

Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes

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Chapter 1 - INTRODUCTION

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Freshwater is a finite resource, essential for agriculture, industry and even human existence. Without freshwater of adequate quantity and quality sustainable development will not be possible. Water pollution and wasteful use of freshwater threaten development projects and make water treatment essential in order to produce safe drinking water. Discharge of toxic chemicals, over-pumping of aquifers, long-range atmospheric transport of pollutants and contamination of water bodies with substances that promote algal growth (possibly leading to eutrophication) are some of today's major causes of water quality degradation.

It has been unequivocally demonstrated that water of good quality is crucial to sustainable socio-economic development. Aquatic ecosystems are threatened on a world-wide scale by a variety of pollutants as well as destructive land-use or water-management practices. Some problems have been present for a long time but have only recently reached a critical level, while others are newly emerging.

Gross organic pollution leads to disturbance of the oxygen balance and is often accompanied by severe pathogenic contamination. Accelerated eutrophication results from enrichment with nutrients from various origins, particularly domestic sewage, agricultural run-off and agro-industrial effluents. Lakes and impounded rivers are especially affected.

Agricultural land use without environmental safeguards to prevent over-application of agrochemicals is causing widespread deterioration of the soil/water ecosystem as well as the underlying aquifers. The main problems associated with agriculture are salinisation, nitrate and pesticide contamination, and erosion leading to elevated concentrations of suspended solids in rivers and streams and the siltation of impoundments. Irrigation has enlarged the land area available for crop production but the resulting salinisation which has occurred in some areas has caused the deterioration of previously fertile soils.

Direct contamination of surface waters with metals in discharges from mining, smelting and industrial manufacturing is a long-standing phenomenon. However, the emission of airborne metallic pollutants has now reached such proportions that long-range atmospheric transport causes contamination, not only in the vicinity of industrialised regions, but also in more remote areas. Similarly, moisture in the atmosphere combines with some of the gases produced when fossil fuels are burned and, falling as acid rain, causes acidification of surface waters, especially lakes. Contamination of water by synthetic organic micropollutants results either from direct discharge into surface waters or after transport through the atmosphere. Today, there is trace contamination not only of surface waters but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites.

The extent of the human activities that influence the environment has increased dramatically during the past few decades; terrestrial ecosystems, freshwater and marine environments and the atmosphere are all affected. Large-scale mining and fossil fuel burning have started to interfere measurably with natural hydrogeochemical cycles, resulting in a new generation of environmental problems. The scale of socio-economic activities, urbanisation, industrial operations and agricultural production, has reached the point where, in addition to interfering with natural processes within the same watershed, they also have a world-wide impact on water resources. As a result, very complex inter-relationships between socio-economic factors and natural hydrological and ecological conditions have developed. A pressing need has emerged for comprehensive and accurate assessments of trends in water quality, in order to raise awareness of the urgent need to address the consequences of present and future threats of contamination and to provide a basis for action at all levels. Reliable monitoring data are the indispensable basis for such assessments.

Monitoring is defined by the International Organization for Standardization (ISO) as: “the programmed process of sampling, measurement and subsequent recording or signalling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives”. This general definition can be differentiated into three types of monitoring activities that distinguish between long-term, short-term and continuous monitoring programmes as follows:

- *Monitoring* is the long-term, standardised measurement and observation of the aquatic environment in order to define status and trends.
- *Surveys* are finite duration, intensive programmes to measure and observe the quality of the aquatic environment for a specific purpose.
- *Surveillance* is continuous, specific measurement and observation for the purpose of water quality management and operational activities.

The distinction between these specific aspects of monitoring and their principal use in the water quality assessment process is described in the companion guidebook *Water Quality Assessments. A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, 2nd edition (edited by D. Chapman and published on behalf of UNESCO, WHO and UNEP by Chapman & Hall, London, 1996).

It is important to note the emphasis given to collection of data for a purpose in the definitions of water quality monitoring above. This purpose is most commonly related to water quality management, which aims to control the physical, chemical and biological characteristics of water. Elements of management may include control of pollution, use and abstraction of water, and land use. Specific management activities are determined by natural water quantity and quality, the uses of water in natural and socio-economic systems, and prospects for the future.

Water quality requirements or objectives can be usefully determined only in terms of suitability for a purpose or purposes, or in relation to the control of defined impacts on water quality. For example, water that is to be used for drinking should not contain any chemicals or micro-organisms that could be hazardous to health. Similarly, water for agricultural irrigation should have a low sodium content, while that used for steam generation and related industrial uses should be low in certain other inorganic chemicals. Preservation of biodiversity and other conservation measures are being recognised increasingly as valid aspects of water use and have their own requirements for water quality management. Water quality data are also required for pollution control, and the assessment of long-term trends and environmental impacts.

1.1 Elements of a water quality monitoring programme

Before the planning of water sampling and analysis can be started, it is necessary to define clearly what information is needed and what is already available and to identify, as a major objective of the monitoring programme, the gaps that need to be filled. It is useful to prepare a “monitoring programme document” or “study plan”, which describes in detail the objectives and possible limitations of the monitoring programme. Figure 1.1 outlines the contents of this book in relation to the process of developing such a plan, its implementation and the interpretation of the findings. If the programme’s objectives and limitations are too vague, and the information needs inadequately analysed, the information gaps will be poorly identified and there will be a danger of the programme failing to produce useful data.

Many reasons can be listed for carrying out water quality monitoring. In many instances they will overlap and the information obtained for one purpose may be useful for another. Water quality monitoring data may be of use in the management of water resources at local, national or international level. Where water bodies are shared by more than one country, a water quality monitoring programme can yield information that may serve as a basis for international agreements regarding the use of these waters, as well as for evaluation of compliance with any such agreements.

Water quality monitoring is the foundation on which water quality management is based. Monitoring provides the information that permits rational decisions to be made on the following:

- Describing water resources and identifying actual and emerging problems of water pollution.
- Formulating plans and setting priorities for water quality management.
- Developing and implementing water quality management programmes.
- Evaluating the effectiveness of management actions.

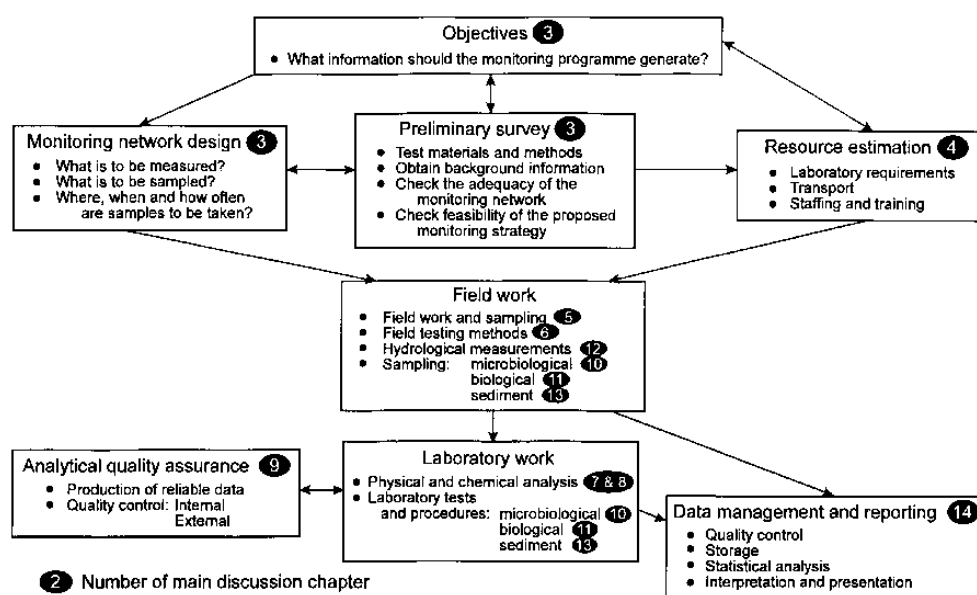


Figure 1.1 Links between the critical elements of water quality monitoring discussed in the various chapters of this book

To fulfil these functions some preliminary survey work must first be done to provide basic, background knowledge of existing water quality conditions (Figure 1.1). Subsequent monitoring efforts will identify problems and problem areas, short- and long-term trends and the probable cause of the problems. Once sufficient data have been gathered, it is possible to describe the average conditions, the variations from average and the extremes of water quality, expressed in terms of measurable physical, chemical and biological variables. In the meantime, priorities may have been set, plans may have been made and management programmes may have been implemented. Ultimately, information from the monitoring programme is fed back into the management system so that any necessary changes to priorities and plans can also be made.

Specifications for the collection of data should be uniform so as to ensure compatibility and make it possible to apply to any particular location the experience gained in another. Networks for water quality monitoring should be developed in close co-operation with other agencies actively collecting water data. This not only minimises the cost of establishing and operating the network but also facilitates the interpretation of water quality data. The particular hydrological measurements and water characteristics required will differ from one water body to another. For example, in rivers and streams it is necessary to measure the velocity of flow and intensity of longitudinal mixing, while thermal regimes are important considerations when monitoring lakes. Measurement of wastewater discharges containing nutrients may not be necessary for many rivers but may be important in lakes (which act as traps for nutrients) because the additional input of nutrients may accelerate the eutrophication process.

Networks for water quality monitoring must conform to programme objectives (Figure 1.1). A clear statement of objectives is necessary to ensure collection of all necessary data and to avoid needless and wasteful expenditure of time, effort and money. Furthermore, evaluation of the data collected will provide a basis for judging the extent to which programme objectives were achieved and thus justify the undertaking. Before observations begin, it is also essential to specify the location of sampling stations, the frequency of sampling and the water quality variables to be determined.

Monitoring programmes should be periodically reviewed to ensure that information needs are being met. As greater knowledge of conditions in the aquatic system is gained, a need for additional information may become apparent. Alternatively, it may be concluded that some of the information being collected is unnecessary. In either case, an updated monitoring programme document must be prepared and distributed to the information users. If such users are not kept fully informed of the exact scope of the programme they may expect more than it can deliver and may not support its continuation.

1.2 Monitoring for management

The elements of water quality monitoring and assessment described above and discussed in detail in the following chapters are only part of a wider picture of water quality and quantity management, environmental protection and policy formulation and of development concerns. The critical element stressed is the development of objectives. It may be that long-term objectives (such as integrated monitoring for environmental and health protection) may be set for the monitoring programme but that the programme operates, and is practically structured, to meet specified short-term objectives (such as monitoring for immediate health

priorities). This illustrates that water quality monitoring operates within a larger structure of policy decisions and management priorities. A programme may need to be flexible to meet short-term objectives but still be capable of developing over longer periods to meet new concerns and priorities.

The elements outlined above and described in more detail in the following chapters should be implemented flexibly according to the different priorities of the monitoring programmes. The initial phases of surveys and design may extend over periods of months or even years before a clear idea of needs and priorities is achieved. The time required for other elements of the monitoring and assessment process varies. Sampling missions may take several days, as may sample transport to the laboratory. Complete chemical analysis of a sample may take a week. Data treatment can take weeks, depending on the amount of data that is to be dealt with, while interpretation of results and the writing and publication of reports can take from a few months to a few years. If operational surveillance is one of the aspects of a multi-purpose monitoring programme, the field work, data assessment and reporting should be accomplished within a time limit appropriate to the operational requirements. For example, reports on the surveillance of drinking water quality should be made very quickly so that corrective actions can be taken when a contaminated supply threatens public health.

The importance of the use of information should be stressed. There is little point in generating monitoring data unless they are to be used. It is essential that the design, structure, implementation and interpretation of monitoring systems and data are conducted with reference to the final use of the information for specific purposes.

In some countries, water quality standards may be laid down by national legislation. A government authority is then charged with monitoring the extent to which the standards are fulfilled. This is particularly common for water intended for drinking and is carried out as a public health protection measure. The monitoring objectives in this case will be concerned with detecting any deterioration in raw water quality so that appropriate source protection or treatment can be applied. In other instances, it may be necessary to develop a new water source in order to meet increasing demands; the objective may then become that of monitoring the quality and quantity of sources that might fulfil this need.

Where water quality legislation is rudimentary or non-existent, the water authority's mandate may be to develop legislation and regulations appropriate to the country's economic development plans. In this case the monitoring objectives will probably focus, in the first instance, on acquiring background information on water quality. The objectives will change as information on water quality is accumulated, as problems emerge and solutions are developed, and as new demands are made on the water resources.

1.3 Monitoring and assessment

This handbook concentrates on providing the practical information which is necessary to design, to implement and to carry out monitoring programmes in freshwaters. Emphasis is placed on the collection and analysis of water samples because, at present, this activity forms the principal component of most monitoring programmes. The fundamental techniques associated with the use of sediment and biota in monitoring programmes are also presented in order to illustrate how they may be incorporated into existing programmes based on water sample analysis. Further details of the growing application of these approaches is available in the companion guidebook *Water Quality Assessments*.

Monitoring, as a practical activity, provides the essential information which is required for an assessment of water quality. However, assessments require additional information, such as an understanding of the hydro-dynamics of a water body, information on geochemical,

atmospheric and anthropogenic influences and the correct approaches for analysis and interpretation of the data generated during monitoring. The companion guidebook gives further detail on the supporting information which is required for the full assessment of water quality in rivers, lakes, reservoirs and groundwaters, illustrated by examples of assessments from different world regions. A detailed description of different approaches available for the interpretation of monitoring data is also given.