

**Discussion document on Sediment Monitoring Guidance
for the EU Water Framework Directive**

Version: 2

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Date: 25 May 2004

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1. Introduction

1.1. General

Sediment constitutes an important part of aquatic ecosystems. It provides a habitat for benthic organisms and can be a significant sink as well as a potential source of contaminants. In recognition of this, the Water Framework Directive (WFD) contains provisions that call for assessments of contaminated sediments. Firstly, Article 16(7) of the Directive states “The Commission shall submit proposals for quality standards applicable to the concentrations of the priority substances in surface water, sediments or biota”. If quality criteria were to be defined for sediment, then monitoring would be required to establish compliance with such criteria. Secondly, it is clear from the WFD that sediment monitoring can play a roll when assessing impacts on environmental quality, when monitoring trends in pollutant levels and compliance with the WFD’s no deterioration objective (Annex V 2.4), and in any investigative monitoring of pollutants’ fate and behaviour.

In order to address these requirements of the WFD, the working group on Analysis and Monitoring of Priority Substances (AMPS) has considered the technical implications of sediment monitoring. This document is intended to summarise the key issues and give technical expert advice to the EC on analysis and monitoring aspects, in order to justify the choices made in the forthcoming proposal for a daughter Directive on priority substances. The document could provide a) suggestions for drafting proposals on sediment monitoring for the daughter Directive and b) recommend areas of sediment assessment to be further developed in the near future, to yield annexes to legislation or a separate guidance document.

1.2. Importance of sediments to the WFD

Sediment is an essential, integral and dynamic part of river basins, estuaries and coastal waters. Most sediment is derived from the weathering and erosion of minerals and soils in upstream areas and from the erosion of river banks and organic material, and is susceptible to being transported downstream by surface water. Sediment is thus not restricted or limited to a particular area or part of a river basin. As flow rates tend to decline in lowland areas, transported sediment settles along the river banks and on the bed of the river (i.e. sedimentation). Sedimentation also occurs on floodplains during flooding, and in reservoirs and lakes. At the end of most rivers, most of the remaining sediment is deposited within the estuary and on the seabed of the coastal zone.

Sediment has ecological value. It forms a variety of habitats and environments. Sediment-dwelling species, such as amphipods, molluscs and worms, are supported by soft sediment systems. Furthermore, sediment is an important source of nutrients for these organisms and thus, indirectly, for species higher in the food chain. Sediment dynamics (erosion and sedimentation) and gradients (high–low and wet–dry) form favourable conditions for a varied environment (biodiversity), from the source of the river until the coastal zone. Sediment is also a beneficial, socio-economic resource. For centuries, people have exploited the fertile sediments in river systems for farming, or have used sediments as a source of minerals and materials. Sediment is, for example, used as construction material, to replenish eroded beaches and as a “filling material” in dykes and land reclamation [SedNet 2003].

Sediment quantity has been managed for centuries, mostly by dredging. This was, and still is, very necessary in order to keep waterways prone to silting up and open to the flow of water. Dredging ensures a proper drainage capacity for precipitation and melting snow and ice, so it aids in flood prevention. But it also ensures there is enough water for drinking, irrigation and for shipping. However, the natural hydrodynamic conditions of many waterways have been altered directly by hydraulic constructions (e.g. dykes, dams, seawalls, artificial drainage) and indirectly by changes in land cover and use (e.g. deforestation and urbanisation). These changes

have resulted in the unwanted accumulation of sediment at certain places. The removal of sediments from locks, floodplains, harbours, navigation channels and stretches of river is a high capital cost for authorities and agencies responsible for the maintenance and water quality of these features.

Since the beginning of the Industrial Revolution, anthropogenic emissions of chemicals to waters have caused sediment quality to deteriorate rapidly. In the second half of the 20th century this resulted in a new type of management: sediment quality management. Sediments and dredged material became subject of waste regulations. Stimulated by the EU WFD, the view on sediment is changing from seeing sediment as a waste to the recognition of the key role that sediment plays naturally in the functioning of river systems. It is now realised that the contamination issue cannot be viewed in isolation. Sediment should fit into the holistic view on river basin systems. There are parallels here with the evolution of policy for contaminated soil. That also started with the perception that soil is a vital part of our environment that deserves to be protected by proper management. The big difference, however, is that contaminated soil is a site-specific issue, while the mobility of contaminated sediment makes it a river basin issue and thus needs integrated river basin management. This also means that for river systems that cross national borders, trans-boundary management is needed [SedNet 2003].

2. Definition of sediment

Sediment is particulate material such as sand, silt, clay or organic matter that has been deposited on the bottom of a waterbody and is susceptible to being transported by water.

3. Aim of sediment monitoring

Under the Water Framework Directive the purpose of analysing the levels of priority substances in sediments might be i) to monitor the progressive reduction in the contamination of priority substances (PS) and phasing out of Priority Hazardous Substances (PHS) and ii) to demonstrate conditions of “no deterioration” in sediment quality. This is implicit in the need to ensure adequate provision of pollution prevention and control. Sediments have an impact on ecological quality because of their quality, or their quantity, or both. Therefore, sediment monitoring programmes should also address the basic physicochemical properties of sediments (grain size distribution, organic carbon content etc.) as well as the geomorphological processes within each river system, including those operating in floodplains, wetlands and coastal zone. The physicochemical quality of sediments features in the definition of good and moderate ecological status in rivers and lakes (Annex V 1.2). However, as this issue is not related to priority substances it is outside the scope of this document

3.1. Risk assessment

The presence of contaminated sediments might be one of obstacles to achieving “good ecological status” for a waterbody. One widely accepted way of obtaining an initial indication of the likely causes of a waterbody’s poor ecological status is the sediment quality Triad [Chapman 1996], i.e. the simultaneous observations of sediment chemistry, sediment toxicity tests and, in the field, the benthic community. The observed concentrations of sediment-associated chemicals can be compared with Sediment Quality Guidelines, if these are available. Over the years, research has demonstrated that contaminated sediments that exceed Sediment Quality Guidelines do not always result in toxic effects in sediment toxicity tests or in the benthic community as a result of decreased bioavailability of the sediment-associated contaminants. Sometimes the opposite has been observed, i.e. sediment that meet a suite of Sediment Quality Guidelines has caused adverse effects to the benthic community in the field or in laboratory toxicity tests because of combination toxicity or the presence of unidentified compounds. This demonstrates our need to better understand the relation between sediment contamination (a hazard) and its actual risk to the

functioning of the ecosystem (ecological status) in order to be able to take effective measures to restore the ecological status of a given waterbody (Heugens et al., 2001). Complementary tools that are useful for improving this understanding include AVS/SEM extraction, biomimetic extraction (POM, SPME, TENAX, etc.), functional monitoring techniques (SPM grazing, OM mineralisation, etc.), Effect Directed Analysis (EDA) or Toxicity Identification Evaluation (TIE) and Model Ecosystems [Brils et al. 2004; Brack 2003].

3.2. *Trend monitoring*

Trend monitoring will provide an indication of temporal changes over a prolonged period, e.g. increases or decreases in concentrations of contaminants over time. The ICES Working Group on the Statistical Aspects of Environmental Monitoring in the marine environment has developed statistical methods for trend detection, including trend detection in sediments. For the results of trend analyses, see <http://www.ices.dk/iceswork/wgdetail.asp?wg=WGSAEM>. These studies might contribute to a sound basis for the future development of statistical methods for sediment monitoring under the WFD.

3.3. *Spatial monitoring*

Spatial monitoring will provide an indication of the status of contamination over an area. Such monitoring is necessary to detect the horizontal spread of a contaminant over a river basin, and possibly to locate its source. It will provide basic information for appropriate sediment management. Historic contamination at hot spots is often reflected in the deeper sediment layers. The spatial variation in sediment contamination is influenced by differences in sedimentation rate of newly formed particulate material as it influences the degree by which historic contamination is covered-up. Consequently, the choice of sediment sampling depth is a critical issue in mapping the status of sediment quality.

3.4. *Compliance monitoring*

WFD quality standards for priority (hazardous) substances are currently being established for the water phase. In cases where Water Quality Standards have been violated, one of the sources of pollution might have been the emissions of contaminants from contaminated sediment to surface waters and groundwaters. This demonstrates the connectivity between the water and sediment phases. However, compliance monitoring of sediment quality is not yet appropriate because of the lack of valid Sediment Quality Standards and the complexity of deriving such criteria in a European context. The limitations of Sediment Quality Standards in assessing contaminated sediments have been indicated briefly in paragraph 3.1. A further obstacle is the anticipated high costs of obtaining full spatial coverage.

4. **Selection of compounds**

There are currently 33 priority substances (cf. 2455/2001/EC). Additionally, there are 8 other substances covered by the daughter directives 86/280/EC to 76/464/EEC: DDT, Aldrin, Dieldrin, Endrin, Isodrin, trichlorethylene, perchlorethylene tetrachloroethylene and carbon tetrachloride. The primary criterion for the selection of compounds to be monitored in sediments is their physico-chemical preference for the solid phase, i.e. when they are poorly soluble in water. The more hydrophobic (water repulsing) a compound, the less soluble it is, therefore the more likely it will adsorb to sediment particles. A simple measure of the hydrophobicity of an organic compound is the Octanol–Water partition coefficient (K_{ow}). The coefficient is determined by calculating the concentration of a given contaminant in the Octanol phase compared to its concentration in the water phase. The K_{ow} of a compound is a good predictor of the partition coefficient of the contaminant in the organic fraction of the sediment (K_{oc}). As a rule of thumb, compounds with a $\log K_{ow} > 5$ should *preferably* be measured in sediments, but compounds with a $\log K_{ow} < 3$ should preferably be measured in water. For instance, HCB (hexachlorobenzene)

should preferably not be monitored in water but in sediment, because of its preference to adsorb to sediment particles (organic carbon, in particular). Atrazine, on the other hand, should be monitored in water and not in sediment, because of its high water solubility. For compounds with a logKow of 3 to 5 the sediment matrix is *optional* and will depend on the degree of contamination.

Based on the rule of thumb mentioned above, a distinction has been made between *preferred* and *optional* priority substances to be monitored in sediment (Annex 1). Monitoring in sediments is preferred for 8 of the 41 priority substances and is optional for a further 21 of the substances.

Annex 1 also refers to monitoring in biota (see WFD AMPS biota monitoring guidance discussion document DRAFT version: 160404). It is suggested that Member States should be able to choose at least one matrix for trend monitoring the levels of the priority substances.

5. An overview of current sediment monitoring practices

A questionnaire on current practice in sediment monitoring was circulated to Member States in early 2004. The responses received (from fifteen countries) are summarised below.

- Most of the programmes of sediment monitoring seem to have been established and stable for little over 5 years. Some degree of international coordination is evident for the marine environment (ICES, OSPAR, JAMP).
- The sampling methodology varies. The depth of primary sampling of sediments is generally >5cm. The choice of depth may or may not be related to ecological issues or sedimentation rate.
- In the marine environment, the use of core samplers appears to predominate slightly over the use of grab samplers, but in the freshwater environment the preference is reversed. There is no particular tendency to favour pooling of subsamples. The number of samples taken at a given site ranges between >4 and 1, with 1 being the most common. Few agencies take samples smaller than 50g.
- There is little agreement about the depth of sediment subsampled from cores/grab samples. Similarly, although the issue of normalisation is recognised, there is no consensus on the parameter to be used or how normalisation should be done (see section 8). Over half the respondents (8) do determine grain size and TOC but only a minority reported that they normalise for these parameters (4 for grain size and 3 for TOC).
- Maximum storage time and time to analysis was longer for marine samples than freshwater samples, though few special preservative measures were taken for either.
- Numbers of sites/ability to cover numbers of sites and frequency of monitoring were variable. The motivation for choosing sampling locations remains somewhat obscure: more than a third reported reasons other than “hotspot” or spatial drivers. Flooding was reported as rarely leading to increased sampling.
- Approximately half of the respondents reported determining more than 10 priority substances in sediment, though the application of quality guidelines/standards was not widespread. The derivation and implementation of background levels are at an early stage.

The questionnaire revealed that currently there is a wide range of approaches to sediment monitoring. Even within individual countries, different authorities appear to organise their sediment monitoring in different ways. This may be because different programmes address different objectives, but a more probable reason is that a critical element in addressing trend analysis (currently the primary objective of sediment monitoring) is consistency over time, rather than consistency between locations. Once a set of data has been obtained, the producers and

users of the data are reluctant to change the basic approach selected at the programme's inception, on the basis that such a change could introduce experimental artefacts into the data set. Harmonisation of sediment monitoring is particularly relevant at a river basin level.

6. Sediment collection and sample handling

6.1. Sediment collection

Before starting a monitoring programme it is essential to establish the quantitative objectives. For instance, the quantified objective could be to detect an annual change of 5% within a time period of 10 years with a power of 90% at a significance level (α) of 5% with a one-sided test. The necessary or possible power of a monitoring programme will vary with the purpose of the investigation and with the contaminant, matrix and area being investigated. It is thus not possible to specify values for all situations. It is the duty of the programme manager to specify the size of the changes the monitoring programme is expected to identify and at what *power*, or for the programme executor to estimate what it is possible to achieve.

Sediment samples should be collected at an appropriate *frequency* that will have to be defined on a local basis, taking into account the sedimentation rate of the waterbody studied and hydrological conditions (e.g. flood events). Typical sampling frequency will vary from once every 1 to 3 years for large rivers or estuaries that have high sedimentation rates, to once every 6 years for lakes or coastal areas with very low sedimentation rates. A maximum interval of 6 years is suggested, to fit in with the WFD 6-year cycles.

The locations for sediment *trend monitoring* should be representative of a waterbody or a cluster of waterbodies. Where possible, sampling should be done in non-erosion areas, to obtain sediment with a relatively high content of clay and silt that will probably contain measurable levels of contaminants. For dynamic systems it might be useful to collect suspended matter for monitoring purposes. An example of guidelines for site selection to use for lakes is given in Annex 2.

In *spatial surveys*, samples should be distributed throughout the area, taking account of the known distribution of contaminant inputs. If point sources of contamination are of interest, the positioning of the stations should aim at obtaining gradients. The sampling depth should be decided on the basis of knowledge of the sedimentation rate. Denser sampling grids are required close to point sources than in areas of diffuse contamination, and also in areas that have more uneven bottom topography than in more uniform areas. Analysis costs can be reduced by using *composite sampling* techniques (i.e. pooling subsamples). To test representativity of a single sediment sample at a location, several cores or grabs should be taken. If sediment subsamples are heterogeneous, it is advisable to collect several samples at each site and pool them into a composite sample.

As a general principle, the *sampling equipment* should not unduly alter the properties of the sediment (e.g. by contaminating or disturbing the sample or losing the surface layer). A wide range of sampling devices is in use for sampling sediments. Which equipment is chosen should depend on the local conditions at the sampling site (water depth, type of sediment, etc.), given the objectives of the sediment sampling. Box or tube corers that are capable of sampling the surface sediments without disturbing the structure and are relatively free from "edge effects" are recommended. Grab samplers (e.g. Van Veen, Eckman-Birge) can only be used provided they do not disturb the sediment. In shallow waters or tidal areas, manual sampling is also possible.

The relevant *sampling depth* for the top layer of sediment must be chosen in accordance with the local conditions at the sampling site, and bearing in mind the bio-relevance and sedimentation rate. In principle, the sediment top layer sampled should be between 1 and 10 cm thick. The *amount of sample* collected will depend on the parameters to be determined at each site. In principle, a sample size of 100g wet weight should be sufficient.

6.2. Sample handling

During sampling, *visual observations* of the samples should be recorded in a *log book*. The description should contain the following points: a) colour (e.g. Munsell colour chart); b) homogeneity (presence or absence of stratification); c) the presence or absence of animals (as an indication of bioturbation); d) textural description; e) surface structure (e.g. ripples); f) odour; g) visual contamination and h) redox conditions.

It is advisable to monitor the total content of contaminants in sediment (fraction < 2mm) and to determine the grain size distribution of the sediment in parallel from a separate subsample (i.e. for data normalisation). Though the JAMP OSPAR marine pollution monitoring guideline recommends sieving to 63µm, many scientists have questioned the current routine of wet sieving prior to contaminant analyses, because it is time-consuming and there is a high risk of sample contamination. Detailed information on sieving and the normalisation of geographically different sediments from estuarine and marine environments is provided by Smedes et al. (2000).

For organic contaminants, *drying procedures* are varied and depend on factors such as the class of substance. Special care should be taken for volatile compounds; for these, freeze-drying, drying at low temperature or analysis of wet samples are preferable. However, recent data indicate that losses of some determinands (e.g. PAHs, semivolatiles) do occur if sediments are dried, even when the drying is done at cool temperatures (<30°C). Prior to analyses for inorganic constituents (e.g. metals) sediment samples should be freeze-dried or, alternatively, dried at 105°C (except for mercury, which should be dried at <50°C).

If necessary, as in the case of metals analyses (where very small subsamples are needed for analysis), samples should be *disaggregated and homogenised* prior to analysis. During this procedure care should be taken to avoid contamination (e.g. use agate mortar, clean equipment made of appropriate material).

Subsamples for the analysis of inorganic and organic contaminants, total organic carbon, nitrogen or phosphorus should be *stored* frozen, dried or freeze-dried, in non-contaminating containers (e.g. glass, Teflon). As regards the feasibility of using older, archived dried sediment samples for the analysis of metals: with the exception of mercury there is no evidence that storage conditions are critical; however, the sample must have been stored under non-contaminating conditions. For mercury, samples must be stored in glass containers, as mercury can move through the walls of plastic containers. For longer-term storage, temperatures of -20°C or below are preferred for organic contaminants.

7. Analysis

In general, there are fewer analytical limitations for sediments than for water, but they vary with the compound. The costs involved are mainly in the pre-treatment (the sequence of manipulations until the actual analytical sample is obtained) of sediment samples and the necessary harmonisation of these methods in Europe. It is proposed that the selection of appropriate methods be left to the discretion of Member States but should in the first instance be based on the ASTM table of existing standard methods. Standardised methods of analysis are available or are being developed for most of the priority substances likely to be found in sediment. Most of these methods, however, have been developed for contaminated soil. It is therefore common practice in laboratories to dry the sediment samples and then to treat them in the same way as soil samples. Although this practice may lead to correct results, it is not recommended for sediment monitoring. As not only the digestion methods for the determination of metals but also the extraction methods for the determination of organics are “method-defined” procedures, it is absolutely essential for these first steps in the analysis process to remain the same over a long period of time. This is particularly true for organics, since there are no field-moist certified reference materials available to verify the recovery of an extraction procedure.

Extraction of wet sediment samples requires the use of a first extractant that is miscible with water (such as acetone), followed by a less polar extractant such as pentane or hexane. This

procedure works well for non-polar priority substances such as the organochlorine pesticides, polycyclic aromatic hydrocarbons and chlorinated benzenes and is described in the corresponding ISO standards.

A recent overview of methods of extraction and subsequent analysis is given in "Chemical Analysis of Contaminated Land" ed. by K. Clive Thompson and P. Nathanail (Blackwells, 2003).

For trend monitoring, the recovery of the extraction procedure should be constant over time; it is not necessary to know the numeric value of the recovery. In the case of compliance monitoring, the numeric value of the recovery should be known, or a standardised procedure should be specified for each individual priority substance or group of priority substances.

The analytical methods applied after extraction or digestion are generally the same for water and sediment samples. The use of standardised methods is recommended, because these methods have been validated in interlaboratory trials. Standardised methods should only be made mandatory if the analysis or the quantification contains "method-defined" parts. This is the case for e.g. the selection of congeners of brominated diphenyl ethers, the quantification of alkylated phenols, and both the selection and quantification of short chain chlorinated paraffins. For the latter group of compounds, standardisation has not even started.

For proper Quality Assurance / Quality Control procedures, including the determination of measurement reliability, certified reference materials must be available. For many organic priority substances no suitable certified reference materials (CRM) are available, not even as the commonly dried, milled and sieved materials. A concerted action for development of a series of suitable CRMs is highly recommended, even in the case of sediment trend monitoring.

Furthermore it is recommended that laboratories participate in suitable interlaboratory comparisons. This will already be the case for the most common priority substances. For the less common priority substances a concerted action to set up a scheme for international interlaboratory trials is recommended, because the number of national laboratories involved in sediment monitoring may be quite low.

Finally, as the concentrations of sediment contaminants are expressed on a dry weight basis (105°C), the water content of the sediment sample should be determined on a separate aliquot and the concentrations corrected accordingly. In order to normalise results the following parameters should be measured: a) Grain size distribution (e.g. <2, <16, <32, <63 µm; can be obtained by wet sieving or laser counting), b) TOC and c) Al, Li (for metals; optional).

8. Normalisation

Normalisation is defined here as a procedure to correct contaminant concentrations for the influence of the natural variability in sediment composition (grain size, organic matter and mineralogy). Most natural and anthropogenic substances (metals and organic contaminants) show a much higher affinity for fine particulate matter than for the coarse fraction. Constituents such as organic matter and clay minerals contribute to the affinity for contaminants in this fine material (OSPAR, 2001).

Fine material (inorganic and organic) and associated contaminants are preferentially deposited in areas of low hydrodynamic energy, while in areas of higher energy, fine particulate matter is mixed with coarser sediment particles which are generally unable to bind contaminants. This dilution effect will cause lower and variable contaminant concentrations in the resulting sediment. Obviously, grain size is one of the most important factors controlling the distribution of natural and anthropogenic components in sediments. It is, therefore, essential to normalise for the effects of grain size in order to provide a basis for meaningful comparisons of the occurrence of substances in sediments of variable granulometry and texture within individual areas, among areas or over time.

When analysing whole sediment (i.e. < 2mm fraction) for spatial distribution surveys, the resulting maps give a direct reflection of the bedded sediments. If samples used for a spatial

survey are predominantly of fine material, the influence of grain size distribution is of minor importance and may be neglected. However, in areas with varying grain size distributions, a map of contaminant concentrations will be closely related to the distribution of fine-grained sediments, and will obscure the true spatial distribution of contaminants. In temporal trend monitoring, too, differences in grain size distribution can obscure trends.

Two different approaches are widely used to correct for variable sediment compositions: Normalisation can be performed by relating the contaminant concentration to components of the sediment that represent its affinity for contaminants, i.e. binding capacity. Such co-factors are called normalisers. Normalisation can be performed by simple contaminant/normaliser ratios or linear regression. Another procedure takes into account that the coarse sediment fraction contains natural metal concentrations in the crystal structure. Combinations of co-factors, possibly identified from multiple regression analysis, can be used as normalisers.

Isolation of the fine fraction by sieving (e.g. <20 µm, <63 µm) can be regarded as a physical normalisation to reduce the differences in sediment granulometric compositions. It is applicable to both metals and organic contaminants (Ackermann et al. 1983; Klamer et al. 1990) and it removes the coarse particles, which usually do not bind anthropogenic contaminants. The contaminant concentrations measured in these fine fractions can then be directly compared. Subsequently, the geochemical differences in sediment composition remaining after sieving can be further corrected for by the use of co-factors.

Further details on normalisation are provided in the technical annex of JAMP guidelines for monitoring contaminants in sediments (OSPAR, 2001). Statistics on the normalisation procedure can be found in an annex to a report of a working group on marine sediment of ICES (International Council for the Exploration of the Sea): <http://www.ices.dk/reports/MHC/2002/WGMS02.pdf>.

9. Costs

The overall cost of a sediment monitoring programme is a product of the number of samples times the unit price for sediment collection plus chemical analysis. As discussed in section 6, the number of sediment samples required in order to conduct an effective trend monitoring programme will vary with the spatial and temporal variation. Table 9.1 provides an overview of costs of sediment collection and table 9.2 indicates the cost of analytical parameters. For example: in a given waterbody, levels of priority substances are monitored in sediments annually at 10 locations. A composite sample of three subsamples is analysed. The annual costs of sediment collection and analysis are €7350 and €29700, respectively.

Table 9.1. Cost of sampling and transport: indicative figures for The Netherlands

Action	Cost in €
Ship with sampling equipment ^a	5500 per day
Transport	60 / sample
Sampling and mixing sample	100 + 17 m ^b
Administration	10 / sample
Reporting / data management	100 / sample

^a for inland waters; the anticipated sampling costs in coastal waters are higher

^b m = number of samples in a composite sample

Table 9.2. Cost of analytical parameters: indicative figures for The Netherlands.

Parameter	Costs in €
Grain size, organic carbon, dry wt., nutrients	200
Metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn, As)	320
PAHs	150
PCB, organochlorine pesticides Drins, DDT,	320
Mineral oil	30
Organotin compounds	350
Brominated diphenyl ethers	500
C ₁₀₋₁₃ Chloroalkanes	~1300
	Total 2970

10. Programme to develop sediment monitoring guidance

The foregoing sections have indicated that there is a clear need to develop diagnostic and technical guidance for sediment monitoring. Such guidance should be made available in the year 2006 in order to support Member States in their effort to implement the WFD. Firstly, there is the need to develop new monitoring programmes under the WFD. Secondly, analyses are under way to identify the necessary measures to meet the good ecological status and water quality standards.

The development of a sediment monitoring guidance can benefit from the ongoing activities of SedNet (the European Sediment Research Network), a network for environmentally, socially and economically viable practices of sediment management at the river basin scale. The SedNet network activities are funded by the European Commission (EC contract No. EVK1-CT-2001-2002). In the past three years, through a series of dedicated workshops and conferences (see www.SedNet.org), SedNet has reviewed the state of the art of the fundamental and applied science of several major sediment management topics. SedNet is currently preparing a series of books on, amongst others “Sediment Quality and Impact Assessment of Pollutants” and “Risk management of sediments and communication”. SedNet proposes to take the specific WFD AMPS needs into account when finalising these books. The book manuscripts are scheduled to be ready by December 31, 2004. Furthermore, SedNet suggests to come up with a more detailed proposal on how to derive Technical Guidance for sediment monitoring related to the WFD needs. The proposal could be worked out in close consultation with EC DG Environment, the AMPS sediment monitoring drafting group and other experts (scientists and stakeholders) involved in SedNet.

11. Recommendations

The recommendations of the ASTM working group on sediment monitoring to the EC are to:

- 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 normalisation 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;
- Instruct Member States to *apply sediment monitoring in selected waterbodies* in order to determine the trends in the priority substances that are poorly soluble in water (in accordance with Annex 1);
- Stimulate the *harmonisation of sediment status&trend monitoring programmes* of Member States at river basin level.

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Annex 1 Water Framework Directive priority substances suggested for trend monitoring in sediment or biota. P = preferred matrix, O= optional matrix.

Priority Substance	Sediment	Biota
Alachlor	O	---
Anthracene	P	O
Atrazine	---	---
Benzene	---	---
Brominated diphenyl ethers ^a	P	P
Cadmium and its compounds	O	O
C10-13-chloroalkanes	P	P
Chlorfenvinphos	O	---
Chlorpyrifos (-ethyl, -methyl)	O	---
1,2-Dichloroethane	---	---
Dichloromethane	---	---
Di(2-ethylhexyl)phthalate (DEHP)	O	O
Diuron	---	---
Endosulfan	O	---
Fluoranthene	P	O
Hexachlorobenzene	P	P
Hexachlorobutadiene	O	O
Hexachlorocyclohexane ^b	O	P
Isoproturon	O	---
Lead and its compounds	O	O
Mercury and its compounds	O	P
Naphthalene	O	O
Nickel and its compounds	O	O
Nonylphenols	O	O
Octylphenols	O	O
Pentachlorobenzene	P	O
Pentachlorophenol	O	---
Polyaromatic Hydrocarbons ^c	P	O ^d
Simazine	---	---
Tributyltin compounds	P ^e	P ^e
Trichlorobenzenes	---	---
Trichloromethane	---	---
Trifluralin	O	---
DDT (including DDE, DDD)	P	P
Aldrin	O	O
Endrin	O	O
Isodrin	O	O
Dieldrin	O	O
Tetrachloroethylene	---	---
Tetrachloromethane	---	---
Trichloroethylene	---	---

^a Including Bis(pentabromophenyl)ether, octabromo derivate and pentabromo derivate;

^b gamma-HCH (Lindane);

^c Including Benzo(a)pyrene, Benzo(b)fluoroanthene, Benzo(g,h,i)perylene, Benzo(k)fluoroanthene, Indeno(1,2,3-cd)-pyrene;

^d Preferable in mussels;

^e marine environment

Annex 2. Guidelines on the selection of (A) lakes and (B) sites within a lake for sediment studies of priority substances (from EPRI, 1996)

A. Guidelines for selecting lakes for sediment studies.

Favourable	Unfavourable
Simple bathymetry	Complex bathymetry
Undisturbed catchment	Disturbed catchment
Natural lake	Reservoir
Thermally stratified water column	Mixed water column
Reasonably high sediment accumulation rate > 1 mm / a	Slow sediment accumulation rate < 0.5 mm /a
Previous paleolimnological/sediment studies	Unknown sediment conditions
Representative lake type	Unusual lake type

B Guidelines for selecting sites within a lake for sediment studies.

Favourable	Unfavourable
Extensive flat bottom	Steep holes, irregular bathymetry
Site far from stream inputs	Deltaic deposits
Fine organic sediments, consistent stratigraphy	Sand lenses, lag deposits (e.g. shells)
Deep, wave-free area	Shallow, wave-mixed zone
Sediment free of physical/biological disturbance	Sediments mixed (e.g., anchors, dredging, bottom dwellers)

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