

### 3. Sediment Management at the Catchment Scale

Sediment quantity has been managed for centuries, mostly by dredging. This was, and still is, very much needed in order to keep waterways, that tend to silt up, open to the flow of water. This ensures a proper drainage capacity for precipitation and melting snow and ice, so it aids in flood prevention. However, the removal of sediments for the maintenance of waterways and water quality from locks, floodplains, harbours, navigation channels and river stretches is a high capital cost for responsible authorities and agencies.

Since the beginning of the industrial revolution, hazardous chemicals were emitted to our surface waters. Lots of these chemicals do not readily dissolve in water but rather stick to the sediment. Therefore, sediment quality rapidly deteriorated also because several chemicals do not readily break down in sediment. This introduced the need for a new type of management: sediment quality management (SedNet 2004).

This chapter deals with five aspects of sediment quality management: (1) Legislation on a European and national level, (2) management practice in The Netherlands and Germany, (3) biological effects-based sediment quality in ecological risk assessment for Dutch and German waters, (4) sediment management issues in the Water Framework Directive (WFD) for monitoring and emission controls of priority substances, and (5) future challenges on sediment management at the catchment scale.

#### 3.1. Legal Aspects<sup>6</sup>

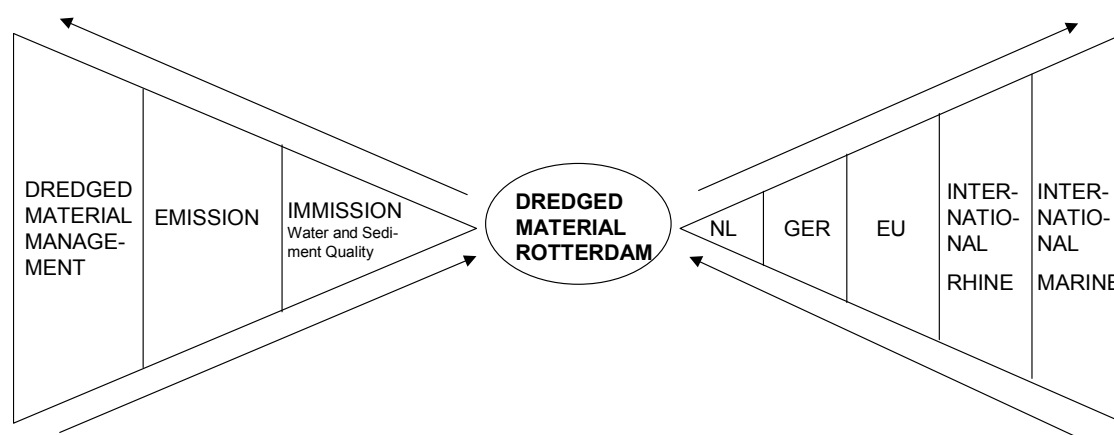
##### 3.1.1. European Directives on Water, Soil and Waste (Landfills)

The *European Water Framework Directive (WFD)*, which came into force in 2000, will replace existing EC-directives for surface water and groundwater within the subsequent 7 years. Dredged materials (DM) and sediments are not mentioned explicitly in the WFD (Förstner 2002). Germany and The Netherlands expect that the WFD is likely to have implications on Dredged Material (DM) handling, since sediments have an influence on water quality. An increased monitoring requirement for selected substances (see priority list in Annex 10 of WFD) is expected (section 3.4). Furthermore, it is not clear yet whether and how the demands of the WFD about “heavily modified waters (e.g. waterways)” will affect the DM management.

A *European soil protection directive* does not exist, but the European Committee issued a communication paper as basis for discussion on the development of an *EU Soil Strategy*. The *European Construction Products Directive*, that aims to harmonise European legislation for the market of building materials in the EU, has relevance to this discussion. The Construction Products Directive regulates the re-use (beneficial use) of soils or soil material as building material and therefore could interfere with national soil policy (3.1.3).

### Interactions of National and International Regulations (from: Rhine Research Project II Part D 2001)

Figure 3.1 indicates that the national, Dutch and German, European and international regulations concerning the immission and emission approach and dredged material management build a complex system of interactions. Both The Netherlands and Germany are contracting parties of the International Commission for the protection of the Rhine (ICPR, Rhine catchment area) and conventions as the Oslo and Paris (OSPARCON) concerning the receiving coastal environment (North Sea).



**Figure 3.1** Overview over the interactions of national and international regulations

### Differences between Dutch and German Regulations concerning Sediment Quality

#### ***Sediment Quality Targets*** ( page 260)

The Netherlands have established two sets of sediment quality objectives for metals and organic substances, which are valid for both marine and freshwater sediments and which are based on ecotoxicological assessment and political decisions (environmental yield/costs ratio): the target level (long-term objective) and the limit level (short-term objective). In a long-term perspective a harmonisation of inland and marine quality targets is anticipated. The improvement of surface water quality aims as well at the unrestricted marine disposal of estuarine dredged material.

In Germany there are no marine sediment quality targets yet, but national freshwater sediment quality targets for seven metals currently do exist (German federal working group on quality targets, BLAK QZ). These sediment quality targets are based on ecotoxicological assessments. A comparison of the Dutch and German sediment quality targets for metals, lead, cadmium, chromium, copper, nickel, mercury and zinc shows, that in most cases the Dutch long-term sediment quality targets are more stringent than the German ones. On the other hand the Dutch short-term sediment targets are in most cases less stringent than the German quality targets.

<sup>6</sup> selection from: Dutch-German Exchange on Dredged Material, Part 1 (DGE-1, 2003)

***Feedback between dredged material quality and emission control*** ( page 262)

The international conventions for the protection of the marine environment state in their dredged material management guidelines that high priority should be given to the identification of sources as well as the reduction and prevention of further contamination of sediments. Furthermore, both point and diffuse sources should be addressed adequately.

The Netherlands follow the principle that the quality of the dredged material to be disposed at sea should be improved by reducing inputs of contaminants in rivers and estuaries. These emission reductions should be achieved by the application of Best Available Techniques. The Dutch emission measures address both point and diffuse sources, with a current emphasis on the latter. Dredged material quality is not yet used in a feedback system to emission control, but it has been advised to implement such an effect-oriented emission approach. On the other hand, private initiatives to reduce emissions in the River Rhine by the Port of Rotterdam authorities have proven to be successful.

It is not obvious, whether Germany has a feedback system for dredged material quality to source control as required internationally. The environment objective of different German environmental laws include sediments as a compartment of nature. The emission principle (with its emission standards) is the main tool in German environmental law, e.g. for wastewater discharges to surface water the Best Available Technique is required to fulfil the environmental objectives. To assess whether the Best Available Technique is applied, a wastewater assessment is carried out by using bioassays. But at present the effects of effluents on organisms living in sediments (benthos) are not considered.

***Dutch and German regulations for dredged material*** ( page 263)

The Netherlands established five levels of sediment quality criteria, which are based on ecotoxicological assessment and political decisions. Coupled to these levels there is a sediment classification system on which the decision about the inland disposal option is based: the lowest 3 classes of sediment (below the testing value) can be disposed in surface water or on land, whereas the highest two classes should be treated or stored. In addition to this there are so-called Uniform Quality Criteria as (chemical) decision criteria for the marine disposal of estuarine dredged material. The use of bioassays in the assessment of estuarine dredged material quality is foreseen for 2002. (refer to current status)

In Germany two action levels are stated for dredged material management in Federal coastal waterways. They are derived from the prevailing contaminant concentrations measured in North Sea sediments from 1982 – 1992. Ecotoxicological and biochemical data support decision-making, but in general only one bioassay is used for that purpose. The action levels are not environmental quality targets or objectives, but guide values. The decision is generally guided by the values, but is made on a case-by-case basis. For Federal inland waterways the disposal decision is based on chemical and ecotoxicological criteria (applying a bioassay testset). The criterion for the disposal decision is that a deterioration of water and sediment quality at the disposal site is not allowed. The decision is, like for Federal coastal waterways made on a case-by-case basis.

The *European Landfill Directive (1999/31/EC)* regulates the landfilling of waste, including DM. If DM will be disposed of upland without any further use, it has to be decided which category of landfill has to be chosen. Technical demands for those landfill categories (disposal facilities) are defined in the European Landfill Directive. An important exemption for DM is made in article 3: “...the deposit of non-hazardous dredging sludges alongside small waterways from where they have been dredged out and of non-hazardous sludges in surface water including the bed and its sub-soil” is excluded from the scope of the European Landfill Directive. This exemption is implemented in the Dutch waste legislation (Environmental Act) for “slightly contaminated DM” as defined in the Dutch Soil Protection Act. The German Landfill Ordinance (DepV, 2002) does not explicitly highlight the exemption of the European Landfill Directive for aquatic disposal of DM.

### **3.1.2. International Commission for the Protection of the Rhine (ICPR)<sup>7</sup>**

In 1950 the “International Commission of the Protection of the Rhine” (ICPR) was founded on the initiative of The Netherlands. The members are Switzerland, France, Luxembourg, Germany, The Netherlands and since 1976 the European Community. In 1963 the Commission’s contract was based on the Law of the Nations; the actual legal basis of the Commission’s work, the new Rhine Convention, was passed in 1999.

One of the objects of the ICPR is to achieve such a sediment quality of the River Rhine that all the dredged material can be relocated into the North Sea. But although the water quality of the River Rhine has improved significantly during the last 25 years – the actual concentrations of heavy metals in water (including suspended matter) are lower than the European Threshold for drinking water – the concentrations of heavy metals (except mercury) in the sediments of the upper Rhine are still frequently higher than the Dutch thresholds for relocation of DM into the North Sea. With regard to some PAHs and PCBs the Dutch contamination threshold was also exceeded.

The pollution reduction was quite successful and other topics such as flood protection or the ecological improvement of the river basins became more important. The ICPR elaborated a programme for the “Sustainable Development of the River Rhine” with the participation of NGOs and representatives from different industries. The ICPR is one of the important institutions to establish the river basin management plans required by the EU-WFD.

However, management of contaminated sediments remains a controversial issue. In 1995 the water quality working group analysed the national standards of the member states for the disposal of dredged material. The national regulations were embedded in other laws, as for example, for waste, waterways, environment or nature protection (see below). With regard to dredged material management, in 1997 the ICPR defined, among others, criteria for the relocation of dredged material in the River Rhine and its tributaries. The criteria are based on the “prevention of degradation principle” (see Box, selection and translation from the German version by U. Förstner).

### **ICPR - Recommendation to the Criteria for the Relocation of Dredged Material into the Rhine and its Tributaries** (Document Ssed 06-04=No. 89=PLEN 40/97)

"An objective science-based assessment of the effects of contaminant contents during the relocation of dredged material at present is not possible. The second best assessment principle for dredged material is the "no deterioration requirement", which, however, only represents an interim solution. In the following, criteria are recommended, which refer to the actual quality of suspended particulate matter, and therefore imply a continuous improvement. Due to the very high anthropogenic inputs in former years contaminants have been enriched in the sediments and, with it, in the dredged material"

#### **1. Purview of the recommendation – definitions and types of measures**

Relocation in the sense of this recommendation is the relocation of dredged material (here aquatic sediments) within the aquatic system. In the regular case of relocation in the course of maintenance measure aquatic sediments are dredged and relocated at another site of the same aquatic system. Relocation is also performed under water, e.g., by means of a hydraulic dredge or jet stream.

Dredged material from maintenance measures mostly consists of aquatic sediments of varying grain size composition, depending from the availability and respective flow conditions. There is a characteristic high proportion of fine grain sizes in zones of low water velocity; this fine-grained material (silt, clay) is oftenly contaminated.

#### **2. Obligation of investigations for dredging plans**

Prior to each relocation measure investigation of the dredging site, the dredged material and the depositional area have to be made. Morphological and biological criteria must be respected and, if needed, respective investigations have to be performed. Laying down the extent of investigations of chemical-physical parameters is made on the basis of available measuring data (not older than 5 years) and the local peculiarities (discharges, harbours). Accordingly the extent can be reduced or enlarged. Samples must be representative for the dredging site and must allow statistical evaluation.

#### **3. Obligation to discard**

If dredged material cannot be relocated, e.g., because of the criteria indicated below, it has to be discarded according to national criteria.

#### **4. Qualitative criteria for the relocation of dredged material**

The qualitative criteria must not be attained by mixing less and strongly contaminated dredged material..

Chemical-physical criteria: Dredged material is allowed to be relocated only when the mean concentration of every pollutant is less than three times (nationally partly stricter criteria are valid, see Table 3.1) the mean concentration in suspended matter of three years before dredging occurred.

Ecotoxicological criteria: In principle, for the assessment of dredged materials ecotoxicological criteria should be applied with priority. However, at present this cannot be achieved at an international level due to the lack of an uniform assessment procedure.

The concentration of oxygen in the water must be higher than 4 mg/l.

#### **5. Quantitative limitations of the contaminant**

Relocations of dredged material are permitted only when the actual river flow is significantly above the mean longstanding minimum flow. General care should be taken that the contaminant load of the dredged material has only minor effects on the annual contaminant load in the aquatic system.

<sup>7</sup> after Hagner and Peters in Rhine Research Project II report (2001)

### 3.1.3. National Legislation and Guidelines on Dredged Material

#### Water Regulations

In The Netherlands there is a national policy document on water-management in use (NW4) for the period 1998-2006. It gives an overall strategy for water-management in The Netherlands including specific quality criteria (target and/or risk levels) for surface water, and sediments (DM). The policy document also contains specific criteria for aquatic relocation of DM in sea-water. In general, quality criteria for DM, and surface water (freshwater) have a regulatory link to the Soil Protection Act (WBB) and the Pollution of Surface Waters Act (for seawater WVZ, and freshwater WVO) too. In addition to the policy document on water-management, there is a governmental policy document on the removal of DM (BVB, 1994), which describes the policy on DM management in The Netherlands. A national directive for large (aquatic) disposal sites is part of the governmental policy document on the removal of DM. Very important are the criteria for the protection of groundwater quality. Recently, also a master plan for the removal of DM was presented in The Netherlands (*Tienjarens scenario*). The master plan made clear that in recent years the amount of DM did not equalise the sedimentation-rate. Consequently the total amount of sediments that have to be removed from Dutch waterways has increased. In order to make up these arrears in dredging, large efforts have to be made in the near future.

In Germany, comparable policy documents for DM do not exist. National water quality criteria for inland waters (freshwater) were developed by the LAWA (Länder Expert Group on Water). This classification includes quality criteria for suspended matter but not for DM. The system is going to be revised and is foreseen for implementation as part of the EC-Water Framework Directive. For DM in the coastal region there is a political mandate between the federal government and the regional (Länder) governments at the coast to work out a national recommendation for the handling of DM in coastal waters (North Sea and Baltic Sea). A recommendation for the handling of TBT-contaminated DM in coastal waters was introduced in November 2001 (BLABAK TBT-Concept).

#### Soil Protection

The *Dutch Soil Protection Act* includes aquatic soils (sediments/DM) and gives quality criteria for soils, aquatic soils and groundwater. The Soil Protection Act is divided into a soil protection section and a soil remediation section. Both sections deal with aquatic and terrestrial soils and groundwater. The protection section prevents soil degradation and addresses all kinds of soil quality threatening activities. The soil remediation section regulates whether or not action should be taken on contaminated soils and what kind of action that should be. Quality standards for soil and groundwater are included. An ordinance to the prevention section of this act (but also to the Pollution of Surface Waters Act) is the *Building Material Decree*, which makes a difference between 3 categories of building materials. The difference is based upon the leaching of the building material. The Dutch Building Material Decree has been notified to conform to the *European Construction Products Directive*.

In Germany the *Federal Soil Protection and Contaminated Site Act* has in general the same goals as the Dutch Soil Protection Act. The rules for practice were set into force by the *Federal Soil Protection and Contaminated Site Ordinance*. The main difference between the Dutch and the German Soil legislation regarding DM is that the aquatic soils (bottom sediments) are not in the scope of the German Soil legislation (BBodSchG). The German soil regulations (act and ordinance) relate to upland disposal (re-use/beneficial use) of DM. There is a close connection to waste legislation with regard to restoration of contaminated sites. Permits are needed if DM shall be placed on soils for further (e.g. agricultural) use. These permits have to include an expertise about the soil planned to be covered by DM and the DM itself with regard to possible deterioration of soil and groundwater quality or other subjects of protection connected with soil. In consequence of the introduction of the Federal Soil Protection Act and Ordinance (BBodSchV) the soil standards in different environmental regulations are going to be harmonised with regard to groundwater protection.

### **Waste Regulations**

National waste regulations in both Germany and The Netherlands are strongly influenced by the European waste policy. Main goals of the European waste policy are the avoidance of waste, the stimulation of re-use or beneficial use of waste, and to ensure that the handling of waste is safe. Waste which cannot be used environmentally sound has to be treated and/or to be disposed of in waste facilities (landfill). The superior definition of waste is given by the *European Framework Directive on Waste* and is implemented as such in the national waste regulations of The Netherlands and Germany. Because of this superior definition of waste all DM that has to be discarded without any further use is waste irrespective of its contamination.

In The Netherlands there is a national ministerial decision under the Environmental Management Act for the disposal of non-hazardous DM in landfills. By means of this ministerial decision the European Landfill Directive was implemented in Dutch legislation. The ministerial decision can be regarded as the Dutch directive for upland (*above groundwater*) confined disposal facilities (CDFs) for DM. It defines the “maximum” impact on groundwater that is regarded as tolerable. This Directive is similar to the Dutch directive for large-scale (aquatic) disposal sites for DM that is part of the policy document (BVB) on the removal of DM, and has to be applied on CDFs within groundwater. Both directives do not prescribe specific isolative means, but define the maximum tolerable effects on groundwater quality. The maximum tolerable effects are in line with the goals of the Dutch soil protection policy. Possibly in the near future both Dutch directives for confined disposal facilities for DM will be combined.

Germany does not have comparable national DM guidelines for the disposal alongside small waterways and for confined disposal facilities. The term “small waterway” is not defined in any German law or standard. Within the new German Landfill Ordinance the special characteristics were considered with some compromises, which allow waste authorities to permit upland DM disposal sites in an adequate way. The German DM directives HABAK (coast) and HABAB (inland, see 3.1.4) apply to all German federal waterways (7700 km), which do not include waterways/ports/reservoirs/rivers/lakes under the competence of the 16 Länder. HABAK and HABAB do not regulate the disposal of DM along-

side small waterways (exemption in the European Landfill Directive) or in a confined disposal facility in a special way. Despite the complex situation, there are presently no political activities in Germany to create a harmonised national guideline that regulates all aspects of DM handling.

### **3.1.4. Dredged Material – Where Does Waste Term Apply and End?**

#### **Dutch considerations**

In the Dutch situation all dredged material is regarded as waste if there is a need for disposal. Based upon the quality, the dredged material is divided into classes. Class 0 is clean material (target-values are not exceeded). Class 1 and 2 are regarded as lightly contaminated and classes 3 and 4 are heavily contaminated. In general the Dutch Environmental Management Act forbids the disposal of waste outside a facility (WM art. 10.2). All waste should be disposed of in specific facilities like prescribed in the decision on facilities and permits (WM, Inrichtingen en vergunningen-besluit, Ivb). Facilities for the disposal of soils are mentioned in category 11 of the IVb, but since contaminated DM is regarded as industrial waste (bedrijfsafvalstof) facilities for contaminated dredged material are belonging to category 28 of appendix 1 of the IVb (facilities for the disposal of waste).

In the Environmental Management Act (WM) an exception on article 10.2 of the WM is made for DM of classes 0,1 and 2 (besluit vrijstelling stortverbod buiten inrichting, 1993 (1) Stb 616, revised 28-07-2000, staatsblad 2000, 352). Clean material (class 0) can be relocated in surface-waters without restrictions from an environmental point of view. DM of Classes 1 and 2, originating from maintenance dredging, can be relocated in - or alongside waterways within certain conditions.

Permits based upon the Pollution of Surface Waters Act are needed for relocation in waterways. For the excavation of contaminated DM a permit based upon the Soil Protection Act is needed also. In order to obtain both permits the sediment (soil) quality has to be known. In this way before the dredging operation takes place the quality of the DM is known. This is necessary because the sediment quality determines indirectly if waste regulations or water or soil regulations apply to the dredging project. Transport of contaminated DM needs a permit based upon the provincial environmental ordinances. The Dutch Building Materials Decree allows re-use DM of class 1, 2 or 3 as a secondary building material. Waste regulations allow this if the DM quality complies with the demands of the Building Materials Decree. During the use of DM as a building material the waste regulations are no longer relevant.

#### **German considerations**

The issue of whether dredged material should be classified as waste and when the term should apply is based on the definition of waste in the Closed Substance Cycle and Waste Management Act (*Kreislaufwirtschafts- und Abfallgesetz* - KrW-/AbfG). Under Article 3 para. 1 of this Act, which corresponds with Article 1 a of the EC Framework Directive on Waste (Council Directive 75/442/EEC), waste is defined as "all movable property in the categories set out in Annex I which the holder discards, or intends or is required to discard". In order for the term waste to apply to dredged material, the individual fea-



tures of the definition must be met. Ultimately, the deciding factor is whether one of the statements with regard to discarding can be applied. The "desire to discard", which must always be checked if movable property occurs unintentionally due to certain processing or treatment activities, is particularly significant. Pursuant to Article 3 para. 3 no. 1 of the KrW-/AbfG, "desire to discard" must be assumed in the case of property occurring in connection with certain treatment measures or services, when such occurrence is not the purpose of the action. Under Article 3, par. 3 no. 2, the desire to discard must also be assumed for such movable property whose original purpose no longer exists, or is given up, without being directly replaced by a new purpose.

Since the extraction of dredged material is not the primary purpose of dredging in waterways, it could be assumed that there is a desire to discard in the sense of Article 3 par. 3 No. 1 of the KrW-/AbfG, when dredged material is relocated. It should be noted, however, that a particular measure can also have secondary objectives. Under the European Court of Justice (ECJ) ruling of 18 April 2002 (case C-9/00), the term waste and in particular the feature of discarding must be given a wide interpretation, and therefore stringent requirements have to be met in order for sediment to qualify as a by-product. Under this decision, the sediment could only be classed as a by-product if its environmentally sound re-use without prior processing and following directly on from the extraction process is certain. Uncertain, potential re-uses, or those only possible in the long-term, are not sufficient. Before dredging begins, therefore, and taking ecological aspects into account, it must be clear what role the relocated sediments will play in navigational safety, hydrology, morphology or water management.

Where sediments must be defined as waste they are subject to the waste regime of the KrW-/AbfG. Under the obligations and requirements of this Act, priority must be given to the environmentally sound recovery of dredged material (cf Articles 5 ff KrW-/AbfG) or "if recovery is not technically possible or economically reasonable (cf Article 5 par. 4 KrW-/AbfG)" dredged material must be disposed of in a manner compatible with public interest (cf Articles 10 ff KrW-/AbfG). The waste producer also has the option of recovery in water rather than recovery on land. The decisive factor is whether the material resources are used, or, as formulated in the ECJ decision of 27 February 2002 (case C-6/00), whether the dredged material can fulfill a useful task in the proposed recovery, which entails substituting the materials which must otherwise be used for this purpose and thus enabling conservation of natural resources. Here too, hydrological, morphological, water management and navigational safety aspects all play an important role in the technical assessment. Whether or not discarding dredged material classified as waste in water bodies can be seen as recovery must be decided on a case-by-case basis by the competent authorities on site.

As soon as wastes are discharged or dumped into water bodies, however, they are no longer subject to the provisions of the KrW-/AbfG (cf Article 2 par. 2, no. 6). However, all material and formal requirements of waste law apply without restriction until the moment the wastes are introduced into the water body. The principle of waste avoidance has priority over waste management obligations (cf Article 4 par. 1). Before beginning the measure, therefore, a study must be undertaken to determine whether and to what extent it is possible to avoid or reduce wastes as defined under waste law. The

waste characteristic ends when a material obtained from dredged material is actually used in an environmentally sound way, or if a secondary raw material is produced of such a quality as would appear to ensure its environmentally sound use (e.g. pre-treated and purified sand as building material).

### 3.1.5. Relocation of Dredged Material in German Inland Waterways

The general approach to dredging and relocation (aquatic disposal) of DM is in principle the same in Germany and The Netherlands, including permissions and standards. DM can be relocated in surface waters (freshwater and saltwater) under specific conditions, which guarantee no harm to the environment or on the banks alongside small regional waterways (freshwater), instead of disposal in specific landfills/facilities. Quality criteria are used both in Germany and The Netherlands to decide if relocation in water/waterways is possible environmentally sound. However, contents and levels of standards are different, and in addition standards for sediments are more detailed in The Netherlands.

Similar to the international guidelines on dredged material management the tiered procedure according to Directive for the Handling of Dredged Material on Federal Inland Waterways (HABAB-WSV, BfG 1997, 2000) includes: planning of the project, avoidance of dredged material; physical, chemical and if necessary ecotoxicological and ecological characterisation; relocation or direct beneficial use; pre-treatment and recovery on land or aquatic disposal besides the Federal waterways; and as the last option, disposal on land; examination of the disposal site and selection of the suitable option. Here, some aspects of the chemical and biological characterisation, and the criteria for the different management options will be highlighted (Peters & Hagner 2001):

- 1) The physical characterisation of the dredged material is compatible with international guidelines. The chemical parameters include As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, and Fe (metals) and organic contaminants such as PCBs (7 congeners),  $\alpha$ -HCH,  $\gamma$ -HCH, HCB, Pentachlorobenzene, p,p'-DDT, p,p'-DDE, p,p'-DDD, total of six PAHs,  $\Sigma$ HC, DBT, mineral oil. However, the programme can be adjusted to regional and local special conditions.
- 2) Ecotoxicological studies have to be conducted, if chemical analysis and biological structure analysis indicate that ecotoxicological effects might be possible and the option of relocation is not excluded because of the chemical analysis. According to the HABAB-WSV, the bioassays, which have to be applied in such cases, are in general porewater tests with bacteria (bioluminescence inhibition of *Vibrio fischeri*), algae (freshwater algae growth inhibition test) and crustacea (Daphnia toxicity test). In addition other tests are conducted in special cases.

Criteria for relocation of dredged material in the Federal waterways are summarized in Table 3.1.

In cases of relocation of dredged material in Federal waterways, the Federal Waterway Act (*Bundeswasserstraßengesetz* – WaStrG) has to be considered. For maintenance dredging no permission is necessary (§ 7 III WaStrG), but in case that interests of the *Länder* are affected, they have to give their consent to such actions (Einvernehmen)(§ 4 WaStrG).

**Table 3.1** Criteria for the decision of relocation according to HABAB-WSV (Federal Inland Waterways)

Chemical criteria and decision		
Case	Criteria	Decision
Case 1	The median concentration of each single contaminant in the dredged material does not exceed the 1.5 times value of the median concentration of contaminants of the suspended matter (3-annual-median) at the relocation site.	The dredged material can be relocated.
Case 2	The median concentration of at least one contaminant in the dredged material exceeds the 1.5 times value but none exceeds the 3 times value of the median concentration of contaminants of the suspended matter (3-annual-median) at the relocation site.	The decision about relocation has to be proven in every single case. Inputs of pollution into the water body have to be considered. In addition the ecotoxicological assessment of the dredged material can be considered.
Case 3	The median concentration of at least one contaminant in the dredged material exceeds the 3 times value of the median concentration of contaminants of the suspended matter (3-annual-median) at the relocation site.	It is not allowed to relocate the dredged material in principle.
Biochemical Criteria		
The relocation must not cause an oxygen consumption in the water body below 4 mg/l		
Ecotoxicological Criteria		
Case 1	Porewater of the dredged material in a dilution of 1:4 does not cause toxicological effects.	The dredged material can be relocated.
Case 2	Porewater of the dredged material in a dilution of 1:4 causes toxicological effects.	A case-by-case decision will be made, further ecotoxicological studies might be necessary.
Ecological Criteria		
Negative effects on the benthos have to be avoided. The extent of acceptable effects has to be decided on a case-by-case basis		

In addition, the Federal Nature Conservation Act (*Bundesnaturschutzgesetz* - BNatSchG) has to be considered. Pursuant to § 3 III 2 BNatSchG the other authorities shall inform and consult the authorities in charge of conservation of nature and of landscapes as early as in the preparatory stages of any public plan or measures which may affect the interests of nature and landscape conservation. If the dredging operation causes encroachments on nature and landscapes, as defined in the BNatSchG, compensation or substitution measures have to be carried out (§ 8 I, II, VI and IX BNatSchG). In parallel to the relocation option it should be proven, whether the dredged material might be directly used (without technical treatment). If the dredged material cannot be relocated or directly used, then in general also one of the three alternatives of disposal is fulfilled.

If the dredged material is waste in the sense of KrW-/AbfG (see 3.1.4), the basic principles of the KrW-/AbfG must be applied: avoidance, recovery and disposal (§ 4 KrW-/AbfG). For recovery of dredged material, a treatment step is necessary. There are in general different treatment techniques possible (see HABAB-WSV). Several regulations regarding recovery exist, which have to be considered depending on the purpose, e.g. for agriculture and forestry use the technical guidelines of the *Länder* Working Group Soil (LABO) and the Ordinance on Sewage Sludge (*Klärschlammverordnung* - AbfKlärV). For land disposal of dredged material, several regulations, e.g. the Technical Directive on Waste Disposal (*TA-Abfall*) have to be applied (HABAB-WSV, Bertsch & Köthe, 1996 & 1999).

Aquatic disposal is part of the Water Management Act (*Wasserhaushaltsgesetz* - WHG) and its implementation by the *Länder*. For any aquatic disposals a permit or concession is necessary (§ 2II Nr.6 WHG). Generally, solid matter shall not be introduced into waters for the purpose of disposal. However, sludge and dredged material shall not be deemed to be solid matter. Substances may only be stored or deposited near waters if no pollution of the water or any other detrimental change in the properties of the water or in water flow is caused (§ 26 I, II WHG). To summarise, the German dredged material management consists of a complex system of regulations. The Federal approach, stated by the HABAK-WSV and HABAB-WSV is not based on environmental quality objectives but on prevailing contaminant concentration and therefore a prohibition of deterioration is stated. The Federal and *Länder* regulations differ in their evaluation of contamination of dredged material that results in different disposal strategies. There is a strong need for a harmonised, nation-wide regulation (Netzband 1997; Köthe et al. 1998). The German Association for Water Pollution Control (ATV) has compiled a Memo M 362 Recommendation for the Handling of Dredged Material (1997) for German inland waters. However, this association did not have a political mandate for co-ordination between the *Länder*. Such a mandate was given by the Conference of *Länder* Ministers for the Environment to the *ad-hoc* Working Group on Dredged Material of the Working Group of the Elbe (*Arbeitsgemeinschaft Elbe* - ARGE Elbe).

### **3.1.6. Subaquatic Disposal of Dredged Material**

#### **Dutch considerations**

The EC Landfill Directive (1999/31/ES) (see 3.1.1) is relevant to disposal sites for DM on land only. In the Dutch point of view this does not mean that subaquatic disposal is prohibited. A confirmation to this point of view can be found more or less in Art. 3 of the EC Landfill Directive. Article 3 states that the relocation of non-hazardous dredging sludges alongside waterways or in surface waters is excluded from the scope of the Directive. Also the Dutch definition of surface water is relevant to this question (Annex I). For example the CDF "Ijsseloog" is situated in the lake Ketelmeer. However the water inside the facility (pit) is not surface water according to the Pollution of Surface Waters Act. The water in the pit is part of the facility because of the surrounding dike (protection of the surface water).

In The Netherlands a way was found to deal with this issue. The EU Landfill Directive was implemented in 2001 by means of the Ministerial Decision under the Environmental Management Act, for dispo-

sal facilities for non-hazardous DM on land (above groundwater). A directive for Subaquatic disposal of DM is part of the policy document on the removal of DM (1993). In the Dutch point of view DM is a very specific kind of waste. Because of the specific properties (low permeability, low leaching under anaerobic conditions) of the DM, subaquatic disposal is possible without severe effects on the environment, including groundwater-quality. The Ministerial Decision on upland disposal and the Dutch directive for subaquatic disposal take the specific properties of the waste category DM into account. Specific isolative measures are not prescribed for disposal facilities for DM, but both documents define the maximum tolerable effects on the environment and especially on groundwater quality. Those definitions are in line with the Dutch Soil Protection Policy. The isolative measures that will be taken to ensure the protection of the environment can therefore be site-specific and differ between facilities. In this way the regulations do not exclude the use of innovative isolative techniques. In general isolative measures must be taken to reduce emission of pollutants *As Far As Reasonably Achievable* (ALARA). However subaquatic disposal sites are only allowed if (amongst others) permits are issued based on the Environmental Management Act and the Pollution of Surface Waters Act (for the discharge of waste-water originating from the disposal facility on the surrounding surface water). Studies carried out in The Netherlands have even pointed out that, under certain conditions, disposal of contaminated DM directly in pits in surface waters is possible without intolerable effects on water quality.

### **German considerations**

In subaquatic (stationary) disposal, DM is placed below the water surface in such a way that no hazard to the environment occurs. The regulations of the commercial and industrial waste management act (*Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG vom 27. September 1992)* are pursuant to §2, Section 6 not applicable to substances if these are introduced or discharged into water bodies or wastewater facilities. Neither does the landfill ordinance (*DepV*) regulate subaquatic disposal. Article 3 (2) of the European Landfill Directive expressly excludes subaquatic disposal of non-hazardous sludges. Consequently, subaquatic, stationary disposal of DM is not governed by waste legislation, but by water and waterway legislation. Many internationally available experiences, partly documented in PIANC reports show that - due to the specific properties of aquatic sediments - this special form of disposal at suitable sites is both economically and environmentally acceptable and is regulated outside waste legislation. It would be desirable to establish this disposal practice legally at the European level.

## **3.2. Management Practice in The Netherlands and Germany<sup>8</sup>**

### **3.2.1. Management Practice in The Netherlands**

In The Netherlands each year 25-30 million m<sup>3</sup> partly contaminated dredged material has to be removed. More than half of this amount comes from maintenance dredging for the main port Rotterdam,

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<sup>8</sup> selection from: Dutch-German Exchange on Dredged Material, Part 2 (DGE-2, 2002)

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  $\frac{3}{4}$  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. 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 contaminated dredged material (CDM) is disposed (3-5 million m<sup>3</sup>/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 95 million m<sup>3</sup> mainly meant for the contaminated dredged materials near Rotterdam. Recently a CDF was constructed in the Ketelmeer (IJsselmeer) with a capacity of 23 million m<sup>3</sup>. 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.

The Dutch Development Program for Treatment Processes for Contaminated Sediments (POSW), starting in 1989 and running until 1996, was aimed at the development of ecologically sound dredging and processing techniques to be used in the remediation and reuse of polluted sediments (Anonymous 1997; Rulkens 2001). Typical research issues of the POSW Stage II (1990-1996) program were:

- Separation of DM into subflows (hydrocyclone separation, upstream separation, settling, flotation, dewatering of fine fractions, practical experience in pilot remediation),
- Thermal and chemical treatment methods (thermal desorption, incineration, solvent extraction),
- Biological treatment (land farming, greenhouse farming, slurry treatment in bioreactors),
- Immobilization of pollutants in products (melting, sintering, experience in pilot remediation),
- Assessment of the environmental effects of processing chains (based on life cycle analysis, LCA),
- Scenarios for large-scale processing, varying from natural processes in treatment plants (e.g.: sedimentation, dewatering, landfarming, ripening) to maximum deployment of classifying and polishing methods.

Until now treatment of CDM is very limited (0.5 million m<sup>3</sup>/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 practised on a smaller scale. Stabilization of dredged material has been applied in small pilot projects only. Thermal immobilization is not (yet) operational.

### **Dutch policy on treatment and disposal**

The Dutch government has approved the Master plan in April 2002 (Tienjarensscenario), what has resulted in the release of an extra budget of € 150 Million to tackle the dredging arrears. 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.

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, which has to be reused as construction material. A tender for this pilot project resulting in a private-public partnership is expected for the second half of 2004. 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 the Minimal Treatment Standard, which at the 1<sup>st</sup> of January 2005 will replace 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. The aim for the subsidy is to encourage new technologies not yet commonly applied in practice on a large scale. 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.

### 3.2.2. Management Practice in Germany

In Germany about 40 to 50 million m<sup>3</sup> 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.

#### German policy on treatment and disposal

There is no common, coherent German policy on dredged material. However, the deputies of the state ministries for environment have set up some guidelines (LAGA, 1997) and requirements for the treatment and beneficial use of mineral waste based on classification of contaminated sediments and target values. The guidelines have to be applied for maintenance or other sediment related activities in inland rivers, harbours, lakes, flood retention and drinking water reservoirs. In practice however, the states have their own policy, which often deviates from these guidelines for several reasons. By the end of 2003 the German Organisation for Water Resources Management, Waste Water and Solid Waste (ATV- DVWK) has produced a draft report on "Treatment of dredged material, Part II, case studies" which presents quite a large spectrum of how different practical problems with contaminated sediment have been solved throughout Germany in the past in compliance with the existing guidelines. The draft is still under revision but it can be expected that it will be finished in 2004. 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.

*Hamburg.* Dredged material is treated in Hamburg in 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. m<sup>3</sup> 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 €/m<sup>3</sup> sediment in-situ. 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 two specially constructed silt mounds which fulfil German criteria for landfills. Each has a capacity for ca. 20 Mio. m<sup>3</sup> 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.

*Bremen.* In the Port of Bremen, about 300.000 m<sup>3</sup> of sediments (mainly silt) have to be dredged annually. The contamination is predominantly caused by heavy metals (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  $1 \cdot 10^{-9}$  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 m<sup>3</sup>. 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.

*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. Then it is used as earthworks material or for agricultural purposes.

### **3.3. Biological Effects-based Sediment Quality in Ecological Risk Assessment for Dutch and German Waters<sup>9</sup>**

Historically, sediment quality has been assessed by making comparisons between concentrations of contaminants with (numeric) sediment quality guidelines (SQGs). Based on such a comparison, the potential risks, or hazard of (groups of) sediment-bound contaminants can be estimated. A recent overview of the use of SQGs in Europe has been given by Babut et al. (2002). An important aspect in the risks caused by sediment-bound chemicals is the degree of exposure encountered by sediment-dwelling organisms. It is well documented that only part of the contaminants are biologically available, because desorption can be thus slow, that the actual exposure level is less than what would be expected on the basis of the total concentrations of the compounds in the sediment (Hamelink et al. 1994; Kraaij 2001). However, it is also known that mixtures of contaminants can have synergistic effects, which may not be well addressed by single SQGs (Hermens et al. 1984; De March 1987; Von Danwitz 1992). For these reasons, and because of the large number of unknown contaminants as explained above, ecological risk assessment of sediment quality has received much attention in the past decades. The advantages of biological endpoints, such as effect bioassays, over chemical quality

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<sup>9</sup> selected from Den Besten et al. (2003)

assessment are that biological testing integrates the effects of all contaminants present at their actual bioavailability (and detect possible synergistic effects).

Most so-called ecological risk assessment (ERA) frameworks deploy biological effect-based sediment quality assessments (BEBA). The basic principle of most of ERA is the use of multiple lines of evidence (Burton et al., 2002). Important lines of evidence are: 1) Assessment of the condition of the benthic macroinvertebrate community; 2) Assessment of sediment toxicity using bioassays (BEBA); and 3) Assessment of the potential effect occurring through food chain poisoning. The present chapter (extracted from Den Besten et al. 2003) gives an overview of ecological risk assessment frameworks that are used in The Netherlands and Germany. Two main goals for sediment quality assessment in these countries are distinguished:

- Biological Effects-Based Assessment of *in situ* risks (in situ BEBA) at sites where sediment remediation is to be considered;
- Biological effects-based assessment of the *ex situ* quality of dredged sediments (ex situ BEBA) in order to select sediment management options (e.g., confined disposal or treatment options).

Comparing in situ and ex situ BEBA, it is likely that the assessments lie at very different levels in a decision making process. In situ BEBA is a front-end investigation necessary to evaluate whether sediments create a risk, before any decision if some action would be needed. Ex situ BEBA is something that is carried out after it has already been decided to dredge (e.g. dredging for nautical reasons), but when disposal options have to be considered. Apart from the ERA approaches explained above, there may be different concepts using risk information for other questions, such as prioritizing.

### **3.3.1. In situ Effect-Based Assessment**

The biological effects-based assessment of the *in situ* risks in sediment (in situ BEBA) focusses on location-specific conditions with respect to the bioavailability of contaminants and the assessment of damage to the ecosystem. Assessment of damage to the ecosystem can be both prognostic and retrospective. *In situ* BEBA can be considered as one of the lines of evidence in ERA (Burton et al., 2002). ERA can be combined with studies focusing on risks related to transportation of contaminants back to the surface water, or to deeper sediment layers, and subsequently to the ground water.

With the growing concern for the potential problems caused by sediment contaminations, ecological risk hazard assessment approaches have been proposed as decision support tools or instruments for prioritization. These approaches generally rely upon a tiered process, in order to allocate properly limited technical and financial resources.

In general, three main purposes can be identified for which in situ BEBA frameworks have been developed (Ingersoll et al. 1997):

- Integration of information from large numbers of parameters that use different lines of evidence (e.g., sediment chemical concentrations, sediment toxicity, benthic community diversity, tissue concentrations, etc.);
- Proof of causality between environmental effects and sediment contamination;
- Tiered approach for increasing confidence in a cost-effective manner.

## The Netherlands

Assessments of *in situ* sediment quality in the Netherlands follow a tiered approach. The *in situ* BEBA is part of a broader evaluation of risks caused by sediment contamination:

- 1) 1<sup>st</sup> tier assessment: comparison of levels of priority pollutants with national standards/guidelines. Contaminant levels are normalised according to the approach described by CUWVO (1990), in order to compensate for differences in sorption characteristics between sediments<sup>10</sup>. Normalised contaminant levels are then compared with the Dutch sediment quality criteria (developed for 1<sup>st</sup> tier assessment of risks for human health and ecosystems). According to the resulting classification, most contaminated sediments (class 4 on a 0 to 4 scale) require a risk assessment (2<sup>nd</sup> tier).
- 2) 2<sup>nd</sup> tier assessment: The primary statement for this second line assessment is as follows: if a priority contaminant exceeds the intervention value, the site needs to be remediated urgently, unless it is shown that there are actually no high risks at that particular site. (so, there is an assumption of risk, until it is disproven). When the data from the 2<sup>nd</sup> tier show no high risk at a site where a priority contaminant exceeds the intervention value, the need for remediation is not considered as urgent anymore. Conversely, if actual high risks were confirmed, the next step would review different remedial options, that are to be compared for the expected risk reduction. Three main pathways are seen for a complete risk assessment, the third being an *in situ* BEBA approach:
  - Human exposure: model calculations are carried out in order to quantify the extent to which humans (adults/children) can be exposed to contaminants via food consumption or via recreation activities in water. When the exposure exceeds maximum permissible risk criteria, actual risk is concluded. The model is based on general assumptions with regard to behavior and diet of human populations.
  - Investigation of the risk for transport of contaminants from the sediment to groundwater, or to surface water. Model calculations are carried out in order to quantify the extent to which these processes occur. When contaminant fluxes (preferably calculated from field data) exceed high risk criteria, actual risk is concluded.
  - *In situ* BEBA. The evaluation of risks for the ecosystem is done using the TRIAD assessment. In the Dutch version of the TRIAD (integrating chemical measurements, biological investigations and ecotoxicological measurements; section 2.4) bioaccumulation measurements are also consi-

<sup>10</sup> standard sediment is defined as having a 25% particle fraction < 2 µm and 10% organic matter on a dry weight basis

dered, using the results of laboratory tests, or preferably by measurements in indigenous organisms (Den Besten et al., 1995). Based on the *most sensitive* parameter, sediments are classified for the categories "field observations" and "bioassays" as either "-" (no effect/risk), "±" (moderate effect/risk) or "+" (strong effect/high risk). The goal is to elucidate the relationship between effects on macrozoobenthos and responses of bioassays, which, in turn, can be related to levels of chemical contamination. For that purpose, chemical concentrations are converted into "toxic units" (TU): These are the ratio between the chemical's normalized concentration and the lowest no-effect-concentration (NOEC) reported in the literature, among the bioassays included in the battery (Den Besten 1995). High risk is inferred when strong effects are observed in field surveys and/or bioassays that can be related to chemicals present in the sediment.

**Table 3.2** NL-classification of effects in bioassays in the Triad approach<sup>\*</sup>)

<b>Daphnia</b>	<b>parameters (equal, take most sensitive)</b>			
	NOEC-mortality (in % dilution of pore-water)	Mortality in undiluted pore water	NOEC-reproduction	Inhibition of reproduction in undiluted pore water
Criterion 1	NOEC < 100% NOEC > 10%	-----	NOEC < 100% NOEC > 10%	Inhibition >10% Inhibition <50%
Criterion 2	NOEC ≤ 10%	mortality ≥ 50% within 48h	NOEC ≤ 10%	Inhibition ≥50%
<b>Chironomus</b>	<b>Parameters (equal, take most sensitive)</b>			
	Mortality of eggs, prior to start sediment bioassay (incubation in elutriate)	Mortality larvae	Inhibition of development	Effect on weight (negative effects are scored only)
Criterion 1	mortality > 25%	mortality > 10% mortality < 50%	inhibition > 10% inhibition < 50%	effect > 10% effect < 25%
Criterion 2	mortality ≥ 50%	mortality ≥ 50%	inhibition ≥ 50%	effect ≥ 25%
<b>Microtox</b>	<b>parameter: 1/EC20 (5, 15, 30 min: equal, take most sensitive)</b>			
Criterion 1	1/EC20 > 2			
Criterion 2	1/EC20 ≥ 10			

<sup>\*</sup> Exceedance of criterion 1 results in class 2 toxicity (moderate effects); exceedance of criterion 2 results class 3 toxicity (strong effects); otherwise, class 1 (no toxicity).

Classification of sediment can be done on each of the bioassays independently (i.e., most sensitive bioassay determines the toxicity score).

Effects on which score depends should be significant at  $p < 0.05$

- 3) Prioritization. When the supplied data from the second tier show that there are actually no high risks at a site where a priority contaminant exceeds the intervention value, the need for remediation is not urgent anymore. In case actual high risks were confirmed, a next step is possible in which different remedial options are considered for the risk reduction that can be achieved. The information from the sediment quality assessment can be used again in setting priorities within the group of locations that need to be remediated urgently. In the Netherlands some experience exists with the use of multi criteria analysis (MCA; also called Analytic Hierarchy Process (AHP);

Saaty 1980) for this purpose. MCA enables a ranking of sites based on risks for the ecosystem. This method (described by Den Besten et al., 1995) is based on the same classification of results as described above. For each criterion (= parameter), standard numerical values (scores) were assigned to the effect/risk classes, from the value 1 for the class representing the strongest effect or highest risk, to for example 0.5 and 0.25 for the classes representing moderate risk and no risk, respectively. Then the criteria are given a specific place and weight in a hierarchy. The scores are multiplied by the weight of the corresponding criterion and subsequently totalized bottom-up using a computer program, resulting in a final score between 0 and 1. The difference between the final score and the theoretical score 1 (the score for a site with strong effects / high risk for all parameters) gives an indication of the risks for ecosystem health at each of the sites. For this method all available information from the field surveys can be used, including site-specific information from bioaccumulation studies. At a higher level of hierarchy, information from human risk studies, ecological risk assessment, and estimates of contaminant mobility (transport) can be integrated. In the MCA, specific weights can be attributed to the different criteria (=parameters) and higher in the hierarchy, at branch points. This makes the method useful for decision makers, who have to deal with all these aspects at the same time and therefore need integrated information. In the near future, estimates of the expected beneficial effects of remedial action will also be integrated in the step of prioritization of dredging locations.

## Germany

Several research groups have recommended application of a Triad approach, (Neumann-Hensel et al. 2000; Ahlf and Förstner 2001; Ahlf et al. 2002, Hollert et al. 2002). Based on an inventory of bioassays and biological classification methods to establish ecological quality criteria (Ahlf & Gratzner, 1999), a classification scheme for screening of ecotoxicological sediment quality was developed, that integrates results of 5 biotests including whole sediment toxicity tests (Heise et al. 2000).

Recently, recommendations were made for the use of an integrated stepwise approach combining toxicological, chemical and ecological information to assess and evaluate the quality of sediments (Neumann-Hensel et al., 2002). A difference with the approaches followed in most other countries is that bioassays are used as a trigger for further research steps, instead of chemical data that is more commonly used. In Henschel et al. (2002) a stepwise approach is described for an integrated assessment of ecosystem health effects and the consequences of sediment contamination for human health.

### 3.3.2. Ex situ Effect-Based Assessment

*Ex situ* BEBA is a *hazard assessment*, in which biological/toxicological endpoints are used as predictors of possible effects that may occur when the sediment is disposed of in the environment. In this BEBA, often bioassays are included in the sediment quality assessment or added as a second Tier. The approach is more prognostic, i.e. based on the outcome of the assessment, predictions are made of the consequences of free disposal of dredged sediments in the environment. In that respect this

approach, using sediment toxicity assessment bears resemblance with total effluent risk assessments (see e.g. Grothe et al. 1996; Tonkes et al. 1999).

### The Netherlands

For the assessment of the possibilities of disposal of marine dredged material in the coastal waters of The Netherlands, recently a new sediment quality approach was developed, the chemistry toxicity test (CTT; Stronkhorst et al. 2001). Three bioassays have been selected for routine application in the CTT approach (Table 3.3), viz a mud shrimp toxicity test, a bacterial test (Microtox solid phase) and the DR-Calux assay, which reacts specifically to dioxin-type compounds. In the CTT approach, in order to allow free marine disposal of sediments, sediment quality guidelines need to be met both for the concentrations of a list of chemicals (see par. 4.2.1). The degree of effect observed in the bioassays are not yet implemented as quality criteria for marine disposal.

**Table 3.3** Ecotoxicological criteria for the CTT test for evaluation of dredged marine sediment

Test/compound	Group	Units	Criterion <sup>1</sup>
Amphipod <i>C. volutator</i>	combination toxicity	Mortality (%)	50
Microtox SP, bacteria <i>V. fischeri</i>	combination toxicity	Decrease bioluminescence (1/EC <sub>50,corr</sub> ) <sup>2</sup>	100
DR-CALUX, cell-line	dioxine-type	ng TEQ/kg dw	50

<sup>1</sup> concentrations without standard correction, <sup>2</sup> EC<sub>50</sub> corrected for fraction of fine silt

### Germany

For an ex situ BEBA type of application, Krebs (1988) proposed an ecotoxicological sediment quality assessment that is based on the number of dilutions steps, that are necessary to decrease inhibition in elutriates or pore water below 20 %. This is expressed as pT-value and part of the HABAB regulation (see Table 3.1: a dilution of 1:4 corresponds to a pT-value of 2).

### 3.3.3. Outlook

The application of bioassays provide ERA approaches with more information about the exposure of organisms in contaminated sediment. At the same time, this step forward also creates concern with regard to quality assurance of the techniques. Several issues are of great importance when using bioassays for the evaluation of sediment quality. Firstly, bioassays are subject to a number of confounding factors that may have nothing to do with contaminant load (such as grain size, ammonia, and countless other issues). Secondly, it is very important to define references and controls that are meaningful for the site under consideration. A third point of concern is the question whether all relevant modes of action can be covered by a set of bioassays. For instance, if only bioassays are used

that measure acute toxicity, sublethal modes of toxicity (effects on fecundity, growth, immuno-competence etc.) could be overlooked with important consequences for ecosystem health.

In order to be able to harmonize *in situ* and *ex situ* BEBA approaches between countries, it is necessary to discuss the goals for sediment management. From the perspective of the EU Water Framework Directive (EU WFD), it seems logical to harmonize the approaches on a river basin level. Because the EU WFD focuses primarily on water quality, it can be expected that *in situ* BEBA approaches will be used mostly as a diagnostic tool, i.e. to determine whether a poor ecological status of waters is caused by sediment contamination. These approaches may already be part of regulations, or will be. Therefore, harmonization will be difficult, or take a long time, and probably dependent on a top-down approach (European directive). But for *in situ* sediment quality assessment this may not be necessary, except for the fact that clearly a need is felt to intensify the exchange of information on the criteria used to infer effects and to classify sediment quality. The situation might be different for *ex situ* BEBA approaches. When the relocation of dredged material in surface water is concerned, harmonizing the sediment quality assessment in river basins is needed. The *ex situ* BEBA can help to more effectively prioritize dredged sediment with high ecological risks, that should be transported to confined disposal sites. Such prioritization can better be made based on effect observations than on chemical measurements, because biological responses integrate the effects of all biologically available contaminants.

### **3.4. Sediment Management Issues in the WFD-Strategies for Monitoring and Emission Controls of Priority Substances**

A main objective of the WFD is to achieve good ecological or good ecological potential and chemical status for each water body. Therefore a singly source/pathway or when considered collectively with other sources/pathways may have a potential to result in the failure of the objective if it contributes to a concentration in excess of the Environmental Quality Standards (EQS) set in the aquatic environment for a specific priority substance (chemical status) and/or if it contributes to the failure of meeting the ecological status. It is also important to note under Article 16 of the WFD there is a requirement to achieve the progressive reduction of discharges, emissions and losses of priority substances and cessation or phasing out of emissions, discharges and losses of priority hazardous substances. A further objective of the WFD is the “no deterioration” requirement. These objectives need to be taken into account when assessing the different sources/pathways.

It is interesting to see that while sediments and dredged materials are not explicitly mentioned in the Water Framework Directive they will play an important role in the forthcoming steps for the implementation of measures against pollution from priority [hazardous] substances (PS/PHS) under WFD Article 16 – monitoring programmes to be operational (Article 8, 2006) and establishment of the programme of measures (Article 11, 2009). In the previous sections of chapters 2 and 3 of the present study, the discussion process among the relevant expert groups has been described:

### **3.4.1. Recommendations of the Expert Group on Analysis and Monitoring of Priority Substances (AMPS)**

In the draft final report from 10 June 2004 the Expert Group on Analysis and Monitoring of Priority Substances (AMPS), based on discussions during their meetings in Brussels (22-23 January 2004) and in Ispra (31 March to 1 April 2004) provided recommendations to sediment-related issues (see Box on pages 36 and 37):

- A majority of AMPS expert group members agreed that whole water is the relevant matrix for compliance checking of the EQS derived for the priority substances other than metals. The approach recommended by the AMPS expert group is that the choice of how to generate the required data and the proof of its fitness for purpose should be the responsibility of Member States. Thus whole water data may be generated by analysis of the whole water sample, or by separate determinations on dissolved and solid phases.
- The recommendation of the AMPS Expert Group is that, it is not advisable to establish specific EQSs for suspended particulate matter (SPM) at this stage. It was noted that the issue of monitoring compliance with any future quality standards will furthermore raise the questions of comparabilities of phase separation methodologies. The AMPS Group did furthermore not consider that, from a monitoring point of view, it would be technically feasible to propose EQSs in the near future for sediment and biota.

The AMPS expert group was asked to provide further insight and recommendations on the practices of sediment and biota sampling, for these purposes, but also to assess the practical aspects of checking compliance in these matrixes of specific EQS.

Separate requirements (for instance location and frequency of monitoring) on surveillance and subsequently operational monitoring of sediment and biota for the purpose of assessing long-term trends in impacts anthropogenic pressure and to ensure the no deterioration objective is reached may therefore be necessary, to ensure that comparable data can be collected.

- The AMPS Expert Group convened two drafting groups to consider these issues. The groups assessed current practices by means of questionnaires and then developed recommendations on the way forward. It emerged that the monitoring frequency varies widely and it was agreed that the appropriate frequency should be based on local circumstances.

#### **Metal Background Reference Concentrations (BRCs)**

In the discussions on monitoring and implementation of measures for priority substances an “added risk approach” has been proposed for metals, and a first step is the use of natural background concentrations. A respective AMPS working group has defined the background metal concentrations as follows:



*"The background concentrations of target metals (Pb, Cd, Ni, Hg) in the aquatic ecosystems of a river basin, river sub-basin or river basin management area is that concentration in the present or past corresponding to very low anthropogenic pressure."*

Various methodologies such as measurements of trace metals in pristine areas, groundwater, selection from long-term data sets applying appropriate statistical methodology, and long-term data sets and partitioning, are employed to provide estimates of the BRC (AMPS draft final report, June 2004).

### **3.4.2. AMPS Drafting Group on Sediment Monitoring**

Recommendations of a drafting group on Sediment Monitoring of the Expert Group on Analysis and Monitoring of Priority Substances (AMPS) were, among others (see Box on page 38):

- Initiate the development of a community-wide diagnostic guideline on the assessment of contaminated sediments in relation to the degradation of both ecological quality elements (benthic community, fish etc.) and water quality. Such a diagnostic guideline should be made available by 2006 in order to support Member States in their effort to implement the WFD;
- Initiate the development of a community-wide technical guidance on sediment sampling and handling, analytical techniques and normalization procedures. Such a technical guideline should be build on existing protocols/guidelines and be made available by 2006 in order to support Member States in their effort to implement the monitoring requirements of the WFD.

The drafting group outlined a list of priority substances of the Water Framework Directive that are suggested for trend monitoring in sediment and or biota (Box on page 38).

### **3.4.3. Quality Standards for Sediments and Biota: Response of the Scientific Committee on Toxicity, Ecotoxicity and Environment**

The opinion of the scientific committee on toxicity, ecotoxicity and the environment (CSTEE) on „The Setting of Environmental Quality Standards for the Priority Substances included in Annex X of Directive 2000/60/EC in Accordance with Article 16 thereof" was adopted by the CSTEE 43rd plenary meeting of 28 May 2004 (see Box 46):

"We note that at this stage the Commission envisages presenting Quality Standards only for the water phase and that this would include reporting the concentration of a priority substance in the whole water; i.e. including the dissolved fraction and that (fraction) bound to suspended organic matter. We believe that there are some difficulties with this being applied uncritically:

- To base protection on a water column standard ignores many of the biological complexities of exposure through absorption and ingestion by sediment organisms .....

- The exposure of chemicals through the food chain is not only relevant for secondary poisoning in birds and mammals, but also for aquatic invertebrates and fish and the EQSs based on waterborne exposures are not protective in all cases .....
- Basing exposure concentrations on whole water may be very misleading with regard to bioavailability... The concentrations of lipophilic substances will depend on the amount of suspended particulate matter (SPM) in the sample, which will depend on where, when and how the sample is taken ....

As a conclusion the CSTEE believes that specific quality standards can and should be developed for sediment and biota, and should be based on direct assessment and monitoring.

#### 3.4.4. Priority Substances in Historical Contaminated Sediments<sup>11</sup>

In order to record the different steps undertaken to identify the measures under Article 16 of the Water Framework Directive, the Expert Advisory Forum (EAF) on Priority Substances and Pollution Control formulated a concept paper on the control of emissions, discharges and losses of priority substances and priority hazardous substances. The process proposed to develop the appropriate mix of emission controls until the year 2009 has the following steps.

1. Inventory of all generic sources that result in releases and their pathways – source screening
2. Identify existing control measures at EU level
3. Identify appropriate sources where measures could be taken under the WFD and possibly other EU legislation (taking into account the effect of the present measures and changes in releases that will take place irrespective of existing and new reduction measures)
4. Set priorities
5. Develop the measure

Under step (1) "source screening" the following systematic presentation of pathways and underlying sources was proposed: (A) Losses to surface water by diffuse sources (S1: Atmospheric deposition on the water surface; S2: drainage and deep ground water; S3: agricultural activities; S4: transport and infrastructure without connection to canalisation/sewers; S5: accidental spills; S6: release from materials and constructions in non urban area); (B) Discharges to surface waters by point sources (S7: discharges in sewage effluents or storm water; S8: discharges in sewage effluents or storm water as a result of household, consumer use; S9: industrial activities; S10: solid waste management; S11: historical pollution: **S11.1 historical pollution from sediments**; S11.2 historical pollution from contaminated land; S12: natural sources).

To effectively identify key sources and pathways a stepwise approach for source screening has been developed. The first step is the identification of potential sources and the second step assesses whether the source/pathway can contribute to a failure of the objectives of the WFD. The final steps 3 and 4 of the methodology deal with the development of measures. The key outcome of the process is to identify Category 1 sources, which may potentially require additional measures for their control.

### Priority Substances in Historical Contaminated Sediments as Possible Secondary Sources for Releases to the Aquatic Environment – WFD Article 16 “Measures”

(from: Concept Paper on Emission Controls to the Seventh Meeting of the Expert Advisory Forum on Priority Substances and Pollution Control, Brussels 14-15 June 2004)

**Systematic presentation of sources and pathways.** Discharges to surface waters by point sources include: discharges in sewage effluents or storm water due to run off in paved urban areas (S 7), as a result of household consumer use (S 8), due to industrial activities (S 9), via solid waste management (S 10), and due to historical pollution from sediments (S 11.1) and contaminated land (S 11.1).

**Categorisation of importance of sources and pathways.** *Category 1:* The available information indicates that the source/pathway contributes to the concentration of the substance in the aquatic environment, which may lead to a risk of failing to meet the objectives of WFD (Chapter 3.1.1). *Category 2:* All other sources and pathways that have not been identified as category 1 or 3, in particular those where insufficient information is available. *Category 3:* The available information shows that the source/pathway does not have a potential for the release of the substance directly or indirectly to the aquatic environment.

**Categories for source/pathway S 11.1 “historical pollution from sediments”.** S 11.1 will be a *category 1* source if monitoring data show that this pathway results in increased concentrations in the aquatic environment; S 11.1 is *category 3* if it is not present in sediment or if it is not released in detectable concentrations to the aquatic environment or if it is biodegraded in sediment (e.g., half life less than 180 days).

**Identification of possible control measures for sources/pathways S 11 according to WFD 16(6).** Explore the possibilities for establishing a strategy at EU level on contaminated sediments and links with the Thematic Strategy on Soil Protection (mainly for S 11.2).

**Table 3.4 gives examples of priority substances (PS) and priority hazardous substances (PHS)** as defined in article 2 (30) of the WFD. There is some indication that historic contaminated sediments might serve as a source for releases into the aquatic environment. Underlying data in most cases are still very insufficient and will have to be completed by further assessments.

**Table 3.4** Examples of Substances for further Assessment on Historically Contaminated Sediments (numbers in brackets refer to the WFD list of priority substances)

Anthracene (2): category 1*	Cadmium (6): category 2 <sup>+</sup>	Lead (20): category 2
Fluoranthene (15): category 1*	Hexachlorobenzene (16): category 2 <sup>+</sup>	Mercury (21): category 2
Naphthalene (22): category 1*	Hexachlorobutadiene (17): category 2	Nickel (23): category 2
PAHs (28) category: 1*	Hexachlorocyclohexane (18): category 2	TBT (30): category 2 <sup>+</sup>

\*contaminated sediment as one possible source of various PAHs that may all contribute at the end to a failure of WFD objectives. <sup>+</sup> Additional indications for classification in category 1 given in data sheets

<sup>11</sup> from the “Concept Paper on Emission Control from 8 June 2004” of the Expert Advisory Forum (EAF) on Priority Substances and Pollution Control (7<sup>th</sup> EAF-Meeting at Brussels, 14-15 June 2004)

The process of source screening using different categories of importance of sources and pathways is demonstrated for historical contaminated sediments in the Box on page 87. Table 3.4 lists several examples; for some of them there are already additional data, indicating a possible change from category 2 to category 1, e.g., for cadmium, hexachlorobenzene, and tributyltin. In most cases, however, information is still insufficient and further efforts are needed in particular for sources such as historical contaminated sediments.

### 3.5. New Challenges for Catchment Scale Management

The Rhine Research Project II study "Dredged Material in the Port of Rotterdam – Interface between Rhine Catchment Area and North Sea" (Salomons & Gandrass, 2001) has described the changes at the catchment level as a major challenge to river basin managers and to the coastal zone managers who are 'at the receiving end' of the catchment. In the comprehensive EU-funded project "European Catchments: catchment changes and their impact on the coast (EuroCat) the scientific coordinator stressed the fact, that the main issue for this interface ("first order coastal zone", Meybeck et al. 2004a) is the *"achievement of 'hydro solidarity' within the basin, i.e. a full upstream/downstream integration of monitoring, stakeholder consultation, models and expert systems that can link basin pressures to transfers, across various administrative and/or political boundaries, and between the various land users, water users and other stakeholders"* (Salomons, 2004).

In the following short overviews are given on three themes closely related to the catchment scale perspective: "Risk Management" (section 3.5.1), "Sources and Measures" (section 3.5.2), and "Future Research Soil-Sediment Contaminants" (section 3.5.3)

#### 3.5.1. Risk Management at the Catchment Scale<sup>12</sup>

The sediment risk management objective, as defined by SedNet Working Group 5, is *"to reduce risk posed by contaminated sediments to humans and ecological receptors to a level deemed tolerable by society and to control and monitor sediment quality and ensure public communication with the final aim of complying with the EU WFD and Habitats Directive."*

The objectives that drive sediment management activities are generally combinations of the following needs: a) to meet regulatory criteria, b) to maintain economic viability, c) to ensure environmental quality and nature development and d) to secure the quality of human life. Although often interrelated, these distinctions help to make the decision making processes transparent, informing the public of the overall aims, and helping managers to structure the decision process. To this end, measurable risk indicators defined for each objective (such as "decrease of fish yields" for "maintaining economic viability") will help simplify complex information, trigger management activities and support decision and communication processes.

## **Recommendations of SedNet WG 5 “Risk Management and Communication”**

### **Development of a basin-scale decision framework**

- Effective and sustainable management strategies must focus on the entire sediment cycle
- A basin scale framework should be comprised of two principal levels of decision-making: the first for basin-scale evaluation (site prioritisation) and the second for site-specific risk assessment (risk ranking).
- A basin-scale assessment should involve the balancing of a Conceptual Basin Model, which considers the mass flow of particles and contaminants, and the basin-scale objectives (BOs) to generate a Basin Use Plan. This Basin Use Plan should define the goals for both the river basin and specific parcels of sediment.
- In those cases in which sediment management decisions begin at the site-specific level, it is essential that the impacts of these actions upon adjacent sites, and basin-scale quality and objectives are considered.

### **Risk assessment, site-prioritisation and risk ranking**

A prerequisite for sediment management on river basin scale is the harmonisation of site prioritisation and site-specific assessment/risk ranking schemes. This comprises

#### ***a) for prioritisation at the basin scale***

- Development of (an) appropriate indicator(s) for sediment mobility at catchment scale
- Determination of the sediment dynamics and budget in a river
- Development of databases for implementing, testing (and improving) prioritisation methods
- Development/improvement of models that address the basin scale risk implications of site-specific conditions and actions

#### ***b) for risk assessment / risk ranking at the local scale***

- Development of explicit measures of exposure, related to ecological processes which must be selected based upon site-specific conditions and management options (or scenarios)
- Collection and gathering of data from (local) risk assessment studies (establishment of data bases)
- Harmonisation of risk assessment/ranking approaches
- Establishment of obligatory monitoring after sediment management (collate data, use them for “validating” effect or exposure assumptions (class boundaries etc))
- Establishment of a tiered approach for risk assessment for remediation purposes, in which the first tier comprises of “easy to use” bio-tests and chemical analyses for risk assessment.

### **Diversity of sediment regulations and monitoring**

- Assessment of sediment quality and risks: For a basin-scale/site specific sediment quality assessments and subsequent management decisions, harmonised sediment quality criteria and assessment procedures should be developed.
- Regulatory situation: From the scientific-hydrological point of view, dredged material is comprised of natural sediment (sometimes contaminated by external sources) while from the political / legal point of view, it is considered a waste. A new definition and new views of the role of sediments and dredged material within river basins should be developed in support of sustainable basin-wide sediment management strategies.

### **Management objectives and risk indicators**

- There is the need for the development of a modified DPSIR approach<sup>13</sup> for the respective river basins, in which the requirements and interactions between social and societal forces, the objectives of risk management and potential management options are explicitly addressed.

<sup>12</sup> Synthesis paper of SedNet Working Group 5 “Risk Management and Communication” (S. Heise, 30.06.2004)

<sup>13</sup> DPSIR: “Driver-Pressure-State-Impact-Response-Analysis

Because of the dynamic, complex and interconnected nature of sediments, from sources and rivers to estuaries and the sea, effective and sustainable management strategies must focus on the entire sediment cycle, rather than on one unit of sediment at a time. Such an approach will help focus limited resources to maximise the achievement of management objectives, including basin-scale risk reduction. A basin-scale risk management framework should be comprised of two principal levels of decision making; the first being a basin-scale evaluation (prioritisation of sites for further evaluation and/or management) and the second being an assessment of specific sites for risks and management options (site-specific risk ranking). Sites should be prioritised at the basin scale according to a number of criteria, preferably quantifiable at a screening level, including: the location along the up- and downstream gradient (e.g., how are downstream sites affected by contaminated sediment sources upstream?), quantity of sediment (e.g., is the volume large enough to present a risk?), evaluation of sediment quality (e.g., how contaminated is the sediment?), sediment dynamics (e.g., is (contaminated) sediment transported downstream?) and the potential expected benefit of proposed management actions at a given site and for the river basin.

Sediment risk assessment (or risk ranking) generally falls into two categories, based upon different management objectives, and thus requiring different assessment procedures: a) Assessment of the in situ risks caused by contaminated sediments in place, and b) Assessment of risks of contaminants in sediments during and after dredging (ex situ). There is a need for harmonisation of risk ranking approaches; a tiered approach for in situ risk assessment has been proposed by the working group.

In summary, a comprehensive Basin Scale/Site specific risk management approach is suggested that includes the following steps: 1) The communication between managers and the public, throughout the decision process, 2) The identification of management objectives, 3) The determination of appropriate risk indicators, 4) The usage of risk indicators to prioritise sites on a river basin scale and to rank risks on site-specific scale, 5) The decision making process in which potential effects on the river basin and on the site-specific scale are weighed against each other, taking into account the economic, societal and environmental risk, and finally 6) The selection, implementation and monitoring of the final management option(s).

In this report, some of the steps in the site prioritization process of risk management have been taken: The identification of areas of concern in combination with evaluation of resuspension, transport phenomena and the distance of the sites from the Port of Rotterdam results in a site prioritization, that indicates what areas of concern need to be addressed in the first place and where management options should be favoured. A risk assessment at the prioritized site could make use again of the hazard classes of compounds, integrating them into the risk ranking which eventually should be undertaken on the basis of chemical, ecotoxicological and ecological aspects in order to identify the minimally impacting (?), maximally efficient management option, which would – in our case – refer to the level of contamination in the Port of Rotterdam.

### 3.5.2. Sources and Measures at the Catchment Scale

In the process of implementing emission control of priority substances, some key terms are defined in article 2 WFD. For example, the “emission limit values” for substances shall normally apply at the point where the emissions leave the installation, dilution being disregarded when determining them. With regard to indirect releases into water, the effect of a wastewater treatment plant may be taken into account when determining the emission limit values of the installations involved (article 2(40) WFD). The term “sources” is not defined in article 2 of the WFD, and definitions have been given by the Expert Advisory Forum on Priority Substances and Pollution Control Implementation of Article 16 of Directive 2000/60/EC (WFD) in their Concept Paper on Emission Control from 8 June 2004):

- **“Discharges”**: *“shall mean the release of priority substances from individual or diffuse sources in the installation through effluent directly or indirectly into surface waters as defined under Article 2(1) of Directive 2000/60/EC”*
- **“Emissions”**: *“shall mean the direct or indirect release of priority substances from individual or diffuse sources in the installation into air, water or land including ‘discharges’ as defined above”*
- **“Installation”**: *“shall mean a stationary technical unit where one or more industrial activities are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution” (Based on Integrated Pollution Prevention Control [IPPC] Directive 96/61/EC definition)*
- **“Losses”**: *“shall mean any intentional or unintentional release or transfer of priority substances, other than discharges, emissions or the result of accidents, directly or indirectly into surface waters as defined under Article 2(1) of Directive 2000/60/EC”*

The latter source type is probably closest to the case of historical contaminated sediments. Apart from the definition, however, the spatial situation of a source is of prime importance. There are a number of types of sediment and contamination sources in a dynamic system (Apitz and White, 2003):

- Active point sources – in general these are being controlled by legislation. However, catastrophic failures and isolated spillages may still occur.
- Quasi-diffuse sources – these, rather than being specific point sources, can be residues of controlled point sources (as above) or diffuse (but not entirely ubiquitous) sources from the basin. These can be sources of contaminants such as pesticides, veterinary pharmaceuticals, nutrients, inputs from atmospheric deposition etc.; to control such risk requires basin-wide changes in agricultural and industrial practices. Such contamination is not manageable until sources are controlled.
- Non-point sources. If contaminants in sediments result from ubiquitous background levels, either from natural or anthropogenic sources, there is little that can be done about risks as a result of such inputs, so even if present, risk is not manageable in an active way.

- Local historical – in this case, the source of contaminant or sediment is from nearby, has been controlled, and the major concerns are to prevent spreading and to control risk in place. These risks, in general, are controllable at the site (dependent upon site-specific conditions).
- Remote historical, point source – in this case, contamination or sediment came from upstream, but the source has been controlled. Concerns include residual diffuse input (e.g. metals in river bank and flood protection banks).

One of the goals of sediment parcel prioritisation in basins is to assure that such potential risk sources are managed, if possible, before downstream parcels (barring cases in which very high site-specific risk moves a parcel up in priority, in which case the upstream input is not the primary risk driver).

An increasingly important challenge in river basin management is to develop strategies and solutions for the legacy of the past, based on a multidisciplinary, co-ordinated and harmonized approach (Brils, 2002). As outlined in section 1.5.2., the selection of remedial measures should primarily be based on the concept of “geochemical engineering”, applying principles such as stabilization, solidification, and other forms of long-term, self-containing barriers to determine the mobilization and biological availability of critical pollutants. A combination of various existing or planned techniques, examples mainly from the Elbe catchment areas, has been proposed by Förstner (2003):

- Predominantly in the upper and middle course of river systems, sediments are affected by contamination sources like wastewater, mine water from flooded mines and atmospheric deposition. Measures at the source are particularly important and may include improvement of traditional wastewater purification, but also more approaches for in-situ treatment of highly contaminated effluents such as introducing active barriers (fly ash, red mud, tree bark, etc.) into ore mines to prevent heavy metal dispersion during flooding (Zoumis et al. 2000).
- During floods, sediment bound pollutants can undergo a large-scale dispersion of contaminants in flood-plains, dike foreshores and polder areas. The complex mixtures of toxic compounds and the dimension of pollution often preclude technical measures like chemical extraction or solidification of contaminated soil material. Instead, alternative measures have to be taken considering the different local factors such as soil, sediment and water quality, flow velocity, and the dynamic of the water-level. From an initial example of the Spittelwasser case comparison (Anonymous 2000) in a 60 km<sup>2</sup> flood plain of the upper Elbe River it has been shown that problem solutions for such areas deserve thorough consideration of legal and socio-economic aspects. The measures implemented should be flexible and easy to adjust to changing conditions; they have to be planned comprehensively and need controlling for extended periods of time.

Sub-aquatic depots are an emerging science-based technology for the final storage of sediments. The EU Landfill Directive does not refer to waste disposal below the groundwater level, and just there the two most promising prerequisites for a sediment depot can be found (Box on page 25): (i) permanent anoxic conditions to guarantee extremely low solubility of heavy metals, (ii) base layers of compacted fine-grained sediments, which avoid advective transport of contaminants to the groundwater.



## **Die subaquatische Unterbringung von Baggergut in den Niederlanden DEPOTEC Amersfoort/NL by order of Freie und Hansestadt Hamburg (2002)**

### **1. Einführung und Überblick über den Bericht**

### **2. Politik**

### **3. Umweltauswirkungen subaquatischer Depots**

### **4. Technik der subaquatischen Depots**

- 4.1 Merkmale des Depots
- 4.2 Der Weg zu einem Depotentwurf
- 4.3 Rahmenbedingungen bestimmen die Eingliederung eines Depots
- 4.4 Entwurfaspekte des Baggergutdepots
- 4.5 Ausführungstechnische Aspekte
- 4.6 Der Betrieb eines Depots
- 4.7 Verwaltung und Monitoring eines Depots
- 4.8 Ausgleichs- und Ersatzmaßnahmen
- 4.9 Arbeiten und Verfahren in der Nachsorgephase
- 4.10 Nebenfunktionen
- 4.11 Kostenschätzung für subaquatische Ablagerungen

### **ANLAGEN**

- Anlage 1 Niederländische Normen für die Qualitätsbeurteilung des Oberflächenwassers, Schwebstoffen, Sedimenten und Grundwasser
- Anlage 2 Niederländische Vorschriften für subaquatische Ablagerungen von Baggergut
- Anlage 3 Der Niederländische Baustoffbeschluss
- Anlage 4 Ablagerungen von Baggergut in Grubendepots
- Anlage 5 Verwertung von Baggergut in den Niederlanden (Impuls B2)
- Anlage 6 Berechnung und Überprüfung der Verteilung von Schadstoffen aus Baggergutdepots an Land
- Anlage 7 Die Wirksamkeit von Isolationsmaßnahmen für Baggergutdepots
- Anlage 8 Diffusion von Schadstoffen
- Anlage 9 Numerische Modelle
- Anlage 10 Übersicht zusätzlicher Reinigungstechniken für Rückwasser
- Anlage 11 Methodik der Bewertung und des Vergleichs der Depotvarianten im Umweltverträglichkeitsbericht (UVB)
- Anlage 12 Subaquatische Depots in der Praxis

Together with advanced geochemical and transport modelling such deposits offer the most cost-effective and durable problem solutions for dredged sediments.

Actually there are 16 sites of sub-aquatic depots for harbor sediment in The Netherlands (Depotec 2002), most of them at near coast sites. World-wide known is the “Slufter” peninsula disposal facility in the mouth of Rhine and Meuse, the largest example to contain more than 95 Mio m<sup>3</sup>. Much experience has been gained during the last 20 years with the planning, operating and supervising this site. The preparation work before construction took between 4 and 7 years. Filling for the smaller depots will take place within 5 years, for the larger ones within 20 year. Cost estimations for construction, operation and aftercare are between 5 and 10 Euro per m<sup>3</sup>, much less than the costs for conventional separation, drying and land deposition of dredged material.

This cost-efficiency together with the operational safety of sub-aquatic depots should be a convincing argument for the application of these containment technologies at upstream sites as well. Here, some additional precautionary measures should be considered, e.g. an armoring layer which provides erosion protection of the depot. Implementation of sediment capping is a typical example for collaborative projects involving strategic research, applied research and development, and technology sharing projects (Azcue et al., 1998). Major steps are (1) characterization of sediment materials (reactivity, mobility of pollutants), (2) suitability of capping techniques (currents, steep gradients, groundwater seepage), (3) provision of capping material (sand, granular materials, geotextile, additives; logistics; soft sediment/coarse, dense cover; impermeable materials, water flow); (4) thickness of capping material, (5) reactive additives; (6) monitoring of the sediment/cap system, early warning systems.

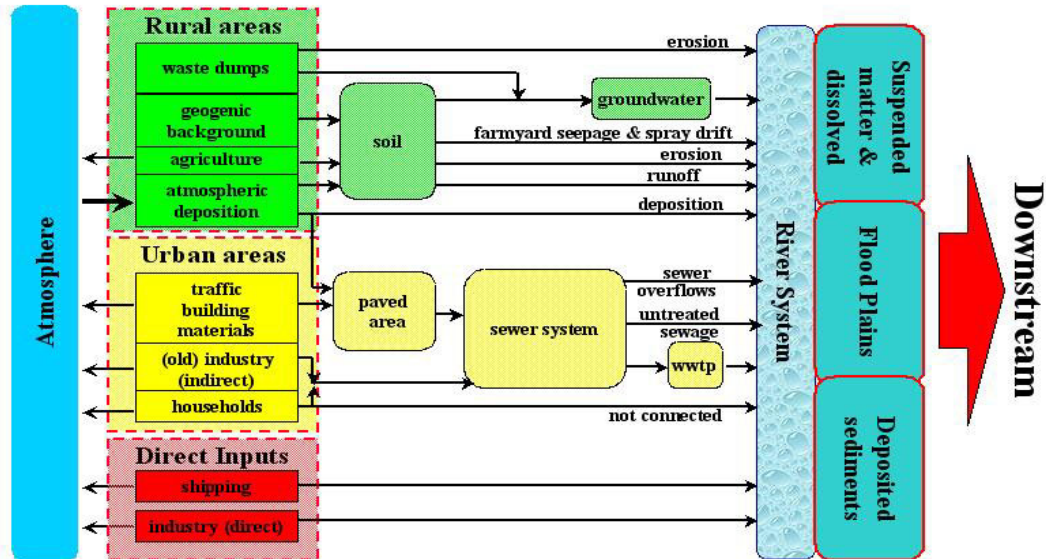
Application of a combined sub-aquatic depot and active capping technology can be considered for small yachting harbors. For the Hitzacker/Elbe harbour site, a draft approval has been made which involves the excavation of approx. 10.000 m<sup>3</sup> fine grained, polluted sediments from the harbour area and their sub-aquatic deposition close to the site, in a communication channel between the Elbe River and the harbour. Active capping of the sediment depot will include natural zeolite additives and monitoring of the site will be performed using dialysis sampler and diffusional gradient technique (DGT) probes (Jacobs 2003).

Examples from sediment depots in gravel pits, separated river branches and harbour basins in Germany, where similar geochemical conditions can be expected as in the specially designed sub-aquatic depots, are described in a recent compilation of case studies by ATV-DVWK (2004).

### **3.5.3. Future Research on Soil-Sediment Contaminants at the Catchment Scale**

Many and various sources contribute to the contaminant concentrations in fluvial sediments. The more important pathways are depicted in figure 3.2.

The Rhine Research Project II study showed the increasing importance of diffuse sources compared to point sources for sediment contamination. Historical analysis as well as future scenarios shows this trend.



**Figure 3.2** Sources and Pathways of Contaminants in River Basins

Not considered in the Rhine Research Project II analysis were possible contributions of the “legacy” of past industrialisation in the Rhine catchment, which are the subject of the current study.

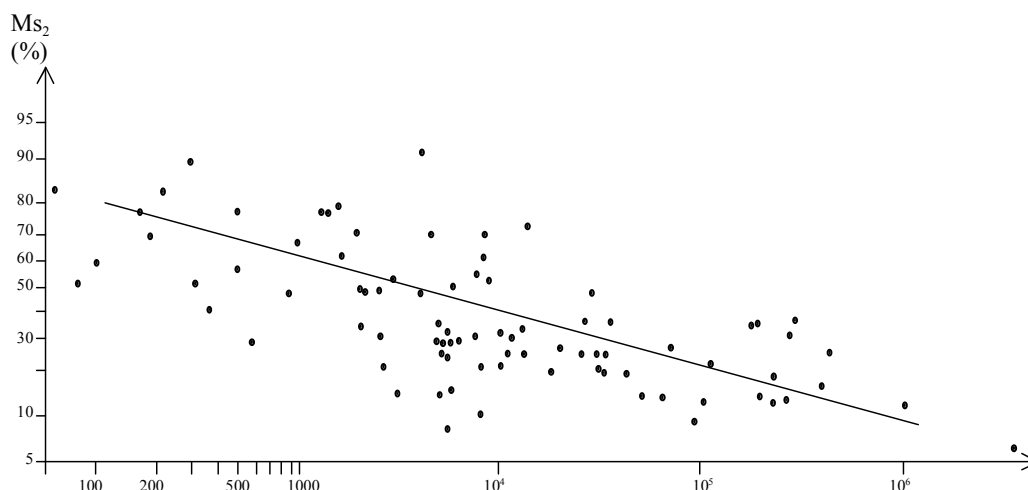
On land these are waste deposits and contaminated industrial and mining areas. In the river system contaminated sediments in harbours and upstream of barrages and dams as well as river flood plains have to be considered.

The Rhine Research Project II focused on averages, often over years, to identify and predict future behaviour of pathways. In contrast, the present study tackles the issue of isolated events of high discharge and its effects on sediment transport and the potential for erosion of historic contaminated sediments. In addition, as a prerequisite, a survey of potential sites of erosion of contaminated deposits in the catchment was carried out.

Hence the following three issues have to be solved (in theory) for a quantitative prediction of the Rhine catchment “legacy” on dredged material quality in the port of Rotterdam.

- Identification of the contaminated sites
- Application of an erosion model to each identified site
- Application of a sediment transport model for the isolated events at the site of erosion (sub-catchment) and subsequently for the whole catchment

On the basis of available data, numerous potential areas/sites of concern could be identified (Fig. 4.2). For some areas, only few or no data were available (no circles). To fill this gap relatively simple, basic investigations like additional monitoring data and sediment survey will be required.



**Figure 3.3** Percentage of suspended solids flux discharged in 2% of time ( $Ms_2$ ) vs log of basin area ( $km^2$ ). Meybeck et al. 2004b

The review part on erosion gave detailed description on the intricacies of erosion modelling, the sediment properties required and the laboratory sediment testing procedures. In principle these data have to be measured for each identified site to arrive at quantitative erosion potential for a modelling effort.

Anyhow, the analysis of available data on contaminant load and discharge showed that under average conditions, the contaminants do not show up. Only during periods of high discharge, high loads for some specific contaminants become apparent: a positive proof for the contribution of erodable formerly contaminated deposits.

The next issue is the sediment transport during events of high discharge. There is a significant relationship between sediment flux discharged and the basin size. In particular in small sub-basins but also in larger basins most of the sediment transport takes place during relatively short time periods. Figure 3.3 shows the relationship between basin size and the sediment transport that occurs in 2 % of the time. These high transport event periods are relevant for the impact from contaminated sites on downstream dredged material quality.

Many studies have dealt with these isolated events on sediment transport and it is well described in the literature. However, validated models for the Rhine catchment seem to be lacking let alone an application of these models to isolated contaminated areas in the Rhine catchment. To fill in this gap will require massive efforts, in particular with regard to obtaining field data and monitoring data sufficient for validating this kind of model. In this respect European research is needed, in particular since the phenomenon of the legacy of past pollution in sediments and waste dumps is not restricted to the Rhine catchments but occurs in other European regions as well.

As such the “worst case approach” taken in this study appears currently to be the Best Available Technique for a first order risk assessment of contaminated sites in river catchments.

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