sharing of knowledge in these fields requires an analysis (classification and comparison) of dredged material terminology of both countries in order to get common understanding of the important terms, despite the legal or technical differences and difficulties with regard to the correct translation of terminology used in Germany and the Netherlands.

DGE aims to organise information to support the further development of dredged material management. Information on different aspects will be presented in dedicated documents. The first document covers "Dredged Material and Legislation". It comprises important definitions, a comparison of the legislative situation of dredged material management and important legal questions against a European background. This document forms a stepping-stone to all coming documents from DGE.

It should be noted that the present regulatory framework for dredged material management and handling is extremely complex. Depending on the dredging objective and dredged material destination, different (parts of) international conventions, European and national laws and regulations apply, e.g. for water, soil, waste and environment. Furthermore, current developments at the European level (Water Framework Directive, Soil Communication) are likely to have further impact on national legislation covering activities such as dredging in (international) catchment areas. With regard to the progress of European and national legislation this document makes no claim to be exhaustive. On the other hand it has to be noticed that the dredged material experts of the competent governmental authorities in both countries formed this contents.

2 Scope of this paper

The paper is based on information available in the Netherlands and in Germany. It gives an overview on the state of development of Treatment and Confined Disposal Technologies applicable to sediments on a large scale in both countries.

The starting point is that handling options are considered for those sediments to be dredged that cannot be relocated in the aquatic system or re-used upland due to contamination or any other reason. In this paper (pre-) treatment, beneficial use and confined disposal are regarded.

Dredged material is regarded as waste in the EU waste catalogue. The EU waste law sets the priority on beneficial use before disposal. The Council Directive 1999/31/EC on the landfill of waste states that "further consideration should be given to the issues of … the processing of dredging sludge's".

The current situation and policy in the Netherlands and in Germany are described. Fact sheets and/or case studies in the annex give more detailed information on different Treatment and Confined Disposal Technologies.

As a first step of harmonisation, gaps and discrepancies in existing guidelines or directives / legislation in order to get a better understanding are identified. A harmonisation seems to be necessary in the framework of European directives. Therefore this paper can also be used for a further discussion in the European context, like SedNet.

Definitions (for a comprehensive list see Part 1(Annex III)):

Beneficial Use

Placement or use of dredged material for some productive purpose. Beneficial use may involve either the dredged material or the placement site as the integral component of the beneficial use. Source: PIANC PTC 17

Confined Disposal Facility (CDF)

A CDF is an engineered construction for the containment of contaminated dredged material the purpose of which is to control potential releases to the environment. Source: PIANC ENVICOM 5

Contaminated Dredged Material (CDM)

Any sediment that is removed by dredging and that contains contaminants at levels and availability that can make the material environmentally unacceptable for unrestricted use. Source: PIANC ENVICOM 5

Dredged material

The term 'dredged material' refers to material that has been dredged from a water body, while the term sediment refers to material in a water body prior to the dredging process. Source: PIANC ENVICOM 5

Treatment means the physical, thermal, chemical or biological processes, including sorting, that change the characteristics of the waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery. Source: Council directive 1999/31/EC of 26.04.1999 on the landfill of waste

[However this definition does not include the main objective for treatment (in the Netherlands) which is the production of building materials for beneficial use.]

3 National situation

3.1 Situation in the Netherlands

Dredging of waterways is of vital importance for the Dutch economy, ecology and water-management. Each year 30-35 million m³ partly contaminated dredged material has to be removed. The main reason is maintenance of waterways for shipping and water discharge, but remediation of contaminated sites is also a reason for dredging. More than half of this amount comes from maintenance dredging for the main port Rotterdam, which has a leading position in the world.

Dredging is mainly done by Rijkswaterstaat (Ministry of Transport, Public Works and Watermanagement), waterboards and municipal authorities.

About ¾ of the dredged material is marine sediment, transported inland by sea currents. The major part (90 %) of these marine sediments is clean or hardly contaminated and can be relocated in the sea. Only 30 % of the dredged material from fresh waters can be relocated because of higher contamination levels. Another reason that hampers relocation on the banks of waterways is lack of space. It should be recognized that sediments form an integral part of the aquatic ecosystem and should be returned if the quality complies with the strict Dutch standards. New legislation on relocation on land and in the sea, based on ecological and chemical criteria, is in preparation

The contaminated sediments are an industrial heritage of the past. The quality of the sediments has tremendously improved in the last years by the reduction of industrial sources of pollution. Further improvement of the quality of the sediments can be achieved by reduction of the emission from non-point sources. Source control is a prerequisite for a sustainable strategy on the management of dredged material. The target for the Dutch policy is that within 25 years the sediment quality will have improved to the level that the dredged material can be completely relocated or beneficially used.

For the dredged material that is too much contaminated for relocation there are two options: treatment for beneficial use and disposal. The major part (approximately 90%) of this CDM is disposed (4-5 million m³/year).

Disposal is mainly subaquatic in confined disposal sites (CDFs), but on a small scale also dewatered DM is stored in upland disposal sites. The largest CDF is the Slufter with a design capacity of 90 million m³ mainly meant for the contaminated dredged materials near Rotterdam. Recently a CDF was constructed in the Ketelmeer (IJsseloog) with a capacity of 23 million m³. New CDFs in combination with treatment facilities are in preparation e.g. in the southwestern part (Koegorspolder) and downstream of the Meuse (Hollandsch Diep). For these CDFs an open and careful communication process was carried out to gain public support.

Until now treatment of CDM is very limited (0.5 million m³/year) and has been done on a small scale only, because of the higher costs of treatment compared with disposal, no guaranteed supply of dredged material for treatment and the lack of a market for the products of treatment.

Ripening is commonly applied in the rural areas on a small scale mainly for clean or lightly contaminated dredged material from regional waterways. The dewatered dredged material (clay) is locally used to raise the land. A pilot project to use the clay from dredged material for road construction is in preparation. Landfarming and phytoremediation is restricted to small scale pilot projects.

Next to ripening, the separation of sand from dredged material is the most frequently applied treatment technique. This is mainly done in sedimentation basins near the large CDFs Slufter and IJsseloog. Separation of sand by hydrocyclones is practisedon a smaller scale.
Stabilization of dredged material has been applied in small pilot projects only.

Thermal immobilization is not (yet) operational. There are plans for a large-scale plant near Moerdijk for the production of artificial gravel (light-weight aggregate).

3.1.1 Dutch policy on treatment and disposal

Following the Dutch environmental policy the order of preference of destinations for dredged material is: relocation, direct reuse and treatment for beneficial use and at the end disposal in confined disposal sites. All these destinations are under pressure and dredging is in arrears. A Dutch Master plan was established to be used as a basis for political decision-making. The main conclusions are:

- A substantial increase of budgets (more than double) is needed to remove the arrears in dredging for which a period of 25 years is envisaged.
- Better coordination of the dredged materials and the joint use of disposal sites and treatment plants to reduce costs.
- A manifold approach to arrive at more destinations for dredged materials such as the stimulation of treatment and beneficial reuse, adaptation of legislation on Building Materials and the realization of more disposal capacity.
- Better coordination of legislation and regulations for dredged material.

The Dutch government has approved this Master plan in April 2002, what has resulted in the release of an extra budget of € 150 Million to tackle the dredging problem. This budget is only the first step and will be invested mainly in maintenance of waterways in urban area and the remediation of contaminated sites in the next 4 years. A decision on a structural increase of budgets, which is needed to solve the problem in the future, will be taken by the next government.

In order to find more destinations for dredged material the Dutch policy is aiming at enlarging the share of treatment of CDM into building materials. First, a national inventory and assessment of the possibilities of large-scale treatment has been set up (project Impulse B2). Second, several measures have been taken to stimulate the treatment of CDM.

The inventory of treatment has led to the conclusion that in general treatment is still more expensive than large-scale disposal for most of the dredged materials. Furthermore, treatment should not be done at the expense of dredging, which means that more budgets are needed. Treatment of all CDM is not possible, disposal remains necessary in the future. Several new subaquatic CDFs in combination with treatment facilities are in preparation e.g downstream of the river Meuse (Hollandsch Diep) and in the Southwestern part of the country (Koegorspolder).

Based on this inventory, the Dutch government has set aside a budget of more than € 70 million for treatment of CDM during a test period of four years. This budget is meant for two purposes: a large-scale pilot project and a subsidy for treatment of contaminated sediments.

The objective of the pilot project is treatment of at least 50% of the supply of dredged material for a CDF in preparation (Koegorspolder). A tender for this pilot project resulting in a private-public partnership is expected in 2002.

The subsidy for treatment is meant to bridge the financial gap between disposal and treatment in order to stimulate treatment.

Another financial instrument, meant to stimulate treatment and reduce disposal, is a tax on the disposal of CDM that can easily be treated. For the time being, the criterion for treatability is 60% or more sand in the DM, but it may be increased at a later stage, when treatment has further developed.

The aim for the subsidy is to encourage new technologies not yet commonly applied in practice on a large scale, whilst at the same time the environmental tax on disposal will penalise non-use of the operational technologies.

Legislative obstacles to the re-use of products will be removed by adaptation of the Dutch Building Materials Act on the parameters sulphate, mineral oil and fluoride. Furthermore, measures will be taken to promote markets for products from treatment.

The policy of the Dutch government is aiming at a step-by-step conversion to increased treatment by an integral approach of measures. The effectiveness and effects on dredging activities will be closely monitored and evaluated to ensure that the objectives of treatment are met and that treatment will not frustrate the dredging activities.

3.2 Situation in Germany

In Germany about 40 to 50 million m^3 of sediments have to be dredged annually for maintenance of ports and waterways, mainly in the coastal areas of the North Sea. Maintenance of the waterways is done by the Federal Waterways Administration; maintenance of the ports is done by the federal states or the cities. The same applies to capital dredging. Rehabilitation works are of minor importance in the coastal area.

Most of the above mentioned material stems from the sea and is more or less uncontaminated and can therefore be relocated. Due to exceeding given standards some of the material especially in ports cannot be relocated. In the North Sea area contaminants like heavy metals, organic contaminants or TBT are of main concern. In the Baltic Sea often the nutrient load does not allow relocation into the sea.

Generally, source control is necessary to solve the problem of contaminated sediments not only to the environment, but also for those responsible for maintenance of ports and waterways. For example the International Commission for the Protection of the River Elbe foresees that the sediments shall be clean by the year 2010 in a way that they can be used, for example, for agricultural purposes.

There is no common, coherent German policy on dredged material. In parts federal government or states have their own guidelines. Treatment and disposal are especially known from the Ports of Hamburg, Bremen, and Rostock. Besides that, flushing fields etc. are in operation on a smaller scale.

3.2.1 Hamburg

For treatment of dredged material Hamburg is operating the large-scale METHA-plant. Its main task is to separate sand and fine-sand from silt and to dewater the (contaminated) silt for further beneficial use and / or disposal. The throughput capacity is roughly 1 Mio. m³ sediment in-situ per year corresponding to more than 500.000 tons dry matter. Total investment cost was € 70 Mio. (in the year of construction 1993). Including capital costs and expenditure for operation, maintenance and personnel, the calculatory specific costs average to 15-20 €/ m³ sediment in-situ. For more details see fact sheet.

The same task as in the METHA can be accomplished by flushing fields (for classification) and dewatering fields. Advantage are lower operating costs, disadvantages are large areas needed and dependence on climate.

The pre-treated silt is mainly disposed in 2 specially constructed silt mounds which fulfil German criteria for landfills. Each has a capacity for ca. 20 Mio. m³ untreated sediment and will reach a final height of 38 m above the ground. In these mounds, the separated sand is beneficially used as drainage material. The mineral seals are made by selected, pre-treated silt.

A Europe-wide participation call for a tender for beneficial use in 2001 showed applications for beneficial use in replacement fill, reshaping of landfills, etc., which means use of the treated dredged material as earth-works material. A decision has not yet been made. Besides that, many other options for beneficial use of treated sediment were examined. Until now, due to too high additional payments or ecological restrictions, only very limited amounts could be beneficially used besides the Hamburg disposal sites.

Besides that, over the years many different technologies for additional treatment or beneficial use were examined and discussed in a broad public. Again and again it was found that, except what is done, theses technologies are not feasible on a large scale due to high costs, limited markets, lack of interest or acceptance, and restrictions for this use.

3.2.2 Bremen

In the Port of Bremen, about 300.000 m³ of sediments (mainly silt) have to be dredged annually. The contamination is predominantly caused by heavy meals (cadmium, zinc, lead) coming from sources upstream and organic substances like TBT.

The dredged sediments are dewatered and stabilised in dewatering fields within 1 year. After the dewatering process, the material is deposited in a landfill / silt mound with an upper and a lower seal system. The mineral bottomsealing system was constructed by using specially selected silt. The dewatered silt has a permeability coefficient less than $1 * 10^{-9}$ m/s and meets other soil mechanic parameters for liners as well. Excess water is collected via drainage layers and diverted to a treatment plant.
Treatment and silt mound cover 127 ha in total, additional 124 ha are for compensation. The mound capacity comprises 4 Mio m³. The planned filling time is 20 years. In parallel, Bremen

has examined possibilities to integrate various sediment treatment techniques into the existing management concept.
The costs for dredging and disposal of the material range between € 10 - 13 Million per year.

3.2.3 Rostock

In the Port of Rostock at the Baltic coast, dredged sediments cannot be relocated into the sea due to nutrient contents, contaminants are of minor importance. The dredged material is dewatered in ripening fields (comparable to Bremen). Then it is used as earthworks material or for agricultural purposes.

4 Overview on Treatment and Disposal Options

4.1 General treatment technologies

Treatment technologies can be categorised as follows:

Processing Principle	
Separation of less contaminated DM fractions	Classification
	Sorting
Dewatering	Evaporation
	Mechanical dewatering
Contaminant separation	Chemical extraction
	Thermal desorption
Contaminant destruction	Biological reduction
	Chemical oxidation
	Thermal oxidation
Contaminant immobilisation	Thermal immobilisation
	Chemical immobilisation

Tab. 4.1-1: Categorisation of treatment technologies

Classification depends on separation of a less contaminated coarser fractions and a more contaminated fine fractions from the original DM. Separation principle is the separation by grain size. It can be done e.g. by sieves or hydro-cyclones. Separation is mainly used in the grain size range of 20 – 63 µm.

Sorting depends on separation into fractions of less contaminated particles and more contaminated particles from the original DM. Separation principles depend mainly on different specific weight of the particles or on different conditions on the particle surface. Sorting can be done by upstream-current-classifiers, spirals, jigs, flotation-cells or sedimentation basins.

Dewatering depends on separation of water from the solids. Separation principle is the evaporation of water or the reduction of the pore volume between the particles. It can be done e.g. in dewatering (ripening) fields or with presses like filter-belt-presses or membrane-chamber-filter-presses.

The **thermal desorption** depends on the difference of the relative volatility of the contaminants and mineral sediment particles. It is normally operated in the temperature range of about 450 °C.

The **thermal oxidation** depends on combustion of organic material at high temperatures. All types of organic material can be burned. (Mostly together with thermal immobilisation)

The **thermal immobilisation** depends on the binding of contaminants like heavy metals in the mineral phase at high temperatures. Products of thermal immobilisation could be bricks, pellets and glass. (Mostly together with thermal oxidation)

4.2 Treatment chains

In the Netherlands treatment chains were examined and compared, comprising one or more of the forenamed technologies.

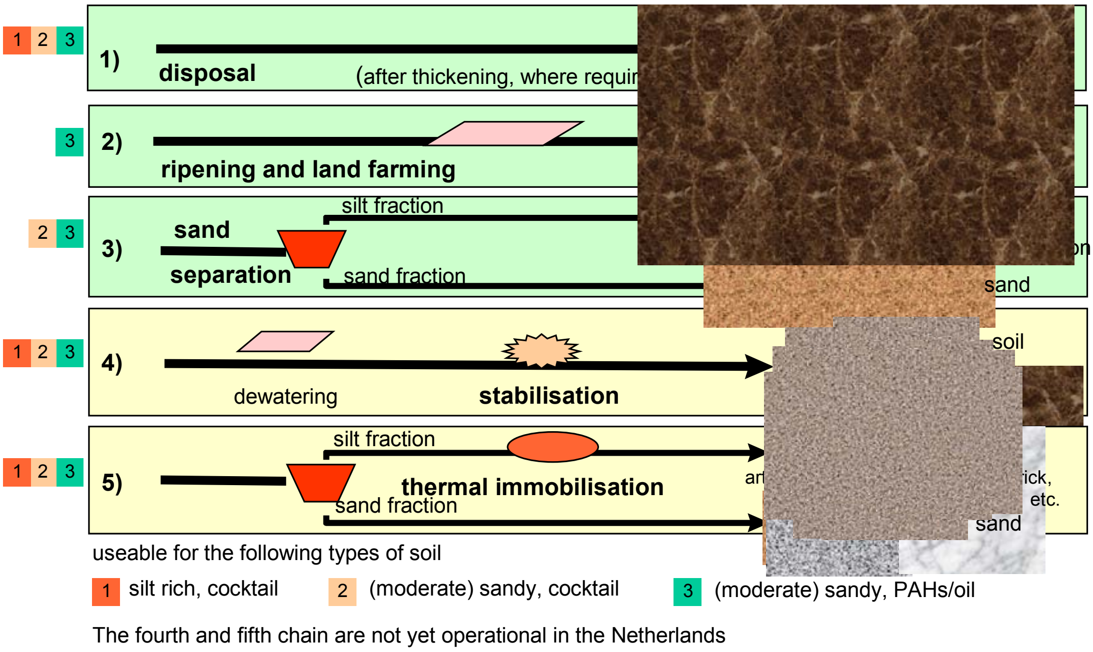

Fig. 4.2-1: Treatment chains

Disposal can be in upland disposal sites or in subaquatic confined disposal sites. Former sand and gravel pits may also be used for subaquatic disposal.

Ripening and land farming are similar technologies where the CDM is spread over tracts of land in order to dewater the material, resulting in a substantial decrease in volume. Land farming stimulates the biodegradation of organic contaminations by aeration. In phytoremediation vegetation is used to take up contaminants. Biodegradation can also be achieved by stimulation of bacterial growth in bioreactors. These technologies require much space, which may be a problem in densely populated areas.

By using sand separation, the soil is separated into a usable sand fraction and a contaminated silt fraction. The silt fraction is disposed or can be further processed e.g. by thermal immobilization. Sand separation can be done in sedimentation basins or hydrocyclones or a combination of both technologies.

Stabilization or chemical immobilisation is based on binding the contaminants by adding certain agents e.g. cement or fly ash.

Thermal immobilisation causes the breakdown of organic contaminants at high temperatures. Several products are possible such as bricks, light weight aggregate (artificial gravel) and artificial basalt.

The main factors that determine the applicability of technologies are the properties of the sediments and the possibilities for use of the products as building materials.

It is evident that by applying simple technologies such as sand separation, land farming, ripening and stabilization, only a limited amount of dredged material can be processed into usable products by applying more advanced technologies, such as thermal immobilisation, more heavily contaminated sediments and residues from sand separation can be processed.

Experience still has to be gained for the technology of large-scale thermal immobilization and the market potential of the products.

4.3 Costs

Of great importance are the costs of different treatment options. They depend very much on the specific circumstances. The numbers named here therefore give only the order of magnitude. Table 1 shows an indication of average costs of treatment chains. Dredging and transport are not included.

Option	Average	Range	Country
Relocation (incl. dredging, transport, disposal)		1,5 - 5	
Subaquatic disposal	11	7 - 36	NL
Sand separation including subaquatic disposal	14	9 -17	NL
METHA treatment (classification and dewatering) including capital costs, personal	ca. 18		D
Upland disposal, like Hamburg silt mound, without pre-treatment		10 - 20	D
Dredging, treatment and disposal in Bremen including investment and operational costs		33 - 43	D
Ripening / landfarming	23	11 - 25	NL
Stabilization	32	23 - 41	NL
Lightweight aggregate production after pre-treatment		15 - 32	D
Thermal immobilisation	54	45 - 70	NL
Brick production after pre-treatment		15 - 20	D

Tab. 4.3-1: Costs of treatment (€/m^3 *in situ* sediment)

It should be noted that depending on the circumstances (e.g. scale, disposal costs) large variations in costs occur. For example the costs for subaquatic disposal facilities are lower for large-sized CDFs. The disposal costs for the residue of sand separation in Table 1 are based on a medium sized CDF (IJsseloog).

Simple technologies such as sand separation and land farming / ripening are in general slightly more expensive than disposal, while costs for stabilisation and thermal immobilisation technologies are substantially higher. The costs for thermal immobilisation are theoretical because this technique is not (yet) operational in the Netherlands

The METHA-plant processes annually roughly 1 million m^3. Unit costs would be much higher for smaller facilities.

5 Conclusions and recommendations

5.1 Conclusions

Sediment management

Sediment management comprises assessment, dredging, relocation, treatment and / or disposal. In the case of capital or remediation dredging a certain amount of sediments has to be dealt with over a defined and limited time span. In the case of maintenance dredging operation is continuous with known characteristics and range of variation. Thus different demands on treatment may result.

Dredged material is sediment, sediments are part of the water system and therefore generally should remain in the water system. This is especially true for marine sediments, which are in general negligibly contaminated, more often fresh water sediments can not be relocated and require treatment or disposal. Dealing with sediments often the large amounts to be dredged have to be taken into account.

Source control

Generally the reason for treatment or disposal of sediments is its contamination. To solve this problem, source control is needed at the first place. This may also mean the clean up of so-called hot spots, limited areas with highly contaminated sediments which pose a risk for other areas due to their potential of dispersion with currents.

More and more the contamination of sediments due to non-point sources (traffic, air, agriculture) comes into focus. In an overall riverine management concept special attention should be given to this aspect.

As a future goal for minimizing the contaminant inputs into the aquatic system a sediment quality has to be reached which does not pose a risk to aquatic systems or any upland use. The time span to reach this objective ranges from 10 (Aim of the International Commission for the Protection of the River Elbe) to 25 years (Netherlands). For the meantime, treatment and / or confined disposal of sediments remain necessary to deal with the contaminated sediments.

It has to be realized that investment in source control upstream is very often more economical and ecologically favourable than the treatment of large amounts of sediments downstream.

Treatment and disposal

For handling sediments which cannot be relocated in the aquatic system different options exist which have to be examined taking into account the special local circumstances.

(Pre-) Treatment ranges from simple technologies like ripening and land farming over separation and technical dewatering to high-tech solutions like thermal treatment. Subsequently in general costs are rising, but of course differently from case to case.

These technologies can be combined in chains. At the end there is one or more products to be used directly or as raw material substitute, and a smaller amount of material to be disposed.

For the time being, the relatively simple sand separation is the mainly used treatment technique. Sand is always needed as construction material. Large-scale treatment and subsequent beneficial use of CDM has rarely been realized due to

- generally higher costs of treatment compared with disposal

- lack of a guaranteed and / or continuous supply of dredged material for treatment to justify the high investments
- lack of a market for the products of treatment as secondary raw materials
- limitations for the beneficial use due to standards for the products

Often the treatment products have to compete with other raw materials or products to gain a market share. To justify the necessary investment, marketing has to guarantee sale over a long period.

Often for beneficial use as earth works or construction material (roads, filling pits, etc.) limitations exist for the material's contamination which limits its application. If no adaptation of corresponding legislation is achieved, the possibilities remain very restricted.

It should be realized that, if the higher costs for treatment are not compensated, this may lead to less dredging activities.

Due to these facts disposal will remain a necessary option for the large amounts which need special handling. Confined Aquatic Disposal is an environmentally sound option in which contaminated sediments can be isolated from the environment in the long run. Its specific costs are comparatively low, there is a lot of knowledge and experience at hand.

In both countries, dredged sediments, which cannot be relocated in the water system or can not be used directly as a soil material, are regarded as waste. European legislation sets the priority on beneficial use (which requires pre-treatment); if this is technically not feasible or not economical, disposal is seen as an option. For dredged material that is regarded as waste, still the largest part is disposed in special confined disposal sites. The reasons for this fact are described in this report.

Also confined disposal has disadvantages, like necessary costs, need of space, monitoring and aftercare. Therefore and due to the reason that those who have to dredge are not responsible for the contaminant inputs which cause the sediment problem, source control has to be emphasized as the only real solution for the future.

5.2 Recommendations

Handling of sediments, which may also comprise treatment and confined disposal, has to be put into an adequate legal framework. At present, this is not the case at the European level. Due to sometimes large amounts of contaminated sediments as result of comparatively small inputs of contaminants at great distances upstream, source control has to be established in the regulations to avoid treatment or disposal of sediments, which is costly and also subject to other disadvantages. The European Water Framework Directive might be the right basis for this.

If the (political) goal is treatment and beneficial use, the following should be considered:

- a (temporary) financial impulse is needed to stimulate the development of large-scale treatment;
- an increase of the budget for dredging is needed in order to compensate for the higher costs of treatment;
- regulations on the side of demand for raw materials are needed in order to create markets for products of dredged material;

- bottlenecks in legislation have to be put to an end in order to promote beneficial use of dredged material.

Confined Disposal of sediment should be regulated on the EU level to make clear the special requirements in comparison to the EU landfill Directive. Subaquatic confined disposal of contaminated sediments is not foreseen in the EU landfill Directive. The European Waste Directive does not take into account the special properties of dredged material and the resulting requirements. For example, contrary to conventional waste disposal, dredged sediments should be stored in an anoxic, subaqueous environment. Very often due to the high content of fine grained material, sediments have a very low permeability, thus ‘they seal themselves’.

6 References

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7 Fact Sheets and Case Studies

CONFINED DISPOSAL

PIANC ENVICOM 5 report distinguishes 3 main types of confined disposal facilities (CDF) for contaminated dredged material

Upland CDF

An upland CDF is a facility in which the dredged material is stored above the groundwater level (Figure 1-1). A dike is constructed on dry land to confine the dredged material. There are two main considerations for upland CDFs: 1) the hydraulic head of water in the facility acts as a permanent driving force with the potential to cause the water to flow down to the groundwater, and 2) the contaminated dredged material may dry and become oxidized, changing the potential for release of contaminants. It may be necessary to use watertight liners to prevent emissions into the groundwater.

Island / Nearshore CDF

An island/nearshore CDF is a diked disposal facility constructed in water in which the dredged material is at least partially stored under the water level (Figure 1-2). Compared with that of the upland type, the hydraulic head of the contaminated water is much smaller. Sometimes a pit is excavated to increase the storage capacity. The main pathway for contaminants to the surrounding water, requiring control, will be the effluent. The quantity of the effluent is about the same as the amount of dredged material placed in the CDF.

Subaquatic CDF

A Subaquatic CDF is a facility in which the dredged material is stored totally under the water level (Figure 1-3). One of the main characteristics of a Subaquatic CDF, also commonly called a Confined Aquatic Disposal (CAD) facility, is that there are no diked structures and the contact with the surface water is a major pathway. If the water pressure beneath the facility is the same as in the surrounding waters, there will be no driving force for water movement. Special pits can be excavated or existing depressions (natural or man- made) can be used.

During filling, the CDM will be in direct contact with the overlying surface water so impacts to aquatic organisms are a contaminant pathway of concern.

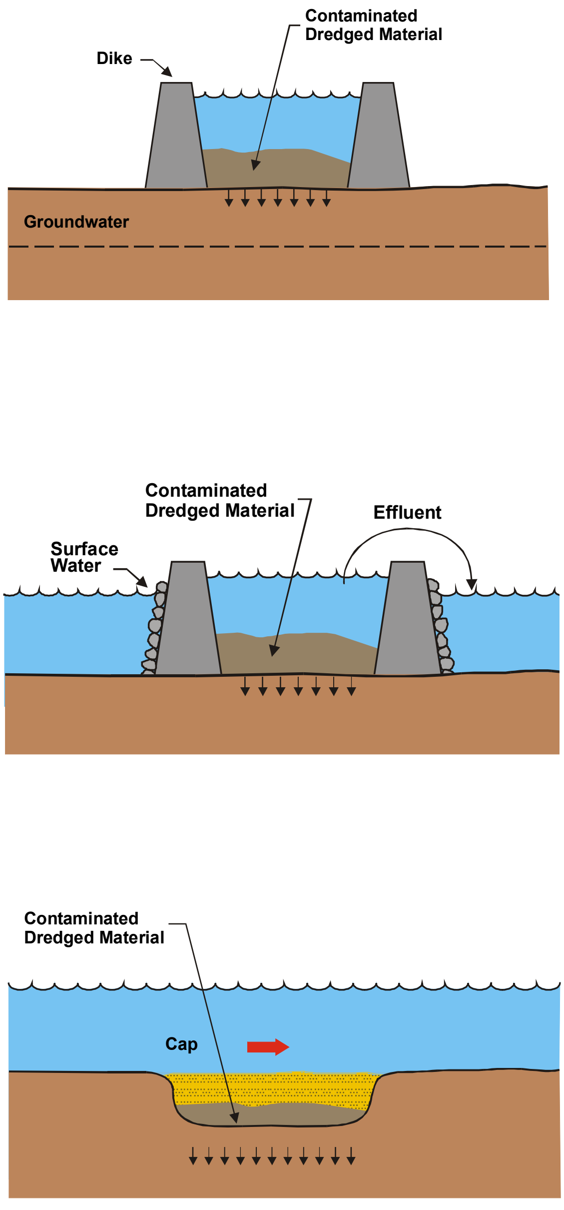

Fig. 7-1 Main types of confined disposal facilities

Each of the 3 types has advantages and disadvantages and has to be examined in a case by case approach taking into consideration the local circumstances. Upland disposal sites are for example the silt mounds in Hamburg and Bremen. Examples of nearshore disposal are the Slufter and the IJsseloog; subaquatic disposal is planned in the Hollandsch Diep area.

CASE STUDIES

IJsseloog Confined Disposal Facility (Subaquatic confined disposal)

To remediate Lake Ketelmeer, studies were carried out which indicated that the best option would be to build a nearshore aquatic disposal facility in the central part of the lake for the storage of the contaminated sediments. The site is a circular nearshore disposal facility with a 45 m deep excavated pit surrounded by a 10 m high containment dike. The site covers a total area of 250 ha and includes a nature-cum-recreation area. The design capacity of the facility is 23 million m^3.

Emissions of contaminants from the disposal site must be minimized in accordance with national standards and regulations ("As Low As Reasonably Achievable"). Primarily, the water level in the disposal facility will be maintained at the same level as the hydraulic head of the subsoil aquifer: CD -4,5 m. Other precautions taken are a clay layer of at least 1 m thickness on the bottom of the pit, the subsoil under the ring dike was only partly removed so as to preserve a poorly drained layer between the disposal facility and the sandy subsoil which is part of the groundwater aquifers, etc.

There are sand separation basins on the site. If sandy material (sand content more than 5070 %) arrives, this material will be separated in theses basins.

Silt Mound Disposal in Hamburg (Upland disposal)

The pre-treated silt is disposed in Hamburg in two mounds, Francop and Feldhofe, of approximately 38 m height each having a capacity of approximately 9 - 10 million m^3 treated material (corresponding to twice the amount before treatment).

The mounds are built on former flushing fields thus gaining space and reducing emissions from the old sites at the same time. The construction of the mounds protects the flushing fields against rainwater influx. This also protects groundwater against further contamination.

The general construction of the silt deposits is done in silt layers each 1.5 m alternating with 0.3 m drainage layers made of sand. One special feature in the construction of this type of silt disposal is using classified dewatered silt with a permeability of kf < 1 x 10-9 m/s as a sealing material. The basic seal for the mounds is created as a double seal consisting of a mineral layer (1.5 m silt) and a HDPE liner (2.5 mm).

The upper seal is created of a mineral layer (1.5 m) made of dewatered silt, sand as drainage and profiling layer and finally a cultivatable covering soil layer (average 1.2 m). The disposal sites will be provided with mixed plantation and trail networks so that they can be made accessible from the public.
The excess water of the drainage layers is treated in a technical water treatment plant. The quality standard of purification meets the regulations and the excess water is discharged into the Elbe

SEPARATION AND MECHANICAL DEWATERING

Case Study

METHA – Classification, sorting and dewatering of dredged material

Since 1993 the METHA-plant in Hamburg separates dredged material into silt, fine sand and sand and dewaters the silt. The plant has a throughput rate of about 500,000 t per year dry substance corresponding to 1,000,000 m³ *in situ* volume with a content of silt and clay of 50 % by weight.

The first separation step is realised at a grain size of 63 µm. With hydro-cyclones and upstream separators, a clean sand fraction with grain size > 63 µm and free of any organic material is produced. Sand is dewatered by a vibration screen. Operation capacity is about 200 t_{DS}/h (input). Sand production is in a rate of about 50 – 80 t/h.

Part of the silt fraction from the first separation step is treated in a second separation at 20 µm. With hydro-cyclone separators and spirals, a clean fine sand fraction with a grain size distribution 20 - 150 µm and free of any organic material is produced. Fine sand is dewatered by a vacuum belt filter. Operation capacity is about 50 - 60 tDS/h (input). Sand production is in a rate of about 20 – 30 t/h.

The dewatering of the silt fraction is realised in two ways. One dewatering line comprises a sieve-belt press and a high-pressure post dewatering press. This dewatering process has a total capacity of 60 tDS/h. The second dewatering system comprises membrane-chamber presses with a total throughput rate of 20 – 25 tDS/h. The objectives of the dewatering is to obtain a silt product with a water content to approximately 45 % by weight and a sufficient shear strength (cu > 25 kN/m²) from mechanical aspects. The total flocculant used in the dewatering process varies between approximately 500 and 1300 ppm, depending on solid matter content and type of dewatering technology.

The capital investment for the plant including all technical equipment, engineering as well as surface and subsurface construction and deep foundation amounts to € 70 million. A total of 96 persons is required for the operation. Annual expenditure for operation is approximately € 6.5 million.

The excess water from the transport of dredged material, pre-treatment and disposal is treated in a two-stage treatment plant with a capacity of 600 m³ per hour. Suspended solids are removed to concentrations below 25 mg/kg. In a nitrification plant comprising trickling filters and rotating biological contactors, ammonia is reduced from values up to 80 to below 2 mg NH4-N / l. One main factor for nitrification is its dependence on temperature, it is reduced very much when the temperature is below 12 °C. Also heavily varying inflow concentrations are not in favour of this biological process, but this can be counterbalanced with special operation techniques.

Author: H.-D. Detzner, Strom- und Hafenbau Hamburg

RIPENING

Ripening is a process in which dredged material is put on land into a temporary depot where dewatering and consolidation can take place. During and after dewatering, oxygen is able to penetrate into the dredged material, resulting in the oxidation of anaerobic organic matter and minerals. The combination of dewatering, consolidation and oxidation improves the engineering properties of the dredged material, which is required for the application as construction material e.g. as a filling or foundation material.

Ripening can be seen as an interaction of three components:

- physical ripening: irreversible loss of water resulting in the formation of permanent cracks and subsidence of the surface
- chemical ripening: changes in chemical composition due to reactions and leaching of soluble substances during the transition from anaerobic to aerobic conditions
- biological ripening: changes in the populations culture of micro-organisms and the structure of organic material during the transition from anaerobic to aerobic conditions

Dewatering and oxidation can be considered as the driving forces of the ripening process. Physical, chemical and biological processes greatly influence each other during ripening. The process of oxidation has a slight positive effect on the degradation of organic contaminants, such as mineral oil and PAH. Sulphides are oxidized to sulphates.

The speed of ripening of dredged material in deposits depends on many factors. The most important factors are:

- weather conditions: the importance of good weather conditions (warm and dry weather), especially during the spring and summer season, in which an surplus of evapotranspiration usually occurs, is evident;
- layer thickness: the time required for getting well ripened material increases with increasing layer thickness. Under normal (weather) conditions a thickness of 1,0 meter is common for a ripening period of 1 year;
- physical properties: ripening of dredged material takes longer when it contains high contents of fine particles and/or organic matter;
- drainage: the existence of a drainage system underneath the layer of dredged material will haven a positive effect on dewatering of the lower layer, especially during and shortly after filling. The effect of this drainage in the long term is expected to be of minor importance. Good drainage of the surface of the upper layer on the other hand, is on the long term very important. This can be achieved by pulling grooves or putting the material in ridges. Vegetation of the dredged material is also a method to drain it.

The suitability of the material for use in public works depends on the geotechnical and environmental quality.

The advantage of ripening is primarily the cost effective way in which the dredged material can be treated: 10 to 15 €/ m^3. Furthermore, the emissions in air are negligible and drainage water can be discharged without major problems when the input sediment meets certain environmental criteria.

Author: Tommy Bolleboom AKWA/DWW

STABILIZATION / SOLIDIFICATION

Stabilization / Solidification (also called immobilization) is a treatment technique that does not remove the contaminants from the sediment. The contaminants are transformed into a less mobile, and therefore less harmful, species.

The input material of stabilization / solidification is a dewatered (almost ripened) material. The first step in the process, stabilization, comprises the addition of chemicals to improve the binding of contaminants by the solid phase. The additives often improve the sediment structure as well. The additive used depends on the type of contaminants present in the sediment. Detailed information is often a trade secret, but most materials have a mineral structure, contain a large amount of calcium, and have a fairly high pH. Examples are: calcium aluminates, fly ashes, bentonite or other clays, lime, and silicate fume (fumed silica = Quarzstaub, Kieselpuder). Stabilization can be an end-point. Particularly, if soil structure needs to be improved for use in public works. This fact-sheet also includes the second step, solidification. The sediment is transformed into a solid material. The contaminants are not only chemically bound, but also physically built in the solid matrix. There are different materials, but in the Netherlands only cement has been used in practice. The sediment is now treated as a stony material, which is mainly used as a road foundation material if concentrations are below the standards of the Dutch building material act.

However, the experience with dredged sediments is very limited. Pilot projects have been made with contaminated soil, sewage sludge, fly ashes. Very recently, a pilot project in Groningen was started with a mixture of dredged sediment and a sandy waste material. The diversity in techniques leads to a wide range in the costs of producing a solid material of approximately 20-40 €/m³.

Sediments show a wide variation in size distribution, organic matter, contamination, and water content. The batch-wise production requires many recipes, which takes a lot of time to develop. However, it will be difficult to produce a reliable product if the input material differs so much. The legislation in the Netherlands restricts the possibility to use stabilization / solidification for all sediments. There is a maximum total amount defined for organic contaminants, because leaching tests are not available. It is therefore impossible to apply this technique to sediments that contain a rather high concentration of organic micro-pollutants, because the total amount is not changed by stabilization / solidification. The standard for Total Petroleum Hydrocarbons (TPH) is the most problematic one.

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Author: Leonard Osté (AKWA/RIZA)

CONSTRUCTION MATERIAL

Place of development and/or application; Operator and time of operation

Dewatered silty dredged material is used for liners in the CDFs in Hamburg and Bremen and also for a disposal site for industrial waste in Bremen.

Description of the solution

Applicable to clayey silt or clay.

The disposal sites are multi-layer constructions to guarantee soil mechanical stability and to prevent penetration of rain water and the transport of nutrients and contaminants (see also Fact Sheet on Disposal). The bottom sealing system in Bremen-Seehausen was constructed by using specially selected dredged material. The dewatered silt has a permeability coefficient less than 1 * 10-9 m/s. In addition, other soil mechanic parameters for sealing layers are achieved as well. For special demands, an admixing of additives like CaO could improve the soil mechanical parameters. This addition is called conditioning.

To cover the industrial landfill in Bremen the same material was used as an element of the top layers without additives.

Scale of operation and experience

Experience on an industrial scale is available, as more than 100.000 m^3 of the respective material were used in all cases mentioned here.

State of feasibility

The projects are technically and environmentally feasible according to standards applied in Bremen. However, the degradation of organic matter, which is higher in dredged material than in silts and clay generally used for containment layers, can have an influence on the long-term stability of the construction and the chemistry of the porewater. This may have an effect on the emission of nutrients and contaminants. In order to be able to control these mechanisms, a monitoring program is conducted.

Costs and market aspects

In Germany, old landfills will be covered with containment sealings within the next years to prevent the penetration of rain water through the waste. The costs for applying harbour sediment as a barrier in covering systems range between 10 and 15 €/ m^3, costs for dewatering and transport excluded.

Uncertainties and open questions

Degradation of dredged material may have an effect on long-term stability and chemistry.

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Building material for dikes

Case study

Place of development and/or application; Operator and time of operation

Lower Saxony; Ostfriesland; backward dike line; Cooperation of the 3rd Oldenburgische Deichband and the Port Authorities of Hamburg and Bremen/Bremerhaven. 2002-2003

Description of the solution

Parts of a dike consist of clays and silts which should be substituted by dredged material.

Scale of operation and experience

Pilot scale with several 100 m^3. Experiences gained from using dredged material as barrier material in landfills are helpful. However, the different construction of dikes and barrier systems in landfills makes it necessary to investigate the feasibility.

State of feasibility

The pilot study will be part of a feasibility study about the applicability of dredged material as a constructional element of dikes.

Costs and market aspects

No data available until now.

Uncertainties and open questions

Should be answered during this pilot study. Some aspects can be similar to the use as a barrier material in landfills (see there)

LIGHT-WEIGHT AGGREGATES

Place of development and/or application; Operator and time of operation

Bremen; Cooperation of BREWA-Umweltservice and FIBO Exclay Deutschland; 1998-2000

Description of the solution

Light-weight aggregates are mostly used to substitute natural gravel as geotechnical fill material or additive to light concrete. Harbour sediment can substitute natural clays and silts. After admixing DM with additives, pellets are formed, heated in a rotation kiln at approx. 1250 °C. On their way through the rotary kiln, the pellets expand to aggregates with a grain density between 0.6 and 0.8 t/ m^3.

This type of treatment combines elements of thermal desorption, oxidation and immobilisation as well.

Scale of operation and experience

Lab-scale with several hundreds of kilograms (laboratory) and 75 t in a full-scale process test with pre-treated, dewatered silt material from Hamburg

State of feasibility

A scale-up from lab to pilot scale is necessary to confirm or precise the existing information: The constructional parameters show that the product fulfils German constructional standards.

The leaching data of light-weight aggregates makes obvious that organic matter was not totally destroyed during the production. However, Arsenic was stabilised and heavy metals were immobilised. Concerning heavy metals and metalloids light-weight aggregates are not to be considered as hazardous to soil or groundwater, neither during their use, e.g. in construction, nor afterwards, when they are disposed of as mineral demolition mass.

Costs and market aspects

The costs for producing light-weight aggregates vary between 15 and 32 € per m^3 sediment in situ after pre-treatment. This price includes consulting and planning, investment and operational costs and depreciation as well and is calculated by the companies.

Uncertainties and open questions

In a next step of investigation light-weight aggregates should be produced on a bigger scale. First, in order to analyse organic parameters in the eluatriate as well.

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BRICKS

Place of development and/or application; Operator and time of operation

Hamburg, Hanseaten-Stein Ziegelei GmbH, private brickwork, set into operation in 1996

Description of the solution

In more than 10 years of research and development the company HZG - Hanseaten-Stein Ziegelei GmbH – developed a process of utilising DM as a clay replacement in brick production. The production is adapted to the specific requirements allowing to manufacture high-value ceramic building materials - e.g. house bricks. This brickwork is peerless in the building material industry with regard to the plant's safety, filter and cleaning technology.

Scale of operation and experience

The annual production capacity of the facility at Hamburg-Neuenfelde amounted to approximately 5 million bricks. The process enables natural clays with a content of 70 % by weight to be replaced by approx. 30,000 tonnes of METHA silt with a dry matter content of 50 - 55 % by weight. The bricks are destined predominantly for industrial and commercial buildings as well as for local authority builders. Mainly sediments from the port of Hamburg were used, as well from the ports of Bremen and Venice.

State of feasibility

Products and production fulfil technical standards as well as environmental demands (Walda 1998). The whole life cycle of the products had been investigated, including the emissions during production as well as states of the bricks use: storage, masonry as well as recycling after demolition (Bäätjer & Detzner 1997; Hamer & Karius, 2002; Karius & Hamer; 2002)

Costs and market aspects

For a throughput of approx. 200.000 m³ dewatered sediment (after pre-treatment!) an investment of 45 Mio. € can be estimated, corresponding roughly 15 – 20 €/ m³ in situ. This makes an amortization time span of up to 20 years necessary, in which marketing of the bricks has to be guaranteed.

Uncertainties and open questions

These costs can be only indicative, because they are strongly dependent on throughput, duration of the project, investment, operational costs including energy and personal costs etc., so that calculations from Hamburg or Bremen cannot be directly transferred to other projects. Of additional importance is the market. Hamburg and Bremen have a market with a traditional demand for bricks (Nowak & Hamer 2000). But, before a final agreement, a market concept has to be developed in order to convince potential credit granters.

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ARTIFICIAL BASALT

In 1996, a pilot-project was carried out on thermal immobilization of dredged material from the river Nieuwe Merwede (Netherlands). A quantity of 1000 m^3 of dredged material was processed by sand separation, drying (220-350 °C), melting (1400-1500 °C) and crystallization.

From approximately 690 tons dry weight of dredged material, 300 tons dry weight of basalt was produced. A small part of the basalt was formed as hexagonal blocks (10 tons), the rest as a granulate.

The columnar blocks and granulates were used for dike revetment in a small harbour (Woudrichem).

The costs for large-scale production are estimated at €100 per ton dry matter input, corresponding to about 70 €/ m^3 in situ. These are the costs of granulate, the production of blocks is more costly.

BIOREMEDIATION

Polycyclic Aromatic Hydrocarbons (PAHs) and mineral oil are biodegradable under aerobic conditions. Part of these contaminants in sediment is bioavailable and can be degraded very quickly as soon as waterfilled pores in the sediment are replaced by air filled pores (dewatering) or oxygen is actively introduced (bioreactor). Biodegradation starts after a short period necessary to develop an active micro-organism population. This population will develop naturally in most sediments. Inhibitive factors (low pH, very high concentration of contaminants) may prevent the development. The non-bioavailable parts have to diffuse to sites in the sediments were biodegradation is possible, and this diffusion is a very slow process. The bioavailability of mineral oil in sediments is often much lower than the bioavailability in soil, resulting in slower degradation. The following biological treatments can be distinguished.

Bioreactor. Treatment of the original sediment, oxygen is actively introduced. Removal of the bioavailable fraction takes days to weeks. With longer treatment times also part of the non-bioavailable contaminants can be removed. After bioremediation, dewatering is still necessary to reduce volume before application. Several bioreactors have been developed, but have shown to be too expensive for treatment (>100 €/ m^3).

Intensive landfarming. Ripening (see other fact sheet) is mainly focused on the transformation of dredged sediment into dry soil that can be used in public works. During dewatering of the sediment, already some of the bioavailable part is biodegraded. This can be enough for reuse of the sediments, specially if the original concentration of the contaminant was slightly above the target value. If a higher amount of the contaminant has to be degraded, stimulation of the ripening and degradation processes can be necessary. Possibilities are cultivation, addition of nutrients and addition of soil improvers. This is more costly. Within the treatment period it is possible to biodegrade the complete bioavailable fraction. Intensive landfarming is already applied to soils, but for sediments first dewatering is necessary which implies a longer treatment (2 years). Intensive landfarming is applied on specially constructed sites (costs 20 €/m^3 and higher)

Passive landfarming. If the availability of the contaminant is the limiting factor, stimulation of the activity of the micro-organisms is less important. The slow diffusion to sites were organisms can be active is the most important step. Bioremediation can be achieved with passive landfarming. The active dewatering is replaced by growing of natural or cultivated vegetation. As soon as the vegetation covers the whole field, the evaporation is very high, given a dewatered sediment in a few years. 3 to 6 years are necessary to reduce the not direct available PAHs by 50%. The available PAHs are biodegraded in the first 1 to 3 years (depending on layer thickness). Passive landfarming can be combined with beneficial land-use, for instance combination with production of biomass or development of natural sites. Both combinations are already applied on the scale of hectares (costs ca. 15 €/m^3, depending on benefits).

Phytoremediation. In fact, passive landfarming is a form of phytoremediation. The presence of vegetation stimulates the activity of micro-organisms (phytodegradation). Phytoextraction is often promoted for the removal of heavy metals. This will be high if the product of accumulation in the vegetation and the yield of the vegetation is high. For the moment, this production is not high enough resulting in treatment times of decades to centuries. Successful application of phytoextraction is only suggested and not proven. Research is going into the possibilities of vegetation to immobilise heavy metals (phytoimmobilisation).

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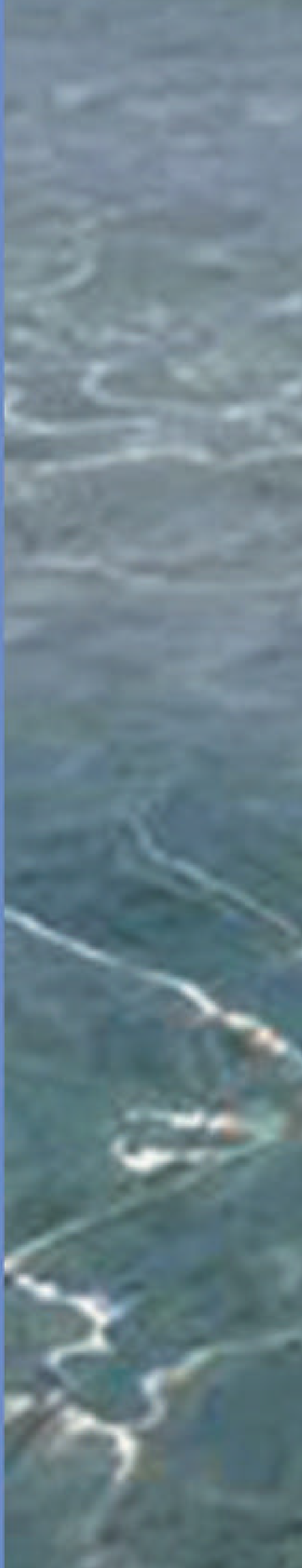

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