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SIMONA

WP 6: Sediment sampling in Large Lakes and Reservoirs

D.T4.2.1 Transnational guidance on sediment quality monitoring in large reservoirs

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AUTHORS:

Prof. Prvoslav Marjanović, PhD, Marko Marjanović, Dragica Vulić, Jaroslav Černi Water Institute, Belgrade, Serbia

Contact to the authors: prvoslav.marjanovic@jcerni.rs

RESPONSIBLE(S) OF THE DELIVERABLE: Prof. Prvoslav Marjanović, Jaroslav Černi Water Institute, Belgrade, Serbia

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Contents

BACKGROUND INFORMATION

EU legislation (2013/39/EU Directive and its previous versions) prescribes sediment quality monitoring and trend analysis, in terms of taking measures to ensure that sediment quality is preserved and/or improved. Although the Joint Danube Surveys (JDS 1 and 2) characterized sediment quality in the Danube several years ago and they concluded that contaminated sediment was an existing problem in the Danube River Basin (DRB), the DTP Countries did not have enough institutional capacity (information, guidelines and methods) to build transnational sediment monitoring network for HS trend assessment. Sediment monitoring is expected to offer cost efficient alternatives to conventional water monitoring for HSs listed in EU WFD CIS Guidance Document No. 25.

SIMONA project responds to the current demand for the effective and comparable measurements and assessments of sediment quality in surface waters in the DRB by delivering a ready-to-deploy Sediment quality Information, Monitoring and Assessment System to support transnational cooperation for joint DRB water management.

The system is a functional composition of sediment (1) sampling, (2) laboratory analysis, (3) evaluation protocols and (4)

The immediate and middle term benefit of the project is a transparent method supported by the SIMONA-tool for sediment quality monitoring that will encourage the cooperation in transnational water management.

One of the main tasks of the project is to deliver recommendations for policymakers in the field of sediment monitoring in large lakes and reservoirs.

INTRODUCTION

The material presented in this section has been prepared on the basis of the UNIECE Working Group on Monitoring and Assessment report entitled "Guidelines on Monitoring and Assessment of Transboundary and International Lakes published by UNIECE Working Group on Monitoring and Assessment in 2003 with appropriate modifications by the authors of this report.

MONITORING OF LARGE TRANSNATIONAL LAKES AND RESERVOIRS AS A PART OF ENTIRE RIVER BASIN MONITORING

The EU Water Framework Directive, WFD (2000/60/EC) has defined a lake as a body of standing inland surface water. The Annex II of the WFD has in a way determined also the minimum size of such systems, which should be taken into account to be 0.5 km^2 (50 ha).

According to UNESCO and WMO (1992), a reservoir is a "body of water, either natural or manmade, used for storage, regulation and control of water resources". In several connections, the term reservoir is used as a synonym for a man-made lake, and the resulting basic classification is either: "lakes and reservoirs" or "natural lakes, regulated lakes and reservoirs". The term reservoir always includes the utilisation aspect.

In addition to the degree of use or regulation, lakes have often been classified according to their origin. From the point of view of large lakes, the most important categories are tectonic and glacial lakes. Reservoirs can also be classified in many ways, e.g., according to their principal use, size or structure.

A lake is only one element, involved in the hydrological cycle of the river basin and monitoring is only a part of river basin monitoring. Different water bodies in the watershed are closely connected to the entire environment.

In water resources monitoring, one needs simultaneously adequate information on the one hand of natural conditions in the watershed area, and on the other hand all the pressure factors of the waterbodies for reliably handling monitoring (quantity and quality) data. The most important background information of the watershed area is as follows:

- Climate (seasons, temperature, precipitation, prevailing wind directions).
- Land use (for agricultural and forestry use, built environment).
- Population density in the river basin area (inhabitants/km^2, also calculated for sub-basins).
- Wastewater load (urban and industrial wastewater, fish farming etc.).
- Non-point loading (agriculture, forestry, storm water etc.).

Each of these items are such large issues, that they cannot be discussed in detail in the context of the preparation and implementation of the monitoring programmes, but some type of rough estimation is, however required. More specific and accurate information is required later in the assessment of monitoring data of lakesand rese4rvoirs or of the total river basin.

A LAKE/RESERVOIR AS AN ECOSYSTEM

Lakes and reservoirs differ from rivers as ecosystems in many respects; hydrological circumstances, thermal properties, production/decomposition relations, sedimentation rate and sediments, and in stability of certain phenomena. Lakes are almost closed systems. Substances once introduced to the lake are permanently incorporated in the circulation. Only a part of them is removed (depending on water exchange rate). Rivers are open systems, in which constant downstream transport of substances takes place (more about lakes Hutchinson 1957, 1963 and 1967, Wetzell 1983, Heinonen et al. 2000).

In lakes and reservoirs, the vertical distribution of temperature depending on the season is a very important phenomenon. During summertime a clear thermal stratification can be detected in all deeper lakes. In the upper water layer the temperature is highest, and can be at the same level than the temperature in rivers at the same time. This warm layer is called epilimnion. The epilimnion can also be called the trophogenic layer in the ecological sense. (Figure 1)

The temperature in the deeper layer of the lake is, on the contrary, usually very cold (5--10 °C) during the whole summer stratification period. This cold layer near to the bottom is called hypolimnion, or tropholytic layer. The hypolimnion is a very important part of the lake from the monitoring point of view. Many slight pollution indications can particularly be detected for the first time just in the hypolimnion, usually in the very thin water layer nearest to the bottom sediments.

The dominant biological phenomenon in rivers is as a rule the decomposition of organic alloctonic matter, and primary production is of less importance. In lakes with clear thermal stratification the dominant biological phenomenon in epilimnion during summer time is primary production. In hypolimnion usually no trophogenic primary production can be detected, and the dominant phenomenon is the decomposition of organic matter mainly by bacteria.

Sedimentation is a very important process in lakes and reservoirs, and has a dominant role in nutrient cycles, and thus also in the eutrophication process. Sedimentation areas must be identified before the implementation of the monitoring programmes.

A lake/reservoir is a very clearly bordered part of a river basin, and it forms a separate aquatic ecosystem. The lake ecosystem consists theoretically of two different parts: the biotope and the biocoenosis (Fig. 2).

The biotope is the abiotic part of the ecosystem. The primary quality characteristics of the biotope are determined primarily by the properties of the drainage basin and the hydrological conditions. It can justified notice, that a lake/reservoir is a “prisoner of the watershed”. If you have a lake on a fertile soil, the lake cannot be clearly oligotrophic.

Because of the natural leaching of more nutrients from the soil, the lake will have more of a eutrophic character.

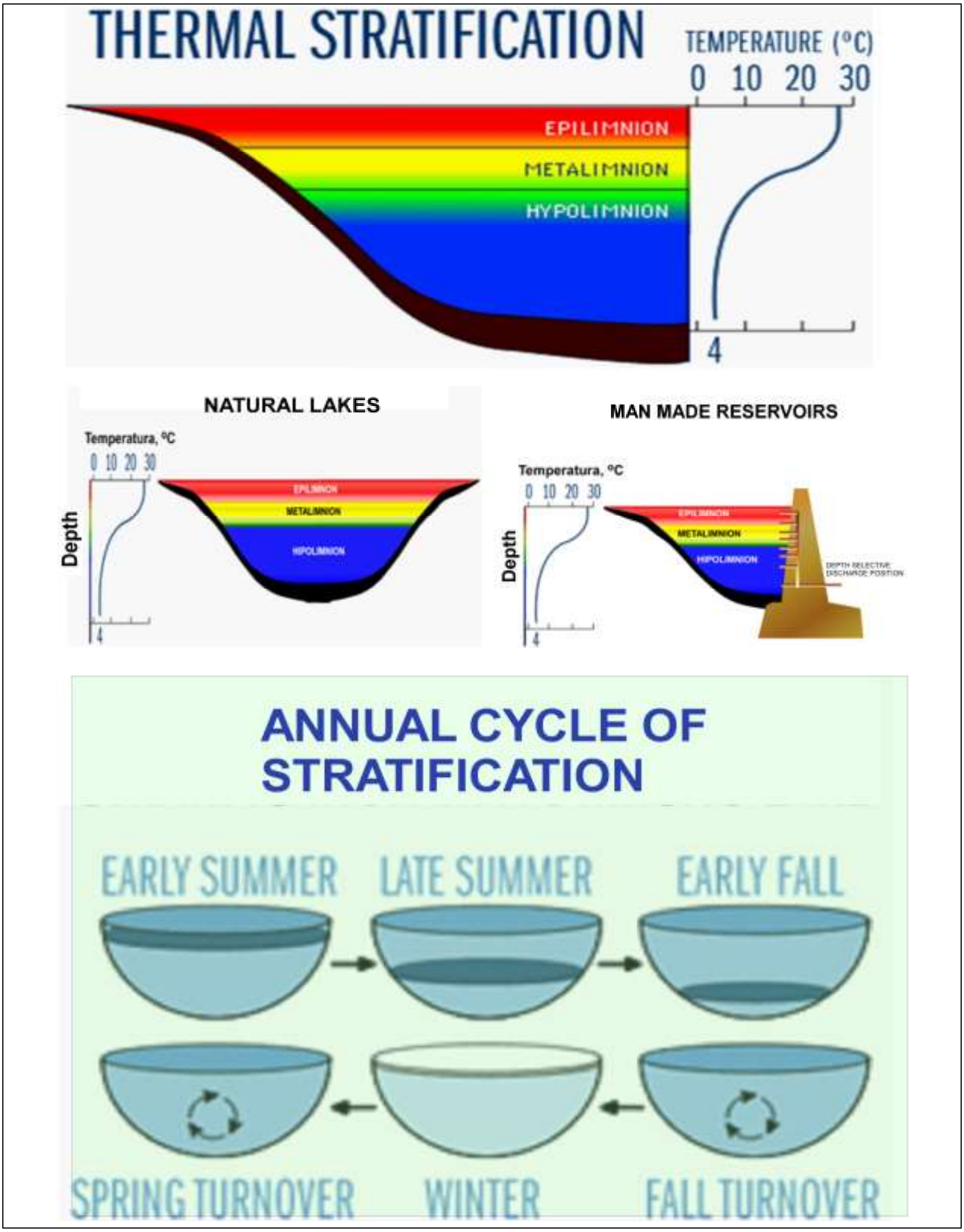


Figure 1. Thermal stratification and seasonal patterns in large lakes and reservoirs

The biotope in a natural state can be satisfactorily described by a relatively small number of ordinary physical and chemical variables, such as measurement of concentrations of oxygen and carbon dioxide in different vertical layers, the content of the main nutrients, phosphorus and nitrogen, and organic materials, alkalinity, pH, conductivity, heavy metals etc.

All the living organisms of the lake/reservoir form the biocoenosis. These organisms are used to live just in the conditions, which are characterised by the different variables of the biotope. The biocoenosis can be characterized by observations of the different groups of plants, animals and microbes. Primary production is a very dominating phenomenon in the upper water levels (epilimnion) of the lake. The algae and macrophytes have the most important responsibility of the primary production of the lake ecosystem. The information of optical properties is significantly linked to primary production.

Theoretically, the biotope is first to change (e.g., the phosphorus concentration increases because of poorly treated sewages), and then the biocoenosis reacts to this change (e.g., the biomass of algae increases, if phosphorus is the limiting factor for algal production). In practise this order can not be seen, due to the fact that these main processes of the ecosystem affect each other continuously.

In Europe, the following types of transboundary lakes can be found:

- *Arctic lakes* These lakes are usually oligotrophic and have long ice-cover period and low water temperature. Aquatic plant communities are not very rich in species, but the abundance of individual species of plants, phytoplankton and zooplankton may be high. The arctic ecosystems are sensitive and tender to any pollution load outside of the lake.
- *Prealpine lakes with great anthropogenic impact*. These lakes have a relatively small catchment area, are thermally stratified and have a relatively large groundwater inflow. Aquatic plant communities in the littoral zone are very much influenced by human activities, as changes in water level, shipping and sailing, discharging of nutrient loads etc. Bacterioplankton (blue-green algae) as well as phytoplankton, zooplankton, and zoobenthos communities are influenced by waste waters, and other human activities. Toxicants can damage fish communities.
- *Lakes on the plains with a large catchment*. Typical for these lakes is a large catchment area and remarkable fluctuations in water level. In deep lakes the thermal stratification is regular but is lacking in shallow lakes. The groundwater inflow is insignificant compared to surface water inflow. Aquatic plant communities in the shallow littoral zone have rapid growth due to nutrient loading from the catchment area, algal blooms can occur during warm summer days, high bioproduction of phyto- and zooplankton is usually in good correlation with high fish production.

Manmade lakes or reservoirs are more numerous than natural lakes in Europe. Most of them have multipurpose functions (flood protection, water supply, energy production etc) and are often the basic infrastructure for a particular catchment or a nation. Reservoirs are typically found in upper catchments but there are numerous large systems in the plains such as are the reservoirs on the Danube River in Hungary, Serbia and Romania. (Gapchikovo, Iron Gate I and Iron Gate II)

SELECTION OF QUALITY ELEMENTS FOR MONITORING OF LAKESAND RESEREVOIRS ACCORDING TO EU WATER FRAMEWORK DIRECTIVE (WFD)

EU Member States, Norway and the European Commission have jointly developed a common strategy for supporting the implementation of Directive 2000/60/EC establishing a framework for Community action in the field of water policy (the Water Framework Directive). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive. The focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

One of the main short-term objectives of the strategy is the development of non-legally binding and practical guidance documents on various technical issues of the Directive. These guidance documents are targeted to those experts who are directly or indirectly implementing the Water Framework Directive in river basins. The structure, presentation and terminology therefore are adapted to the needs of these experts and formal, legalistic language is avoided wherever possible.

The summary of the requirements of the WFD and the interpretation of the experts is expressed in the Fig. 2 (Figure 3.2 in final CIS Guidance on Monitoring (2003), page 47).

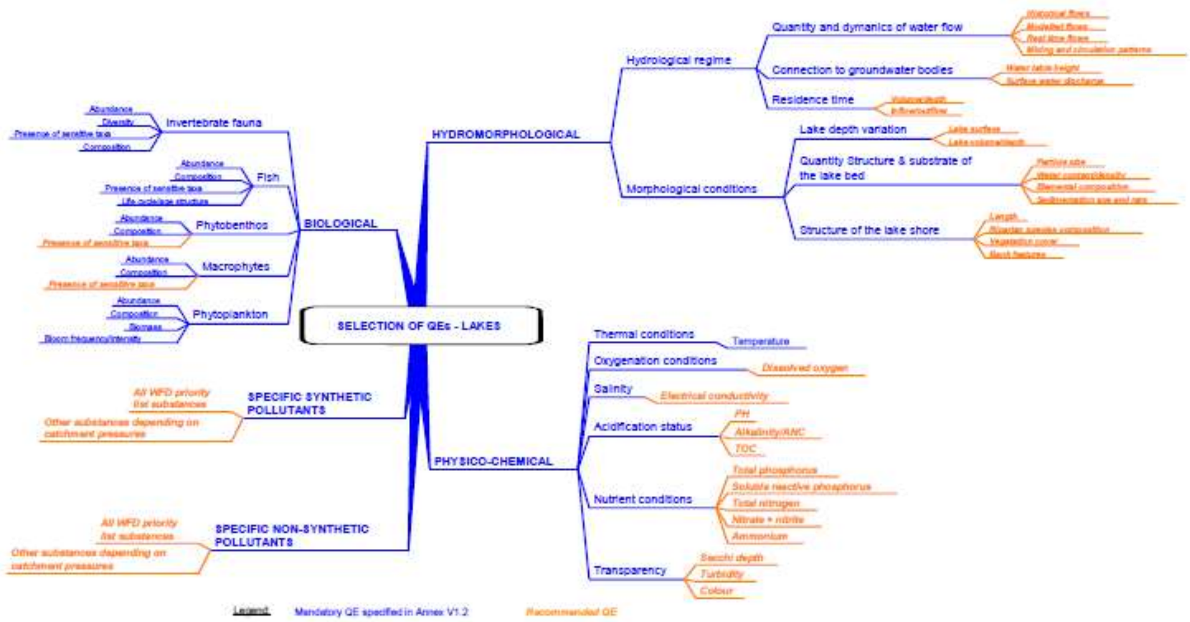


Figure 2. The mandatory Quality Elements specified in Annex V (1.2) of the EU Water Framework Directive (CIS Guidance on Monitoring 2003).

The Water Framework Directive introduced a system of water management through river basin management which allows us to use natural, geographic and hydrological boundaries to view systems as a whole rather than focusing on political or administrative borders. This allows us to observe processes at a level above national level and address problems in an all-encompassing and coordinated manner.

Chemical and physical analysis of sediments can be used as a tool for the monitoring of pollutant discharges to a river or lake system. In order to be able to make valid comparisons among stations or reference sites, consistent sampling techniques should be maintained. Sediments can be used to help locate non-point, historical, or intermittent discharges that may not be readily apparent using samples collected from the water column.

Despite regular sediment quality assessment by member states, a reliable estimation of the overall amount of contaminated sediment in Europe is hard to give. the main reason for this is the absence of uniformity in sampling methods, analytical techniques and applied sediment quality standards or guideline values. This causes a lack of inter-comparability. typically, countries along the same river basin use different methods.

The WFD does not focus specifically on sediment but seeing that sediments are a natural constituent of aquatic environments, the management of sediments, their quality and quantity has to play an important role in water legislation.

According to the data collected through means of questionnaires and review of relevant literature, it was noted that Germany, Slovakia, Serbia, Hungary and Slovenia had national laws and/or regulations dealing with sediment quality and/or quantity in inland waters whilst Bulgaria, Croatia, Bosnia and Herzegovina, Republika Srpska, Montenegro, Austria, Ukraine, Romania and Moldova do not.

None of the basin countries has specific guidelines and legislation for sediments in large lakes and reservoirs despite the significant contribution that sediments can make to the overall status of these aquatic systems.

A review of the specific situations in the project partner countries shows that most of the project partner countries have adopted some form of the ISO 5667-12 international standard which serves as Guidance on sampling of bottom sediments from rivers, lakes and estuarine areas. Whilst some countries have further devoleped or modified the guidelines given within this standard it is safe to say that this standard should serve as a baseline or starting point for further development of advanced guidelines on the methods used for bottom sediment sampling.

For the purpose of suspended sediment sampling, those countries where suspended sediment sampling is being conducted seem to have adopted the guidance and requirements of ISO 5667-17:2008 Water quality Sampling Part 17: Guidance on sampling of bulk suspended solids which in turn suggests that this document could serve as a baseline/starting point for further development of guidelines for the sampling of suspended sediments.

Whilst the sampling methodology between countries may vary the depth of primary sediment sampling is generally no more than 5cm.

Hydrological and morphological features

Morphological features

Several morphological characteristics have been developed to describe the shape of a lake/reservoir surface and bottom. Many of these parameters are important indicators for the ecological characteristics of lakes and reservoirs, and they are very central in lake/reservoir management as well. The basic morphological parameters include area, volume, length, breadth, depth, length of shoreline, hypsographic curve (depth area relation) and volume curve (depth-volume relation). Most of the above parameters can be further divided into groups of more detailed defined parameters.

It should be noted that most of the morphological parameters depend on the variability of the surface water level. Thus, the values of these parameters should include information on the reference water level.

The Water Framework Directive gives a number of so-called quality elements for the definition of the ecological status of surface waters. The following hydromorphological elements should be used for the assessment and classification of lakes and reservoirs:

- Hydrological regime:
    - Quantity and dynamics of water flow,
    - residence time and
    - connection to the groundwater body.
- Morphological conditions:
    - depth variation,
    - quantity, structure, substrate of the bed and
    - structure of the shore.

The hydrological regime elements are primarily related to the water balance.

Key features of hydromorphological quality elements according to the WFD Guidance on Monitoring

In the Guidance on Monitoring for the Water Framework Directive some systematically gathered and processed information of the different quality elements have been presented. In the Guidance the information on the key features of each hydromorphological quality element for lakes and reservoirs is presented in Table 1 (Table 3.5 in the final CIS Guidance on Monitoring (2003), pages 52-54).

The structure of this table (as of all the following corresponding tables) follows Annex V of the WFD by presenting in the same order all the quality elements, and by then discussing the following topics of all the elements:

- Measured parameters indicative of QE
- Pressure to which QE responds
- Sampling and methodology

- Standards
- Applicability of the QE to lakes
- Main advantages
- Main disadvantages
- Conclusions/recommendations.

Hydrological features

The hydrological cycle is the driving force that regulates the water resources of lakes/reservoirs. The hydrological cycle feeds the lakes and reservoirs, removes water from them and combined with climate and geology provides basic features for the variability of water resources. Extreme hydrometeorological events lead into floods and droughts.

Man has a great impact on water resources throughout the world. Changes in land use affect the hydrological cycle, and water is being used on a very large scale for irrigation and the needs of industry and communities. Reservoirs have been built, and the regulation of lakes and reservoirs plays a remarkable role in the water balance and behaviour of river systems.

The water balance equation of a lake is often given in the form (1):

In most of the natural European lakes and reservoirs, the surface flow components are the largest. If a lake has a large surface area, compared to its catchment, the precipitation and evaporation components are very important. In the dry, southern areas, the role of evaporation is remarkable. In some of the reservoirs, the change of water storage may be the largest component. The share of the subsurface flow components is often small.

The residence time is the combined consequence of its morphology and water balance. This parameter is very often used to describe the physical, chemical and biological characteristics of lakes and reservoirs. The theoretical residence time is the ratio of lake's volume and annual net inflow. The actual residence time can be considerably smaller, as only a limited part of the water mass may transmit the flow through the lake.

Table 1. Key features of each hydromorphological quality element for lakes.

Aspect/feature	Quantity and dynamics of water flow	Residence time	Connection to the groundwater body	Lake depth variation (water level variation)	Quantity, structure and substrate of lake bed	Structure of lake shore
Measured parameters indicative of QE	Inflow and outflow rates. Water level, spillway and bottom outlets discharges (reservoirs), mixing and circulation patterns	Volume, depth, inflow and outflow	Lake surface, lake volume	Lake surface, lake volume, lake depth	Grain size, water content, density, LOI, elemental composition, sedimentation rate, sediment age (Cs 137), microfossils in paleolimnological studies	Length, riparian vegetation cover, species present, bank features and composition
Pressures to which QE responds	Climate variability, flood control, manmade activities	Climate variability, man-made activities	Climate variability, man-made activities	Climate variability, siltation, water use, flow discharges	Siltation	Man-made modifications, erosion, run-off Water level fluctuations in reservoirs
Level and sources of variability of QE	Med. variability	Low but may vary under extreme climatic conditions	High variability	Generally low variability, high variability in reservoirs (epilimnetic / hypolimnetic discharges)	Highly variable, dependent on spread patterns and pollution by historical development	Variable
Sampling methodology	Water level gauge, flow meters, and current meters. In situ using scales or submersible probes associated or not to tele transmission	Echo sounding necessary for depth-volume curves, hypsographic curves	Depth-volume curves, hypsographic curves. Water level gauge.	Sonar device (echosounder), bathometer, Transect methodology with metered sounding poles	Core and grab samplers depending on study objectives 3 main sampling types may be distinguished: deterministic, stochastic and regular grid systems	Transects, aerial photography, planimetry
Typical sampling frequency	Weekly/monthly. Hourly/daily (reservoirs)	Every 5/ 10 years or less frequently if no changes are suspected. Once per year for reservoirs.	Variable	Natural lakes: every 15 yrs. Reservoirs: variable	Mostly once a year, or less frequently if no changes expected (reference conditions), in polluted lakes every 3rd to 5th year	Every 6 years
Time of year of sampling	All seasons	All seasons, not during ice cover	All seasons	Reservoirs: generally during operational functioning, spring/ begin fall	Usually winter (from ice in Nordic countries)/ summer	Varied. Spring/summer during growing period
Typical "sample" size or survey area	Inflowing/outflowing waters; gauging stations	Entire lake	Entire lake	Entire lake	Varied depending on study objective	Entire lake shore habitat
Ease of sampling /Measurements	Simple following minimal practical training	Easy for theoretical residence time estimation Difficult for the evaluation of effective residence time	Difficult	Relatively easy following minimal training	Relatively easy following minimal practical training	
Basis of any comparison of results/quality/stations e.g., reference conditions/best quality	Historical data	Historical data	Historical data	Historical data	Paleolimnology/ sediment core studies	Historical data
Methodology consistent across EU?	Yes, according to other countries practices	No	No	No	No	No

Aspect/feature	Quantity and dynamics of water flow	Residence time	Connection to the groundwater body	Lake depth variation (water level variation)	Quantity, structure and substrate of lakebed	Structure of lake shore
Current use in monitoring programmes or for classification in EU	No/yes (reservoirs)	No	No	No, France, UK, Spain	No	No
Existing monitoring systems meet requirements of WFD?	No	No	No	No	No	No
Existing classification systems meet requirements of WFD?	No	No	No	No	No	No
ISO/CEN standards	Yes, refer to ISO/TC 113, CEN/TC 318	No	No	No	No	No
Applicability to lakes	High	High	High	High	High	High
Main Advantages	• Hydrological measurements are essential for the interpretation of water quality data and for water resource management	• Lake hydrology forms the basis for water quality assessment. • Water residence time influences nutrient retention and development of anoxia in deep, stratified water bodies	• Lake hydrology forms the basis for water quality assessment.	• Water level fluctuation has a direct impact on littoral aquatic life • Lake basin morphology influences lake hydrodynamics and sensitivity to nutrient loading	• Can be regarded as environmental tachometers. The paleolimnological study is often the only tool to gather knowledge of past reference conditions. • The contaminants accumulate often in sediments, the contents are high and the sampling frequency may be quite low.	• Indicators in protection of biological integrity
Main disadvantages	Time consuming and costly	Time consuming and costly	Time consuming and costly	Accurate Hydrographic maps of lakes are rarely available in sufficient detail for ecological analysis even if bathymetric maps are available their accuracy should be checked carefully *	Paleolimnological examinations are often relatively expensive and the result depends on the undisturbed state of the sedimental archive. The preservation of microfossils may vary.	Methodology needs to be developed to incorporate requirements of the WFD
Conclusions/ recommendations	Important for calculating mass balances etc. A basic element for use with other relevant parameters	Important for characterising and assessing lake quality data.	Only relevant where groundwater constitutes a major part of the lake water balance. Methodology needs further development	Only relevant where it is of ecological significance Important consideration in the design of monitoring programmes Very important in reservoirs As supporting elements, the measurement of depth over time and space are both important. Thus, recommended that both are used.	Not generally used in monitoring programmes Exchange processes between sediment and water are important in determining the quality of many lakes.	Necessary for interpretation of biological parameters (e.g., macrophytes, some fish species) especially for shallow lakes or lakes with an extensive shallow littoral zone.

Estimation of pressures

In planning monitoring programmes for a lake/reservoir and especially in the assessment of monitoring data, information on the total pressures to the lake is absolutely necessary. The most important data are usually the reliable statistics of wastewater discharges. Also, the WFD (Article 5) requires that the review of the environmental impact of human activity and economic analysis of water use will be carried out in the river basin district. Each Member State shall ensure that for each river basin district or for the portion of an international river basin district falling within its territory, the following estimations are performed:

- An analysis of its characteristics and
- a review of the impact of human activity on the status of surface waters and on groundwater.

Member States shall collect and maintain information on the type and magnitude of the significant anthropogenic pressures, to which the surface water bodies in each river basin district are liable to be subjected to. In many cases the wastewater load discharged direct to the lake forms the most significant part of total loading. However, in increasing cases also other anthropogenic activities have a negative effect on watercourses and their biota.

Especially nonpoint loading from several different sources, such as agriculture and forestry has increased, and even caused bad pollution situations, especially seen in a serious increase of eutrophication. Also, land use has altered the natural status of many water bodies, and made e.g., the usability of water courses significantly worse.

A relatively new phenomenon is so called internal loading in dimictic lakes. There are two main reasons, which are causing internal loading:

- Bottom sediments which have earlier badly deteriorated due to discharges of insufficiently purified waste waters, and which now in the purification processes transfer for a surprising long duration extra nutrient reserves from the sediment to water.
- Excessively dense fish stocks, developed during the increasing eutrophication of lakes, which usually comprise of small roach, bream etc. These fish are commonly bottom feeding and return sedimentated nutrients, especially phosphorus, back to the epilimnetic water mass in mineral form ready to be used by primary production.

Checking the pressures according to the WFD Guidance on Pressures and Impacts

Before the start of planning of a monitoring programme for a lake, you require amongst other things information on all the pressures. In performing this, it is advisable to use separate checking lists to ensure that e.g., all relevant polluters have been detected. As a highly useful example, the corresponding list from the CIS Guidance for the analysis of the Pressures and Impacts (2002) is presented in the Table 2 (Table 4.2 in the final CIS Guidance for the analysis of Pressures and Impacts (2002), pages 55-57).

Table 2. General checklist of pressures to be considered.

	Source within the source type
DIFFUSE SOURCE	
Urban drainage (including runoff)	industrial/commercial estates
	urban areas (including sewer networks)
	airports
	trunk roads
	railway tracks and facilities
	harbours
Agriculture diffuse	arable, improved grassland, mixed farming
	crops with intensive nutrient or pesticide usage or long bare soil periods (e.g., corn, potato, sugar beets, vine, hops, fruits, vegetables)
	over grazing – leading to erosion
	horticulture, including greenhouses
	application of agricultural waste to land
Forestry	peat mining
	planting/ground preparation
	felling
	pesticide applications
	fertilizer applications
	drainage
	oil pollution
Other diffuse	sewage sludge recycling to land
	atmospheric deposition
	dredge spoil disposal into surface waters
	shipping/navigation
POINT SOURCE	
Wastewater	municipal wastewater, primarily domestic
	municipal wastewater with a major industrial component
	storm water and emergency overflows
	private wastewater primarily domestic
	private wastewater with a major industrial component
	harbours
Industry	gas/petrol
	chemicals (organic and inorganic)
	pulp, paper & board
	woollens/textiles
	iron and steel
	food processing
	brewing/distilling
	electronics and other chlorinated solvent users
	wood yards/timber treatment
	construction
	power generation
	leather tanning
	shipyards
	other manufacturing processes
Mining	active deep mine
	active open cast coal site/quarry
	gas and oil exploration and production
	peat extraction
	abandoned coal (and other) mines
	abandoned coal (and other) mine spoil heaps (bings)
	tailings dams
Contaminated land	old landfill sites
	urban industrial site (organic and inorganic)
	rural sites

	Source within the source type
	military sites
Agriculture point	slurry
	silage and other feeds
	sheep dip use and disposal
	manure depots
	farm chemicals
	agricultural fuel oils
	agricultural industries
Waste management	operating landfill site
	operating waste transfer stations, scrap yards etc.
	application of non-agricultural waste to land
Aquaculture	land based fish farming / watercress / aquaculture
	marine cage fish farming
Manufacture, use and emissions from all industrial/agricultural sectors	priority substances
	priority hazardous substances
	other relevant substances
ABSTRACTION	
Reduction in flow	abstractions for agriculture
	abstractions for potable supply
	abstractions by industry
	abstractions by fish farms
	abstractions by hydro-energy
	abstractions by quarries/open cast coal sites
	abstractions for navigation (e.g., supplying canals)
ARTIFICIAL RECHARGE	
	groundwater recharge
MORPHOLOGICAL	
Flow regulation	hydroelectric dams
	water supply reservoirs
	flood defence dams
	diversions
	weirs
River management	physical alteration of channel
	engineering activities
	agricultural enhancement
	fisheries enhancement
	land infrastructure (road/bridge construction)
	dredging
Transitional and coastal management	estuarine/coastal dredging
	marine constructions, shipyards and harbours
	land reclamation and polders
	coastal sand suppletion (safety)
Other morphological	barriers
OTHER ANTHROPOGENIC	
	litter/fly tipping
	sludge disposal to sea (historic)
	mine adits/tunnels affecting groundwater flows
	exploitation/removal of other animals/plants
	recreation
	fishing/angling
	introduced species
	introduced diseases
	climate change
	land drainage

In the same Guidance also certain criteria for different types of pressures have been presented.

Non-point loading

The estimation of non-point loading to a water body is not that easy, because so many different factors affect quantity and temporal variations. Generally, we can assume that the most important factors are of hydrological character. However, the following sub-areas of different activities, which may cause significant increase in non-point loading should be clarified:

- An estimation and identification of significant diffuse source pollution from urban, industrial, agricultural and other installations and activities.
- An estimation and identification of significant water abstraction for urban, industrial, agricultural and other uses, including seasonal variations and total annual demand and loss of water in distribution systems.
- An estimation and identification of the impact of significant water flow regulation, including water transfer and diversion, on overall flow characteristics and water balances.
- Identification of significant morphological alterations to water bodies.
- An estimation and identification of other significant anthropogenic impacts on the status of surface waters.
- An estimation of land use patterns, including identification of the main urban, industrial and agricultural areas and, where relevant, fisheries and forests.

In the WFD especially in Article 10 (The combined approach for point and diffuse sources) points out the importance of non-point loading. The significance of non-point loading from various sources as very important eutrophication factor has been accepted also in other international agreements.

Internal loading

In many cases it has happened that despite totally stopping wastewater discharge to a lake the improvement of the ecological status of the lake/reservoir has been extremely slow. There are two main reasons, which cause internal loading:

- The re-mobilization of phosphorus and other elements from badly deteriorated bottom sediments under anaerobic conditions into the near bottom layer of the lake.
- Excessive fish stocks, which have developed during the increasing eutrophication of lakes, usually comprised up of small roach, bream etc.

The estimation of internal loading requires special investigations in the lake/reservoir concerned. The differences in loadings are so great between different lakes/reservoirs that no general guidelines for estimation can be given. Usually, the most important variables to be investigated are phosphorus and nitrogen.

MONITORING PROGRAMMES, SAMPLING SITES AND FREQUENCY OF SAMPLING

The material presented in this section has been prepared on the basis of the UNIECE Working Group on Monitoring and Assessment report entitled "Guidelines on Monitoring and Assessment of Transboundary and International Lakes published by UNIECE Working Group on Monitoring and Assessment in 2003 with appropriate modifications by the authors of this report.

We particularly note that monitoring of sediment quality contributes to overall monitoring within the river basin and is a tool used to develop appropriate management strategies and program of measures for a particular river basin. In view of this it can not be viewed as an activity which is outside of the other monitoring activities.

In principle, sediment monitoring should be aligned with the other monitoring activities in the river basin. This applies to the monitoring program, sampling site selection, monitoring frequencies and similar as well as the objectives of the monitoring program.

In the context of transnational monitoring activities this requiers also the alligment of monitoring programs between contries.

In view of the above what follows in the rest of this section applies to both sediment and water monitoring programs, sites and frequencies.

MONITORING PROGRAMMES

The very first phase in implementing monitoring is the planning of the monitoring programme itself. There are numerous possibilities in outlining the object of the programme. Sometimes the objective is only one separate part, e.g. one lake/reservoir in some water course. Besides this, in local monitoring there are also different types of regional monitoring programmes. Also many countries have their own national monitoring programmes.

The Water Framework Directive, WFD (2000/60/EC) divides the monitoring activity in the following three principally different parts:

- Surveillance monitoring.
- Operational monitoring.
- Investigative monitoring.

Surveillance monitoring programmes are designed to provide information on the water body concerned for:

- Supplementing and validating the impact assessment.
- The efficient and effective design of future monitoring programmes.
- The assessment of long-term changes in natural conditions.
- The assessment of long-term changes resulting from widespread anthropogenic activity.

The results of such monitoring shall be reviewed and used in combination with the impact assessment procedure, to determine requirements for monitoring programmes in current and subsequent river basin management plans. The implementation of this phase of monitoring belongs to the responsibilities of the water authority.

Operational monitoring shall be undertaken in order to:

- Establish the status of relevant bodies identified as being at risk of failing to meet their environmental objectives.
- Assess any changes in the status of such bodies resulting from the programmes of measures.

The programme may be amended during the period of a river basin management plan in light of information obtained as part of the requirements of Annex II (of WFD) or as part of this Annex. In particular, to allow a reduction in frequency where an impact is found as insignificant or the relevant pressure is removed. The implementation of this part of monitoring belongs to the responsibilities of the polluters.

Investigative monitoring shall be carried out:

- Where the reason for any exceedances is unknown.
- Where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives.
- Or to ascertain the magnitude and impacts of accidental pollution, and to inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution.

SAMPLING SITES

The main hydrological and hydrometeorological characteristics, such as precipitation, snow cover, water level, river flow, sediment discharges (suspended sediment, bed load, bottom sediments), evaporation and evapotranspiration, soil moisture, temperature and data on ice conditions, should be measured and estimated as an important part of any monitoring programme of a lake/reservoir.

The selection of monitoring sites for the management of a transboundary river basin should be governed by the purpose for which the data or records are collected and by the accessibility of the site. In general, a sufficient number of stations should be located within the system.

Hydraulic conditions are an important factor in site selection on streams, particularly where water levels are used to compute discharge records via water level relationships (rating curves). Unambiguous relationships are found at stations that are located at streams with natural regimes, not affected by variable backwater at the gauge, caused by downstream tributaries or reservoir operations or by tidal effects.

Systematic water level recordings, supplemented by more frequent readings during floods, are required for most streams. The installation of water level recorders is essential for streams where the level is subject to abrupt fluctuations. Continuous river flow records are necessary in the design of water-supply systems, and in estimating the sediment or chemical loads of streams, including pollutants.

Factors to be considered in scheduling the number and distribution of discharge measurements within the year include:

- The stability of the stage-discharge relationship; seasonal discharge characteristics and variability.
- Accessibility of the gauge in various seasons.

Member States shall ensure the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of the water status within each river basin district.

For surface waters such programmes shall cover:

- The volume, level or rate of flow to the extent relevant for ecological and chemical status and ecological potential, and
- the ecological and chemical status, as well as ecological potential.
- These programmes shall be operational, at the latest, six years after the date of entry into force of this Directive (December 2006).

Detailed requirements of the monitoring programmes are presented in Annex V.

The surface water and sediment monitoring networkto support evaluation of ecological status and chemical status shall be established in accordance with the requirements of Article 8 (as above). The monitoring network shall be designed so as to provide a coherent and comprehensive overview of ecological and chemical status within each river basin and shall permit classification of water bodies into five classes. Member States shall provide a map or maps showing the surface water and sediment monitoring network in the river basin management plan.

The sampling procedure used in lake/reservoir monitoring differs from that of rivers. As a rule, the state of lakes/reservoirs is more stable than that of rivers. The selection of sampling sites is the very first step in fulfilling the monitoring programmes.

Surveillance monitoring shall be carried out of sufficient surface water bodies to provide an assessment of the overall surface water status within each catchment or subcatchments within the river basin district. In selecting these bodies Member States shall ensure that where appropriate, monitoring is carried out at points where:

- The rate of water flow is significant within the river basin district as a whole; including points on large rivers where the catchment area is greater than 2500 km^2.
- The volume of water present is significant within the river basin district, including large lakes and reservoirs.
- Significant bodies of water cross a Member State boundary.
- Sites are identified under the Information Exchange Decision 77/795/EEC.
- At other sites as is required to estimate the pollutant load which is transferred across Member State boundaries, which is transferred into the marine environment.

Operational monitoring shall be carried out for all those bodies of water which on the basis of either the impact assessment carried out in accordance with Annex II or surveillance monitoring is identified as being at risk of failing to meet their environmental objectives under Article 4, and for those bodies of water into which priority list substances are discharged. Monitoring points shall be selected for priority list substances as specified in the legislation laying down the relevant environmental quality standard.

In all other cases, including for priority list substances, where no specific guidance is provided in such legislation, monitoring points shall be selected as follows:

- For bodies at risk from significant point source pressures, a sufficient amount of monitoring points within each body in order to assess the magnitude and impact of the point source. Where a body is subject to a number of point source pressures monitoring points may be selected to assess the magnitude and impact of these pressures as a whole.
- For bodies at risk from significant diffuse source pressures, a sufficient amount of monitoring points within a selection of the bodies in order to assess the magnitude and impact of the diffuse source pressures. The selection of bodies shall be created so that they accurately represent the relative risks of the occurrence of the diffuse source pressures, and of the relative risks of failure to achieve a good surface water status.
- For bodies at risk from significant hydromorphological pressure, a sufficient amount of monitoring points within a selection of the bodies in order to assess the magnitude and impact of the hydromorphological pressures. The selection of bodies shall be indicative of the overall impact of the hydromorphological pressure to which all the bodies are subject to.

An example of sampling site placement in different lake/reservoir types is presented in Fig. 3.

Investigative monitoring shall be carried out:

- Where the reason for any exceedances is unknown.
- Where surveillance monitoring indicates that the objectives set out in Article 4, for a body of water, are unlikely to be achieved, and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives.
- To ascertain the magnitude and impacts of accidental pollution, and to inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures required to remedy the effects of accidental pollution.

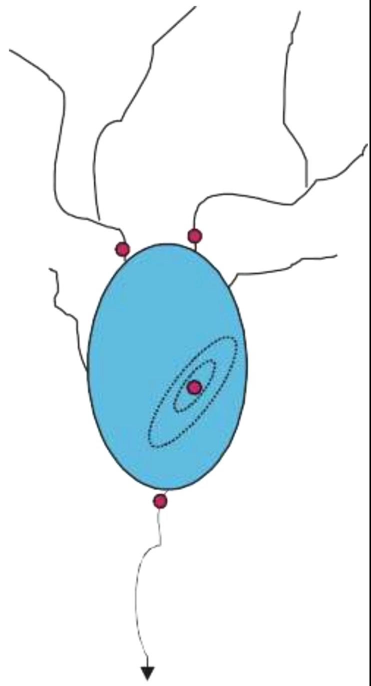
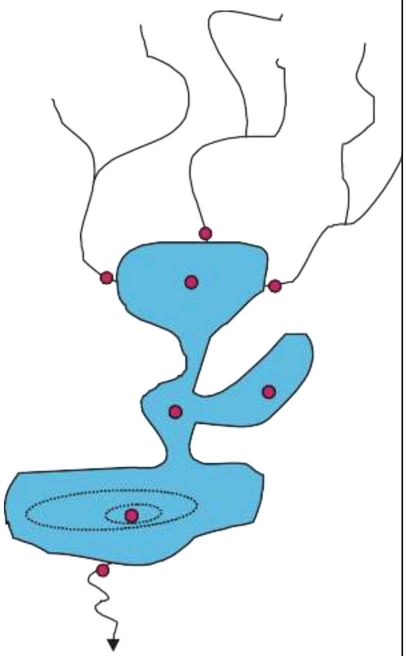
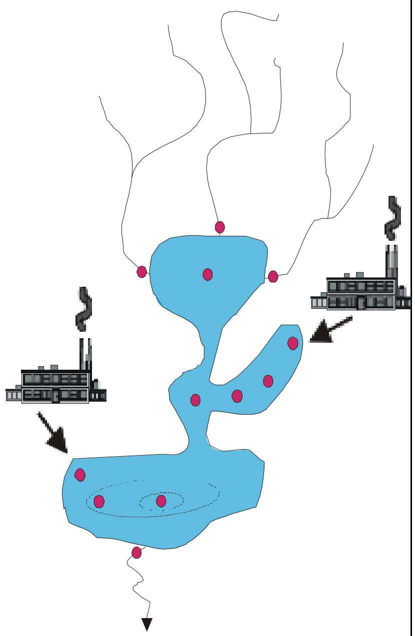
 Almost no pollution One monitoring site in the deepest part of the lake One monitoring site at the mouth of each major inflowing river and at the upper reaches of the outflowing river	 Almost no pollution One monitoring site in the deepest point of each part of the lake One monitoring site at the mouth of each major inflowing river and at the outlet of the lake	 Polluted by point-source loading One monitoring site in the deepest point of each part of the lake Spatially and temporally frequent monitoring in the most polluted subareas of the lake One monitoring site at the mouth of each major inflowing river and at the outlet of the lake

Figure 3. Examples of monitoring site placement in different types of lakes.

In stratified lakes/reservoir water samples should be taken always vertically from varying depths and bottom and suspended sediments should be taken at the same location. Even in natural lakes there can be significant differences in water and sediment quality between the epilimnion and hypolimnion during the stratification period. Especially the oxygen content of hypolimnion can indicate the first signs of pollution at the end of the stratification period, especially where the lakes have ice coverage for a longer period.

Biological phenomena is also different in epilimnion and hypolimnion during stratification. Primary production with higher density of algae and significant diurnal variations in e.g. oxygen concentrations and pH, is the dominating phenomenon in epilimnion. In hypolimnion the bacterial decomposing processes are a dominating role, resulting in lower oxygen concentrations and in a very polluted situation even total anoxic condition.

In all cases it is required to take samples from certain levels, which can be used in all lakes to improve the possibility of comparisons with different lakes. These depths are one meter and one meter above the bottom in the deepest part of the lake. Also, the depth of five meters is quite often used in deeper lakes as a permanent sampling layer due to a more stable quality compared to just below the surface at a depth of one meter.

Other sampling depths should be determined according to thermal stratification so that information on the deeper part of epilimnion, as well as the upper part of hypolimnion, can be obtained. In deeper lakes the vertical set of samples in many cases consists of more than 10 sampling depths. In monitoring programmes with data collected over a longer period, the monitoring depths can be limited to the most informative (and stable) layers.

FREQUENCY OF SAMPLING

The frequency of sampling shall be solved as a compromise between ecological needs and economic possibilities. In routine monitoring of a lake/reservoir, the samples will usually be taken several times during one year. The most important seasons are when the water is stratified. The most important monitoring period is the summer stratification time. The primary production processes are at then at their highest, and also the decomposition of organic matter is most active. Especially in eutrophic or polluted lakes several samplings should be organized during the summer period.

The WFD has also provides some general guidance on surveillance monitoring. Frequencies for monitoring variables indicative of physico-chemical quality elements would be justified on the basis of technical knowledge and expert judgement. For biological or hydro morphological quality elements, monitoring shall be performed out at least once during the surveillance monitoring period, i.e. six years.

For operational monitoring, the frequency of monitoring required for any parameter shall be determined by Member States so as to provide sufficient data for a reliable assessment of the status of the relevant quality element.

Frequencies shall be chosen so as to achieve an acceptable level of confidence and precision. Estimates of confidence and precision attained by the monitoring system used shall be stated in the river basin management plan.

Monitoring frequencies are to be selected which take account of the variability in parameters resulting from both natural and anthropogenic conditions. The times at which monitoring is undertaken shall be selected so as to minimize the impact of seasonal variation on the results, and thus ensure that the results reflect changes in the water body as a result of changes due to anthropogenic pressure. Additional monitoring during different seasons of the same year shall be performed, where necessary, to achieve this objective.

Lakes/reservoirs exhibit a wide range of hydrologic characteristics, from very fast-flushing drainage lakes to seepage lakes with a long residence time. Sampling frequency should be designed to characterize well the annual variability of the lakes/reservoirs. Monthly samples are recommended for most fast-flushing lakes/reservoirs; more frequent sampling may be required occasionally in lakes/reservoirs that undergo short-lived acidic episodes or nitrate peaks. Also, where flow data are available for calculations of yearly transport values of elements from catchments, increased sampling frequency in flood periods is recommended (Mannio 2000).

Quarterly or seasonal sampling is likely to be adequate in lakes/reservoirs with long residence times. In remote areas where frequent sampling is impossible for practical and economic reasons, even one sample per year may be useful for long-term monitoring. Such samples must be taken at the same time of the year each year, usually at the end of summer stratification, but in case of monitoring the acidification trend, preferably shortly after fall overturns (Mannio 2000).

Surveillance monitoring of the WFD shall be performed for each monitoring site for a period of one year during the period covered by a river basin management plan for:

- Variables indicative of all biological quality elements.
- Variables indicative of all hydromorphological quality elements.
- Variables indicative of all general physico-chemical quality elements.
- Priority list pollutants which are discharged into the river basin or sub-basin.
- Other pollutants discharged in significant quantities in the river basin or sub-basin, unless the previous surveillance monitoring exercise showed that the body concerned reached a good status, and there is no evidence from the review of impact of human activity in Annex II that the impacts on the body have changed. In

these cases, surveillance monitoring shall be carried out once every three river basin management plans.

Sediment monitoring specific issues

Sediment as a sink and source of elements

Bottom sediments consist of particles of different size, shape and chemical composition that have been transported mainly by water from the sites of their origin in a terrestrial environment, and they have been deposited on the lake floor. In addition, bottom sediments contain material precipitated from chemical and biological processes in water. Bottom sediments are a sink as well as a source of con taminants in an aquatic environment.

Particles transported in the water become sorted and deposited and re-suspended according to their textural properties in different areas of the lakes. The areas of erosion are characterised by coarse and consolidated deposits. The deposits within the areas of accumulation in the deeper parts of the lake/reservoir are fine and loose with a high organic content and it is here that possible high nutrient and toxic element contents are to be found. In areas of higher hydrodynamic energy, coarser sediments of natural origin and low contaminant content may dilute these substances. The sedimentation rate depends on the location.

Limnological monitoring data are required to make effective environmental decisions. But such observation series are rarely available and they are often somehow limited. However, paleolimnological techniques can provide proxy data of past environmental changes and provide a good foundation for monitoring work. Lakes/reservoirs are continuously depositing sediments, which incorporate fossil remains of organisms that lived in the lake/reservoir. If the sediments are not disturbed, then sedimentary sequences can be dated and the information preserved in the sedimentary profiles represent "archives" of the history of the lake/reservoir.

One can use the testimony of the sediments to establish factors that caused the change, to verify the change in the state of a lake/reservoir, to determine the "natural" state and to weight the influence of man. A considerable archive of information is also contained in the physical and chemical sedimentary record, often providing information on the coupling of catchment and aquatic processes. (Figures 5, 6)

Figure 5. A sediment sample taken with a gravity corer. In this case different layers can be detected easily (Photo Seppo Knuuttila).

Figure 6. A sediment sample taken with a gravity corer. (Photos Marko Marjanović).

In monitoring programmes there are many benefits to focus on the concentrations of micro pollutants in bottom sediments instead of water. These sediments incorporate water pollution over a number of years and are therefore better suited for monitoring than water itself. Most contaminants (metals, pesticides, hydrocarbons) show high affinity to particulate matter and, consequently, are enriched in bottom sediments.

Planning

Especially concerning physical and chemical parameters the correct right timing of sampling is sometimes important and the oxygen state / redox potential of the bottom near water affects the movements of phosphorus. Knowing the status of bottom near water is important; especially oxygen and phosphorus should be analysed.

When defining the positions and number of sediment sampling sites, the following factors should be considered:

- Required accuracy,
- available information,
- bottom dynamics at the sampling area,
- size of sampling area and
- available funds vs. estimated (real) monitoring costs.

The sedimentation rate in lake sediments is mostly low and the thickest sediment beds are concentrated in the deeper parts of lakes. The sedimentation rate fluctuates from parts of a millimetre to several millimetres per year. To correctly select the location of sediment sampling stations in studies of sediment contamination, it is necessary to obtain information on the type of sediments, particularly on the location of fine-grained sediments and their extent at the study area.

Generally, two methods are available to obtain such information. The first is an acoustic survey of the bottom, with a low frequency (50 MHz), of the water body to be sampled and the second is limited scale sediment sampling at selected locations. Preliminary information obtained by one or a combination of both methods will provide guidance in the design of appropriate selection of sediment sampling stations in the final sampling program. Later locating the exact same sampling position is important. One should use GPS preferably DGPS as the sedimentation rate and the quality of sediment may fluctuate. Accuracy should be preferably down to only a few metres.

Sampling

The used sampler should be chosen according to the monitored sediment. Many samples are collected with bed grabbers, although this type of equipment is mostly not recommended, as they do not provide undisturbed samples and the finer topmost sediment layer may be lost. The most common tube sampler is the so-called gravity corer. It is simply a tube with weights and a valve. This corer is suitable for sampling soft, fine-grained sediments. It is lowered into the bottom and, after the valve is closed, it is raised. The valve part and weights are then moved and the monolith can be pushed out with a piston and parted to subsamples.

Sediment samples should generally be kept in glass, polythene, polypropylene or polycarbonate containers, transported and stored cool. Depending on analysis, deep-freezing is recommended whilst paying attention to the physico-chemical changes that can affect e.g., microfossils and colloids when freezing.

Variables

Dating.

To obtain the sedimentation rate one has to date the sediment. The 210Pb method is a much-used tool for dating layers accumulated during the last 150 years. 137Cs was first introduced into the atmosphere in the early 1950s during testing of nuclear weapons and reached then its maximum input in 1963. Then the Chernobyl accident in the year 1986 created a new peak in sediment. Fly-ash particles comprise two particle types, spheroidal carbonaceous particles and inorganic ash spheres. In sediments, these particles form an unambiguous record of atmospheric pollutants.

The best scenario is when sediments are yearly laminated as trees, as one can then study the events with a high degree of accuracy. Dating is the backbone of paleolimnological studies, but on some occasions the amount of sediment matter has, also, to be monitored. Often accurate dating of some sediment profiles provides good knowledge of the future sedimentation rate.

Metals and toxic compounds.

The coarse components that normally have low levels of heavy metals and organic pollutants produce a downward shift of the concentration in the total sample. Normalisation is defined as a procedure to compensate the influence of natural processes on the measured variability of the concentration of contaminants in sediments. It is essential to normalise the effects of grain size in order to provide a basis of meaningful comparisons of the occurrence of the substances in sediments of various granulometry and texture within individual areas or among areas. Excess levels, above normalised background values, could then be used to establish sediment quality.

There are various approaches used for the normalisation of trace elements. The most used is purely physical characterising the sediment by measuring its content of fine material. Another approach is chemical in nature and based on the fact that a small size fraction is usually rich in clay materials, iron and manganese oxyhydroxides and organic matter.

In soft lake sediments, from the depths of the lake, the texture is always very fine and one can overlook the grain size effect. When monitoring great lakes in sites with transportation bottoms with occasionally high hydrodynamic forces, at least the amount of material under 63 µm should be determined. However, sieving the sample at 63 µm is often not sufficient, especially when sediments are predominantly fine grained. In such cases, it is better to normalise with lower size thresholds, since the contaminants are mainly concentrated in the fraction lower than 20 µm.

Organic matter.

Carbon is present in large quantities in lake sediments, which in fact constitute one of the rare permanent sinks in the global carbon cycle. Organic carbon stored in such sediment's comprises of both allochthonous material transported into the lake from the drainage basin and autochthonous carbon derived from biomass produced in the lake itself. Decomposing organic matter affects the oxygen status and may cause azoxies which in turn lead to the escape of phosphorus and some metals in the water phase. The other effective factor is pH. These parameters can be quickly measured. The halved loss-on-ignition value gives an economic approximation of organic carbon. Sediment nitrogen is in correlation with organic matter, but the C/N ratio is used in obtaining knowledge of the parts of material of allochtonic and autochtonic origin.

Sediment phosphorus.

Sediment total phosphorus values are used to provide a picture of the changes. Organic surface sediments usually have a water content of 95-99% in freshwater ecosystems. Only a minor part is bound to solid chemical substances. A major part of water content constitutes the mobile liquid medium, which surrounds the sediment particles. This mobile water fraction is named interstitial water or pore water and is a highly important transition medium for the movement of solute species across the sediment-water interface. The extraction methods are mostly based on filtration, but semipermeable membranes or centrifugation may also be used. Sediment samples readily take oxygen although nitrogen gas is preferably to be used. To obtain a get more precise knowledge of the forms of phosphorus there are fractionation methods available (Al-bound, Fe-bound, Ca-bound P).

The assessment and presentation of the monitoring results

The use of monitoring results

The monitoring results have to be handled and assessed with a certain procedure designed simultaneously with the planning of the monitoring programme. Handling and assessment of data and finally, reporting to all parties involved, are essential parts of the monitoring cycle (Fig. 7).

The monitoring cycle starts always with the evaluation of the data needs for sustainable solutions in water protection and management. The requirements are then described with different characteristics, which are taken into the monitoring programme. The programme will be implemented during a longer period (at present often three years, or in the future six years according to the EU WFD) without any alterations in sampling procedure (same sites, same dates, same depths, and same methodology).

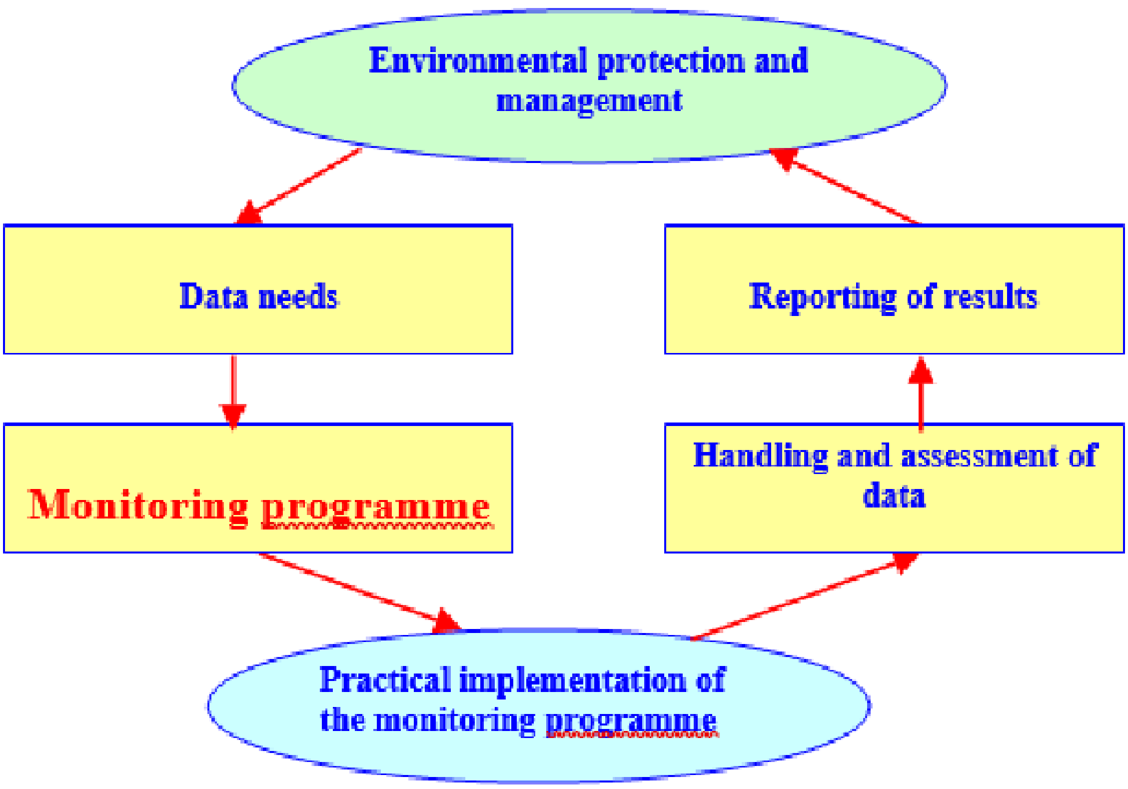


Figure 7. The monitoring cycle.

After the sampling and observations have been fulfilled, and the final results have been completed by the relevant laboratory, the handling of data can commence. The steps after the sampling and analyses are described to a general level in Fig. 8.

The very first step is to check the results, how they fit to the corresponding levels and ranges of the characteristics of the lake concerned. For instance, if you have phosphorus results from a very oligotrophic lake, you will wait for the phosphorus levels to be some 5 to 10 μg/L only. However, if the concentration is greater, e.g. 25 μg/L, you have to check for inaccuracies first from the field documents and then from the corresponding laboratory.

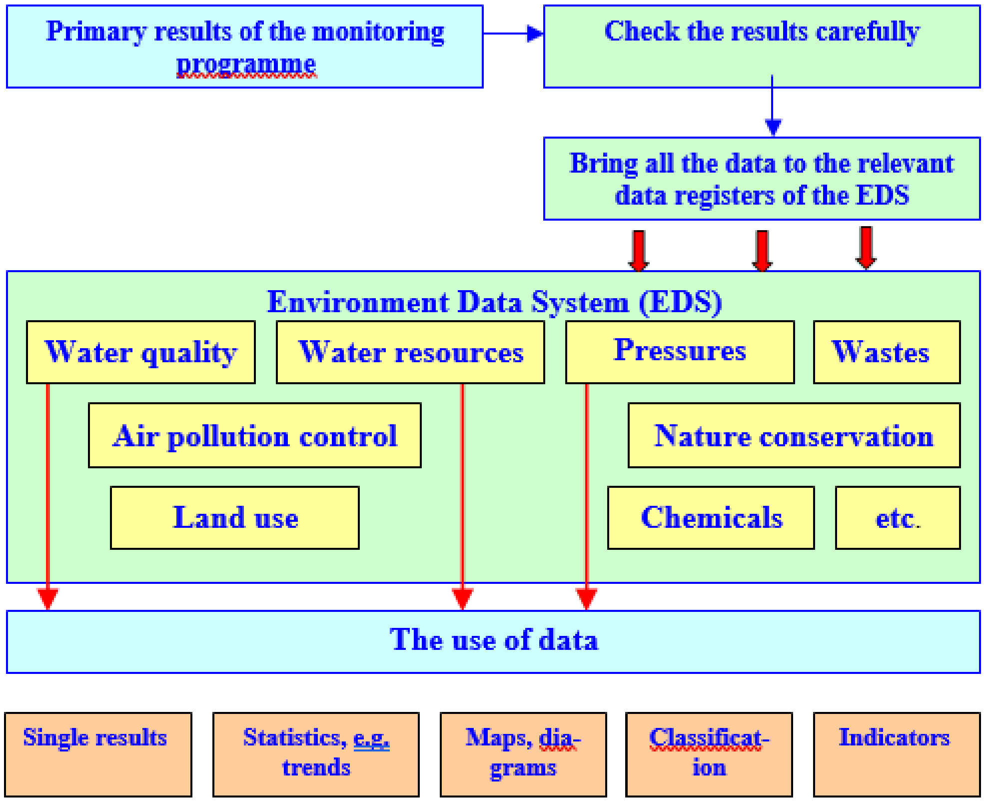


Figure 8. Flow chart of the use of the monitoring data.

You can commence data processing only when you have made all the checks. If the results seem doubtful, they must be considered inaccurate, and you must organise new sampling in order to obtain more reliable data as soon as possible.

Statistical methods

In monitoring programmes, where usually large amounts of different data are collected continuously over several years, you also, in every case, require statistical methods to effectively summarize and manage the data. You have to calculate averages and look at annual variations etc. In most cases you need, however, to use more sophisticated statistical methods to obtain all the possible information from monitoring data. With statistical methods you can also determine the necessary frequencies of sampling.

The attribute of monitoring data should be that the usability of single results is constantly improving when the series are becoming longer and longer. The natural variations in many characteristics can then be understood better on the basis of corresponding results from the reference stations and the important anthropogenic effect, the real main object of the environmental monitoring, can be differentiated more reliably.

There are some important objectives in environmental monitoring, where statistical methods are without doubt required. The first objective is to analyse the appearance of trends. To analyse long term site-specific trends in water quality, the nonparametric Seasonal Kendall test, SKT has become as a standard. It can accept the non-normality of data, missing and censored data and seasonality that are very common in all environmental monitoring data. In a statistical sense, it is a powerful trend test (Minkkinen 2000). The SKT limitation is that it detects only monotonic trends. They need not be linear but must proceed in one direction only (decreasing or increasing).

The other objective is to compare, in a more detailed way, two different areas of a lake. Usually, you are trying to solve the basic question of water protection, if one part of lake is polluted/eutrophied or not, then you have to compare the results of this suspected area (by using relevant characteristics e.g. total phosphorus, phytoplankton biomass etc) with the reference area. For this purpose, Analysis of variance (ANOVA) will be one suitable solution.

This method performs comparisons such as the t-Test, but for an arbitrary number of factors. Each factor can have an arbitrary number of levels. Furthermore, each factor combination can have any number of replicates.

The use of different statistical methods helps also to maintain all key parts (sampling sites, determinants used, frequency of sampling etc.) of the monitoring programme as relevant as possible.

Monitoring reports

The most important phase in the whole monitoring cycle is reporting. The usual requirement is to report monitoring results in different phases of the monitoring period, from different areas of the entire river basin (or country) and finally for different groups of persons. Monitoring material should be used very effectively. All the analyses should be used at least in some of the reports. The reporting phase is also a very suitable moment to revise the monitoring programme according to the results and observations of the previous monitoring period.

The closest local reports are from the public living on the shores of the lake concerned. This report can focus on e.g., the situation of one small part of the lake near some polluting industrial source. Reports of this nature are usually published annually. These short reports should be written very clearly, and not using any difficult scientific terminology. The key message should be concentrated in practical questions like: Is the common situation of the lake improved, is the water in lake suitable for swimming, are the fishes still inedible because of high mercury content, etc.

The regional reports are needed for bigger areas, like river basins or even one country. In these reports all the possible monitoring data should be used as an integrated way. The lake is only one part of larger water system, and the situation should be assessed for whole river basin. The biocenosis and water quality data should be used together with pressure information, as well as with hydrological monitoring data. Important key questions in regional reporting are e.g.: long term changes in pressure factors, phosphorus loading originating from urban waste waters, correlations between different loading characteristics and water quality characteristics, and the trends.

Finally, you need also international reporting in European scale and especially concerning transboundary water bodies. They should be well documented and prepared in good co-operation of all relevant member states. The interval of these thoroughgoing reports may be several years.

RECOMMENDATIONS FOR SEDIMENT QUALITY MONITORING IN TRANSNATIONAL LAKES AND RESERVOIRS

SIMONA project responds to the current demand for the effective and comparable measurements and assessments of sediment quality in surface waters in the DRB, Monitoring and Assessment System to support transnational cooperation for joint DRB water management has been developed for streams, rivers and lakes and reservoirs within different Simona Project work packages. The system developed system covers:

1. sampling,
2. laboratory analysis,
3. evaluation protocols and
4. SIMONA-tool (online IT application)

The tools and guidelines developed are applicable at local and also at strategic level, thus actively contributing to achieving the WFD sediment quality monitoring and chemical status assessment requirements.

The immediate and middle term benefits of the project are a transparent method supported by the SIMONA-tool for sediment quality monitoring that will encourage the cooperation in transnational water management.

The main result of SIMONA is improved, harmonized, and coordinated sediment quality monitoring in the Danube River Basin. SIMONA delivered a benchmark for monitoring the future changes of the water quality via sediment quality, and this benchmark has been co-developed with stakeholders, verified by case studies.

Within WP6 of the SIMONA Project specific attention was devoted to sediment monitoring in large lakes and reservoirs focussing on transnational water bodies. The laboratory protocols and procedures developed for streams and rivers in other Project work packages also apply to lakes and reservoirs and are discussed in appropriate reports from the relevant work packages.

Within WP 6 specific guidelines for sediment sampling and analysis in large lakes and reservoirs have also been developed and are reported in "T4.2.1 Guidance on sediment monitoring in large lakes and reservoirs. These guidelines are technical in nature and apply at local, regional, and transnational levels.

However, neither the laboratory nor sampling guidelines developed within the SIMONA Project address the management and organisational issues of importance in transnational context in general and especially those of relevance for transnational water bodies and transnational lakes and reservoirs in particular.

With the above in mind the remaining part of this section addresses specific organisational and management issues in the context of transnational lakes and reservoir water bodies and makes appropriate recommendations in this regard.

Main recommendations

1. Sediment sampling activities for transnational water bodies need to be jointly planned by the parties concerned (all parties within whose territories transnational water body is located) and should cover the following as a minimum:
    a. Selection of number and location of appropriate sampling locations.
    b. Determination of frequency for sampling sediments at selected location
    c. Specification of sampling equipment to be used for sediment sampling
2. Adoption of common sample storage, transport and record keeping procedures and standards by the parties concerned (all parties within whose territories transnational water body is located) which should cover the following as a minimum:
    a. Standardized sample labelling methods and procedures
    b. Standardized sample storage and transport procedures
    c. Standardized reporting forms and field observation sheets in multiple languages.
3. Adoption of common laboratory standards and procedures for sediment quality analysis by the parties concerned (all parties within whose territories transnational water body is located) which should cover the following as a minimum:
    a. Acceptable analytical methods and limits of detection
    b. Requirement that all analysis is to be conducted by nationally accredited analytical laboratories
    c. Standardized reporting formats and procedures.

In view of the possibility that different legal regimes could exist in different countries we further recommend the following:

1. Bilateral and/or multilateral agreements should be made between the parties concerned which would cover recommendations made above. These agreements can be amended to existing agreements already in place or can be subject to separate dedicated agreements between the parties concerned.
2. If at all possible sampling sediment sampling campaigns should be jointly organised and implemented and sediment samples should be split in equal aliquots for quality analysis in national labs.
3. Reports on sampling and quality analysis should be shared between the parties concerned.

Finally for transnational lakes and reservoirs where water body status as per WFD is at risk or is not good, we recommend that the parties concerned develop a joint focused sediment quality study to trace the source of pollution responsible for violation of sediment quality standards in a particular water body.

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