

## Introduction to water quality monitoring equipment

### 1.1. Definitions and types of monitoring

Water quality monitoring can be defined as “the programmed process of sampling, measurement and recording of various water characteristics, often with the aim of assessing conformity to specified objectives”.

Various objectives can be listed for carrying out water quality monitoring such as:

Type of monitoring	Objectives
Ambient monitoring	- Status and trend detection - Testing of water quality standards - Calculation of loads
Effluent monitoring	- Calculation and control of discharge standards - Monitoring of plant performance
Early warning	- Warning for calamities - Protection of downstream functions
Operational monitoring	- Monitoring for operational uses such as irrigation, industrial use, inlets for water treatment works.

The design of a monitoring network will highly depend on above objectives of the programme. In this way, only the essential data is collected and needless waste of money, effort and time is avoided. Furthermore, periodical **evaluation** of the monitoring programmes is essential, to check whether the objectives are still met.

One can distinguish three levels of monitoring:

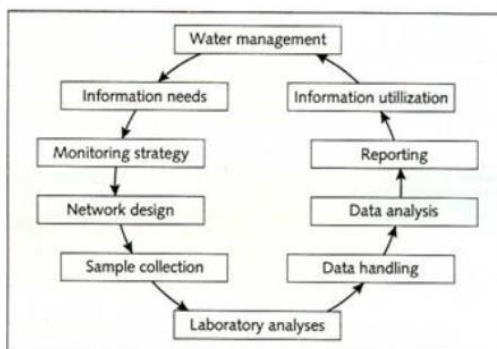
- *Simple monitoring*, based on a limited number of samples, simple analysis or observations, and data treatment which can be performed by simple software programmes
- *Intermediate-level monitoring*, requiring more variables, stations, and specific laboratory equipment and PCs for data handling
- *Advanced level monitoring*, involving sophisticated techniques and highly trained technicians and engineers for sample analysis (e.g. micropollutants) and data handling, often using mainframe computer systems.

Not every laboratory can perform all analyses; it is better then to involve "Central labs". In the following, an overview will be given on the design of monitoring programmes in surface waters, on site selection, monitoring frequency and parameters, *etc.*

### 1.2. The monitoring cycle

Over the last decades, much attention has been given to the various factors that determine a successful water quality monitoring programme.

Fig. 1 shows the water quality monitoring cycle.



The basic rules for successful water quality assessment:

1. Clear objectives, in line with the available resources;
2. A clear understanding of the water body, by preliminary surveys;
3. A choice of the appropriate media (water, sediment, biota);
4. A choice of parameters, stations and frequency, *etc.* **in line with the objectives;**
5. A choice of methods, instruments, laboratory facilities, *etc.* **in line with the objectives;**
6. A good reporting scheme;
7. Integration of water quality and hydrological monitoring;
8. A good Quality Assurance and Control (QA/QC) programme;
9. Clear recommendations to the decision makers;
10. A regular evaluation of the monitoring programme.

The design of a monitoring programme should be based on clear and well thought-out aims and objectives and should ensure, as much as possible, that the planned monitoring activities are practicable and that the objectives of the programme will be met. The design of a water quality monitoring programme, the selection of sampling stations, the frequency of sampling, the parameters to be analysed, *etc.* all depend greatly on the objectives of the programme. No monitoring programme should therefore be started without defining these objectives; also, they should be evaluated regularly! When a new programme is being started, it is very useful to begin with a survey of the region. The duration of such surveys will be between a few months up to a year, and should preferably include the different seasons. Of course, much information can already be derived from previous, historical monitoring data. In the survey, insight can be acquired on the general water quality characteristics of the region and variations herein, the different pollution sources, and on the hydrological variables. Assumptions on representativeness of stations, of mixing regimes in rivers, *etc.* can be tested. The survey

period is of great value for the field and laboratory workers for gaining experience and fine-tuning of the procedures for sampling, storage and analysis of samples. They can also help to refine the logistical aspects of monitoring, such as difficulties in transport and accessibility.

A description should be made of the monitoring area, with at least:

- Definition of the area, and schematisation in clear, not-overloaded maps
- A summary of the environmental conditions and processes, including human activities, such as population, land use, industries, hydraulic structures, (ground)water extraction sites and recreational areas;
- Meteorological and hydrological information, including hydrographs of river flows, and precipitation/evaporation data at stations as close as possible to the water course;
- A summary of actual and potential water uses.

## River basin monitoring

Rivers are lotic or flowing water environments and by themselves are confined to a channel or riverbed, but they receive water from a large area which is called a catchment, watershed or river basin. Rivers can have different morphometries, *i.e.*, geometric looks. They can form straight channels, like they do in mountain areas, or be strongly meandering and braiding, such as in floodplains. Streams consist of clear water flowing over shallow gravel riffles separated by deeper pools that collect organic debris. Rivers are muddier, larger and deeper and usually lack riffles and pools. There are three main types of streams:

- *Ephemeral streams* regularly exist for short periods of time, usually during a rainy period, and may have defined channels even when they are dry.
- *Intermittent streams* flow at different times of the year, or seasonally, when there is enough water from rainfall, springs, or other surface sources such as melting snow or even discharge from a wastewater treatment facility.
- *Perennial streams* are those that flow year-round.

### Physical parameters

Streams may originate in two ways, either flowing from headwaters such as lakes, or from springs or groundwater seepage. The direction of stream flow is dependent upon the slope and obstructions of the landscape. Flow velocity is also determined by the associated land gradient, which, when steep, not only speeds flow, but also increases sediment load and deposition.

Rivers and streams, with flowing water, will create currents within the stream or river

that wear away the sides of the channel, slowly shaping it over time. Currents are also responsible for moving and mixing organic and chemical substances as they enter the water through erosion and transport through weather (precipitation and wind) and animals (e.g. birds dropping seeds and plant matter). For a river system, physical parameters include:

- Stream velocity or current, where one is interested in the rate of particle transport in a certain direction. Due to turbulent flows of water, the measuring exercise can sometimes be tricky.
- Underlying geology: provides substrate sizes from silt to boulders. This influences the amount and type of benthic biota (fist-size stones provide the most favourable habitat for algae and invertebrates).
  - Soft/acid-water streams flow over hard granitic, slate or sandstone which release only few nutrients
  - Hard-water streams on limestone or sedimentary rock.
- The gradient of the water which is defined as the drop in elevation over a given stretch of flow. This is given by the topographical make up of the area in which the river is situated, *i.e.* steeper gradients in mountains than in lowlands.
- The cross-sectional area is usually a rough estimate, by using the width and depth at right angles of the flow direction.
- Another important feature is the discharge rate, *i.e.* how much water is being transported at one point in a certain unit of time. This is assessed by multiplying the average velocity by the cross-sectional area and is usually measured in  $m^3/s$ . High discharge moments are flood events.
- Riparian vegetation: the amount, type, height of the riparian vegetation affects the river temperature per se as well as the diel variations, organic matter input, *etc*

### **Concept of river continuum**

This concept was developed in the 80's. It describes how energy flows change with stream order. First order stream, so small ones with no input except from runoff, will be narrow and shaded by trees with a large amount for nutrients coming from the detritus of falling leaves, etc., so *allochthonous* (external) production. Higher order streams will be wider and allow sunlight to penetrate, thus allowing for *autochthonous* (own or internal) energy production. Subsequently, this concept also divides benthic organisms into different types of consumers: shredders in the first order streams that chew on leaf and branch parts; scrapers, that remove biota (also called Aufwuchs) from

macrophytes and will be found in the intermediate areas; and collectors, which are the filter feeders that take up the very fine particles of the large river beds.

## Monitoring

After having set the **objectives** of the monitoring (e.g. trend monitoring, early warning) the selection of sampling stations can be differentiated into:

- The *macro* location of the stations such as:
  - Background or baseline stations
  - County/district boundaries
  - Impacts of major pollution loads (cities, industries, irrigation areas, etc.)
  - Recreational areas.
- *Micro* location, defining the **exact** position of the monitoring sites:
  - Usually after complete mixing of the river
  - Sites with guaranteed accessibility (e.g., at bridges).

Processes affecting water quality and their influence should be taken into account when monitoring stations are selected. Monitoring stations of **rivers** should be established at places where the water is sufficiently well mixed after a discharge. A bridge can be an excellent place for a sampling station: it is easily accessible and, often, a bridge is a hydrological gauging station (however make sure that you sample UPSTREAM of the bridge). It is essential that water discharge and water quality parameters are measured **simultaneously**, because they are often interrelated. The spatial distribution of water quality stations within a river basin must be chosen in relation to the monitoring objectives, the expected variations, and the overall resources. Certain objectives, such as for compliance towards potable water supply extraction, require samples for **concentration** measurements, whereas others, e.g., for protection of downstream lakes, require **loads** (discharge x concentration) assessments as well.

## Lakes and reservoirs Characteristics: Origins

Most lakes on the surface of the Earth are fresh water lakes. Many lakes/reservoirs are man-made and are built to produce electricity, for recreation, to use the water in the industry, farming, or in houses. There are a number of natural processes that can form lakes. A recent tectonic uplift of a mountain range can create bowl-shaped depressions that accumulate water and form lakes. The advance and retreat of glaciers can scrape

depressions in the surface where water accumulates. Lakes can also form by means of landslides or by glacial blockages. Salt lakes (also called saline lakes) can form where there is no natural outlet or where the water evaporates rapidly and the drainage surface of the water table has a higher-than normal salt content. Small, crescent-shaped lakes called oxbow lakes can form in river valleys as a result of meandering. The slow-moving river forms a sinuous shape as the outer side of bends are eroded away more rapidly than the inner side. Eventually a horseshoe bend is formed and the river cuts through the narrow neck. This new passage then forms the main passage for the river and the ends of the bend become silted up, thus forming a bow-shaped lake. Crater lakes are formed in volcanic craters and calderas which fill up with precipitation more rapidly than they empty via evaporation. Sometimes the latter are called caldera lakes, although often no distinction is made. Most lakes are geologically young and shrinking since the natural results of erosion will tend to wear away the sides and fill the basin. Exceptions are those such as Lake Baikal and Lake Tanganyika that lie along continental rift zones and are created by the crust's subsidence as two plates are pulled apart. These lakes are the oldest and deepest in the world. The Red Sea, for example, is thought to have originated as a rift valley lake.

### **General Characteristics**

Lakes, as lentic (non-flowing) environments, have numerous features in addition to lake type, such as drainage basin (also known as catchment area), inflow and outflow, dissolved oxygen, nutrients and pollutants levels, pH, and sedimentation. Changes in the level of a lake are controlled by the difference between the input and output compared to the total volume of the lake. Lakes can be also categorized on the basis of their richness in nutrients, which typically affects plant growth. Nutrient-poor lakes are said to be **oligotrophic** and are generally clear, having a low concentration of plant life.

**Mesotrophic lakes** have good clarity and an average level of nutrients. **Eutrophic lakes** are enriched with nutrients, resulting in plant growth and algal blooms.

Hypertrophic lakes are bodies of water that have been excessively enriched with nutrients. These lakes typically have poor clarity and are subject to devastating algal blooms. Lakes typically reach this condition due to human activities, such as heavy use of fertilizers in the lake catchment area. Such lakes are of little use to humans and have a poor ecosystem due to decreased dissolved oxygen.

Further, we can divide lakes into three zones: the littoral zone, a sloped area close to land; the photic or open-water zone, where sunlight is abundant; and the deep-water profundal or benthic zone, where little sunlight can reach.

## Monitoring

Lakes and reservoirs can be subject to several influences that cause water quality to vary from place to place and from time to time. Conducting preliminary surveys is therefore a prerequisite for successful monitoring. Assessment of **bathymetry** (depth contours) is required, as well as research on (in)homogeneity, overall sediment mapping (*e.g.*, grain size distribution), *etc.* In general, it can be stated that the number of stations needed for lake monitoring strongly depends on the (in)homogeneity of the lake. For a vertically as well as horizontally mixed lake, **one station**, anywhere, will be sufficient. The criterion for "well-mixed" will mainly be based on statistical evaluation. Also here, often large cost reductions can be achieved by optimising the monitoring. In general, more stations will be needed for:

- Large and/or irregularly shaped lakes, again using above criterion, which can then be expanded as follows: "**one station per homogeneous area**"
- Large variations in water depth and sediment composition (the latter affecting water quality).

Finally, the **monitoring objectives** must be taken into account, *e.g.*:

- Ambient monitoring of overall water quality
- Input/output budgets
- A "one-time" intensive research on the impact of, for example, an industry.

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