Review article

Planning and Management of Surface Water Monitoring

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Abstract

Water quality monitoring is a continuous monitoring of hydrological, quantitative and qualitative characteristics of surface waters: physicochemical, radiological, hydrobiological and microbiological properties of river ecosystems, including water, sediment, suspended sediment and bioindicators, using standard test methods. The strategic goal is that monitoring, in addition to protecting and controlling the sources of water supply, has the function of constantly monitoring the ecological values of watercourses in terms of protecting their ecological status and natural values. Active participation of the public in the process of informing and consulting on the status, causes, and assessments of water quality is also very important. The quality monitoring strategy of surface water is committed to the national environmental policy, with particular emphasis on the development dynamics of national institutions specialized in testing and study of water quality, their financial, personnel, and instrument security, with a plan of continuous improvement and innovation of the same. Monitoring of surface water quality in the catchment level is an integral part of a regional and national system of control over the state line. The development task of water quality monitoring is harmonization with neighboring countries and with countries of the EU, conception, and implementation of a joint test program.

Keywords: the quality monitoring of surface water, quality indicators, ecological status.

Introduction

Surface water monitoring is the implementation of long-term standardized measurements and observations of water in order to determine the status and change of water quality. Systematic testing enables the proper assessment and decision making regarding water quality, such as the use of water for water supply, recreation or use in agriculture, in a technological production process, or just the provision and conservation of specially protected water resources and their ecological status.

Continuous monitoring and care of water quality is a prerequisite for the formation of a successful water management system and the planning of incentive measures that prevent the discharge of polluted water and hazardous substances into natural watercourses. The aim is to apply modern production technologies, introduce recirculation and anhydrous technologies and purify pollution at the point of origin in production processes, known as "black spots". The success of the measures and activities implemented is verified by data, results, and assessments of the actual status of the tested surface water bodies and is the basis for the sustainable use of watercourses and water resources.

General Considerations

The strategy for monitoring the quality of surface waters must be a determination in the national environmental policy at the national level, with special emphasis on the dynamics of development of national institutions specialized in testing and studying the quality of water, their material, human and instrumental security with a plan for continuous improvement and innovation of them. Monitoring of surface water quality at the basin level is an integral part of the regional and national system of monitoring the status of water and is being formed and developed according to material and human resources.

The basic unit and model of the monitoring organization is the natural river basin as a hydrological entity, which should accompany the establishment of administrative organizational forms for monitoring water quality.

The water quality monitoring system needs to be constantly modernized and streamlined. In this regard, continuous work should be done on the optimization of the network of measuring stations, frequency of testing, automation of the testing process, selection of tested quality indicators, as well as the number of test sites - test locations.

Water quality monitoring is a continuous monitoring of hydrological, quantitative and qualitative characteristics of surface waters: physicochemical, radiological, hydrobiological and microbiological properties of river ecosystems, including water, sediment, suspended sediment and bioindicators. In all cases of quality control, using standard test methods, one of the main goals is to mass balance the pollution in the local and regional context or water load in the complete catchment area (Standard Methods, 1995).

It is also a task to develop and harmonize coordinated monitoring of water quality with that in neighboring countries and with EU countries, conceptualizing and implementing joint testing programs. In this regard, it is necessary to constantly review and redact the list of indicators and the frequency of their examination in accordance with the expected pollution, identified sources and paths of possible migration.

The implementation of monitoring program tasks, when all the prescribed conditions are fulfilled, is equally entrusted to both public services and private specialized organizations.

The strategic goal is that monitoring, in addition to protecting and controlling the sources of water supply, has the function of constantly monitoring the ecological values of watercourses in terms of protecting their ecological status and natural values. Active participation of the public in the process of informing and consulting on the status, causes, and assessments of water quality is also very important. (Mijović et al, 2012; Brennan et al, 2005)

Planning of Surface Water Monitoring

The monitoring strategy should be adapted over time to the needs of regulations, but also increased demand for information from stakeholders and general public. At the same time, the necessary continuity of testing should not be neglected but the results of previous measurements and observations should be taken into account. Special attention should be paid to potential sources of pollution, permanent and other sources from which pollution can reach the watercourses in case of an accident.

Potential Sources of Pollution

The strategic commitment is that the future surface water monitoring system should provide multifaceted data and functions related to surface water quality, early announcement of accidental spills and disasters, or targeted testing of the development and migration of pollutants in water. The planning of the parameters, frequency, and location of the tests within the monitoring should be consistent with the possible occurrence of pollution from real, upstream potential pollutants. The observed pollution at constant, intermittent or accidental concentrations, at the key - output profiles of the tested catchments, forms the basis for the design of the monitoring program for these waters.

Basis for sizing water monitoring programs on the key (outlet) profiles of the tested catchments, make a statement of pollution at constant, intermittent or accidental concentrations for these waters. The strategic goal is to scale, on most of these key profiles, for significant catchments and sub-basins, depending on the estimated risk, a constant daily test of water quality and the establishment of automatic stations - monitors.

Accidental spills - pollution contributes to the large pollution of surface waters by the discharge of more abundant toxic substances. The pricelessness of the damage that may occur over a larger territory by migration and distribution of these substances in the aquatic environment imposes the need to introduce, due to the high risk, continuous monitoring of the downstream recipients from a potential source of accidental substances. Water quality control stations that take over this function have priority in instrumentation, communications, observation automation, and personnel support, in order to alert and prevent consequences in the event of an accident. This applies primarily to monitor station positions at border profiles, and certainly to stations downstream of large, high-risk industrial complexes.

If a risk analysis in a particular watercourse sector identifies the occurrence of pollution by specific hazardous substances, these are planned in water quality monitoring programs with a high frequency of control. Therefore, risk assessment analysis must be used in the assessment of priorities for the inclusion of specific pollution parameters in the recipient monitoring program, especially in the part of the relevant physicochemical and toxicity indicators. The dependence of biological indicators and chemical pollution can be useful for monitoring the selective accumulation characteristics of pollution or for identifying hazardous substances in regards to the relationship of dosage and the effects caused, that is, the exposure and the hazard properties of the resulting consequences. (Cibulić et al, 2016)

Ecological Significance

The good quality of the watershed of the catchment area in an ecological sense necessitates that the leached substances from the coastal area have no major adverse effects on the ecosystem. The environmental definition must, in any case, be taken into account as a factor, in addition to chemical status assessments, for the summary classification of water quality. For the relevant assessment of ecological status, it is necessary to separate ecoregions and differences that indicate a specific scale for identifying the type of watercourse, that is, the differences that are important for the gradation of ecological status.

The basic elements for ecological assessment of the status of a catchment area or watercourse are certainly the point of view of biodiversity and the identification and description of reference conditions. In this respect, it is important to consider the occurrence of migration of aquatic organisms and species, which is a disruptive factor of basic ecological characteristics. Some species of organisms extend beyond their natural range and this is one of the most aggressive negative effects on the environment and aquatic ecosystems. Therefore, the development and distribution of these species, as well as the environmental consequences, must be systematically monitored. (Cibulić et al, 2016; Lorez-Roldan, 2015)

Information System and Modeling of Water Quality

The ultimate purpose of monitoring is to obtain reliable information - reliable data on the status of water quality at a given moment. The data collected is processed so that it can be used in the easiest way immediately and in the future. The amount of information needed and the need for it should reflect current policies and strategies for managing this resource. The publication of information is the final stage of data management, and its publication is done according to predefined data analysis protocols. The frequency and level of delivery of the data processed depends on the user. Data should be statistically processed and presented as aggregate information in an acceptable manner, e.g. tabular, graphical with a geographical representation of test locations. Numerical, analytical or statistical models play a particular role in the conception of surface water monitoring and the assessment of their quality status, whether they are used to estimate the occurrence of expected pollution, optimize the network of monitor stations, or to evaluate the effectiveness of the tests conducted and to determine the impact of pollution on surface water. Computational models of watercourses or watersheds provide impact analysis and proposed pollution remediation measures, taking into account the flow and transport of pollutants.

Water Quality Monitoring - General Aspects of the Monitoring Program

All interested entities for a particular river basin should participate in the process of setting up a monitoring program under this cycle. The monitoring network is designed depending on the information requested. The monitoring program, as well as its implementation plan, covers many aspects, such as field measurements, sampling (sample collection, preparation, storage methods, and sample transportation), chemical and microbiological analysis and data collection. Therefore, equal attention should be paid to all these elements in the process of designing a monitoring program. Monitoring program planning includes a selection of water quality indicators, location, frequency of testing, field determinations and laboratory analysis. The basic rules for a successful water quality monitoring and analysis program are:

- Define and adjust the monitoring program and necessary information to the level of planned and secured financial resources and equipment;
- Consider the types and characteristics of watercourses (mostly preliminary surveys), with the coverage of the whole hydrological year;
- Define components of the test (matrix) of the water system (water, suspended and/or sedimentary particles, biological indicators).
- Depending on the purpose of the monitoring, the test parameters, sample types, test frequency, and cell locations must be carefully selected according to the information required and not the other way around. Mobile, field equipment and laboratory devices are selected according to the specificity of the data required, the accuracy and sensitivity of the determination, and not the other way around;
- The monitoring of surface water quality should be coupled woth necessary hydrological measurements and analysis;
- Organize a complete and operational review of data processing by internal and external controls. For laboratory testing, accredited institutions must be hired for this type of test;
- Data and findings should be offered to decision-makers not only in the form of spreadsheets of measured sizes but also in the form of an analysis and assessment of the situation and expertise with relevant recommendations, solutions and administrative measures;

- The monitoring program should be periodically evaluated from the perspective of needs and experiences, especially if conditions in the catchment area have changed and there are extraordinary impacts, whether natural or induced.

The program must be flexible so that it can be applied to the whole basin as well as to its individual parts. Monitoring data collection is carried out centrally to provide an overall assessment of water quality status or any changes that may have occurred. Therefore, it is first necessary to determine the place where the water quality will be monitored, then determine the parameters for testing at each site, determine the method of sampling, transport, and storage of samples, the frequency of sampling (aggregate, proportional, composite sample), as well as the methods of laboratory testing. (Lorez-Roldan, 2015)

Frequency of Water Quality Testing

In a watercourse, regular cyclical quality changes can occur at different intervals (days, weeks, and years), so the frequency of quality testing should be aligned with the water regime and the testing (sampling) performed at the same intervals. Watershed testing should be carried out systematically, taking into account that the entire hydrological year is covered - all seasons, i.e. different weather conditions. Current samples, which are sufficiently representative, can be taken under normal conditions in the period of small and medium waters, while in the case of extreme hydrological conditions - large water, there is a sudden oscillation in the quantitative and qualitative characteristics of the watercourse. These oscillations are particularly pronounced in heavy rainfall. Therefore, in such conditions, it is necessary to take two-hour and eight-hour composite samples, which better shows the water quality under extraordinary hydrological conditions. The frequency of testing shall be determined to ensure an acceptable level of reliability and precision.

In other watercourses, water quality will be controlled 12 times a year - once a month, while sediments are tested twice a year. (Burgeois et al, 2003; Methods, 1988; Rulebook A, 2011)

Determination of Ecological Status of Surface Waters

Quality elements for testing surface waters and classifying their ecological status, using characteristic biological parameters, chemical and physicochemical elements that support biological elements, morphological conditions, hydrological regime, oxygen regime, salinity, acidity, nutrient concentration, specific pollutants, substances-pollutants identified in the tested watercourse, as well as other substances released at significant concentrations. (Rulebook A, 2011; Rulebook B, 2011)

In order to evaluate the harmful effects of pollutants present on the quality of the river ecosystem, the following parameters are tested as indicators of pollution:

- Dissolved oxygen, BOD_5, total organic carbon (TOC), nutrients, pH, temperature conditions, chlorophyll;
- Hazardous substances present - identified in water and sediment;
- Structure of the plankton community, larger bottom animal species, fish, vegetation, sessile algae;
- Reference species, as well as diseases and deformities of organisms;
- Physical and hydromorphological factors (flow, depth-to-width ratio, river bed regulation, sediment structure, shoreline status, land use and density of floodplains in the river valley).

Sampling and Laboratory Testing

Sampling may be continuous, in the case of stationary monitoring stations that perform continuous automatic recording of certain quality parameters, referred to as long-term monitoring. If this sampling is going on continuously, then it is referred to as environmental monitoring. It describes the status of water quality in wider areas and over a longer period of time.

Monitoring carried out over a short period of time is usually for a study, project or related to a specific problem in order to define and find a solution, and is referred to as short-term monitoring.

Water sampling should be well prepared since it is carried out continuously. First, determine the sampling site, clean and arrange the access to the site, prepare sampling equipment, sample collection vessels to be marked, the sampling log to be filled in on the spot while recording all the data measured on the site, as well as any observations that may be made during the sampling. Based on the scope of the test, determine the amount of the sample required and how it should be marked. Samples should also be adequately preserved if they cannot be immediately transported to the laboratory, which is also recorded in the log.

During the laboratory analysis, it is necessary to first prepare a test plan, which will include the number of parameters to be tested, the order of testing - movement of the sample through the laboratory,

establish a system for storing test results, and check the equipment beforehand. Analysis should be done according to standard test methods verified in a given laboratory, or if done by home methods, they must be validated.

Therefore, it is best - most reliable to test water samples in accredited laboratories according to the international standard SRPS ISO / IEC 17025 for this type of test. (Burgeois et al, 2003; Methods, 1988)

Water Quality Management

The publication of the report is followed by the use of the information obtained. Appropriate software packages are used to analyze the data, and there are many on the market today. The monitoring plan envisages when and how often the report is made and their format and distribution. The ultimate goal of monitoring is to collect and provide the information to stakeholders on water quality in systematic manner. Water monitoring and water quality management should be seen as a series of interrelated activities that begin by defining the required information and ending with the use of the data obtained as information for water quality management, Figures 1 and 2. (Rulebook A, 2011; Rulebook B, 2011).

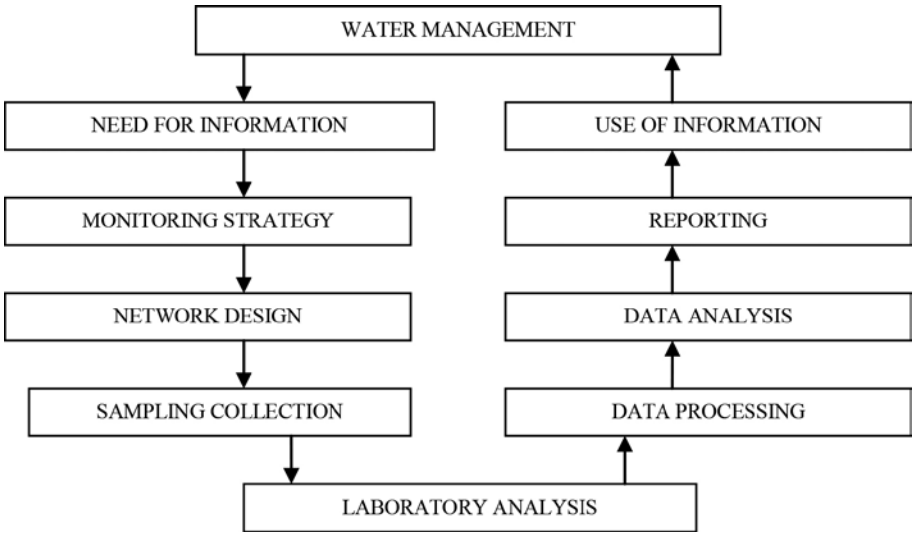

Figure 1: Surface water monitoring cycle.

All interested entities for a particular river basin should participate in the process of forming a monitoring program under this cycle. The monitoring network is designed depending on the information requested. All these parameters depend on whether the data is needed for environmental monitoring, early warning of an accident, or for monitoring surface or wastewater.

An important component of well-designed monitoring is **early warning systems**, based on monitoring data promptly alerting users to changes in quality in the event of an accident or any other situation where significant changes in water quality occur. This early warning is especially important for downstream users, especially those who use it as a source for water supply, i.e. for the preparation of drinking water or other human activities that directly threaten human health (Lorez-Roldan, 2015). So an early warning should be an alarm to protect resources and indicate an error in the production or treatment of wastewater as soon as possible, or some other source of pollution. It is referred to the appropriate authorities, which define the need for water sampling and testing, define the test parameters, identify the source of the pollution and initiate preventive and control measures. (Decree, 2012; Regulations, 2012)

In order to establish early warning system reliably, it is necessary to design continuous or semi-continuous measuring stations for monitoring surface waters, which determine any deviations from the usual trends, as well as provide for automatic sampling and accurate testing - identification of pollutants, using modern measuring equipment in accredited laboratories.

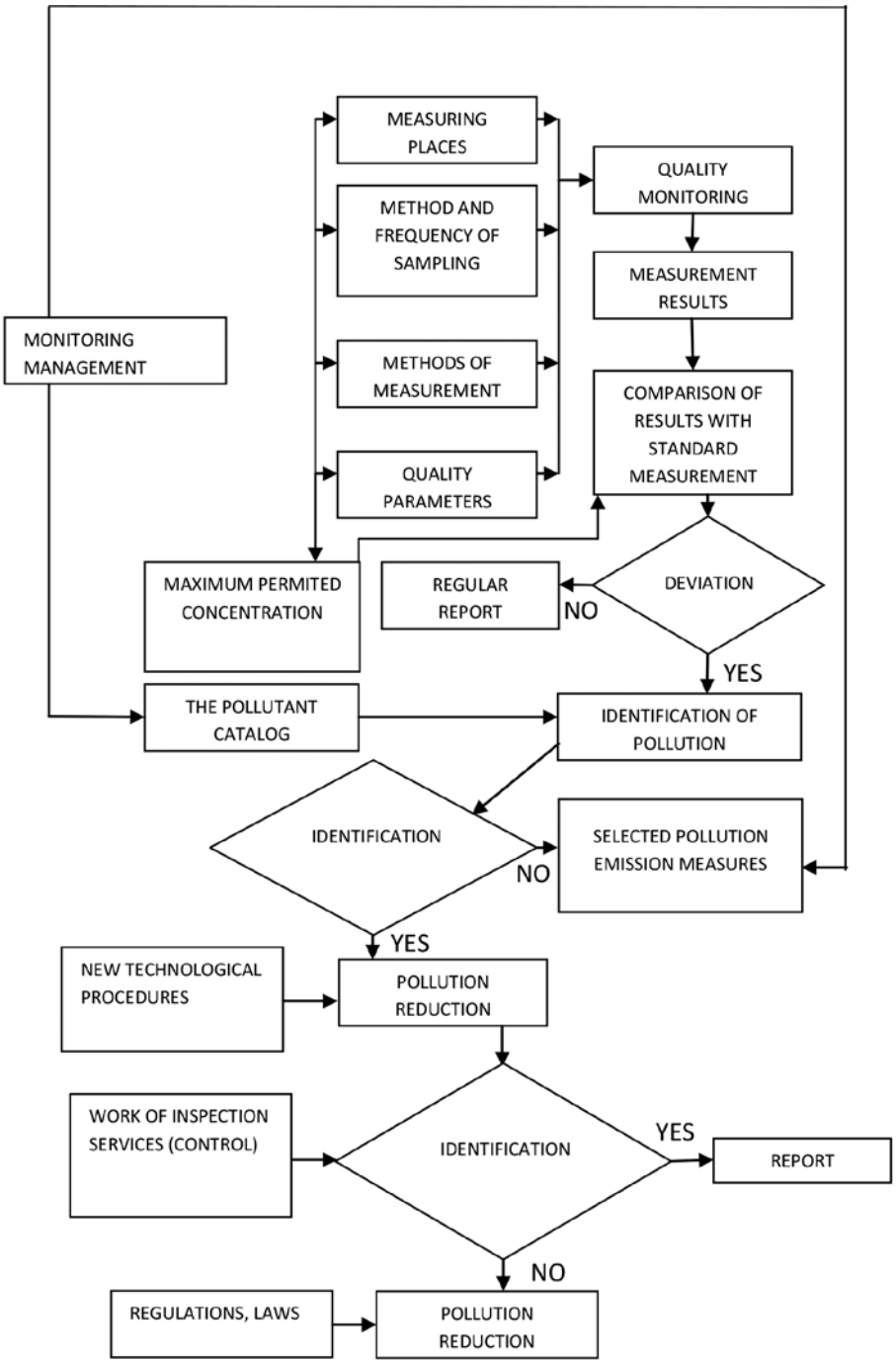

Figure 2: Surface water monitoring management procedure.

Assessment of the Current State of the Surface Water Monitoring Network in Serbia

In the Water Framework Directive (EU / WFD - 2000/60 / EC), the water resource policy has been completely defined. The basic unit is the river basin within which it is required to implement water resources management, with the aim of bringing all existing water bodies to a "good status" to ensure a good hydrological-chemical-ecological status of the waters.

WFD EU is based on several key principles (Law, 2016):

- Comprehensive protection of all waters;
- Good status for all water bodies;
- Integrated water management;
- "Combined approach";
- Proper pricing;
- Public Involvement.

In order to comply with the principles of the WFD EU, the RS has adopted a number of laws and by-laws, such as:

- Law on Water (Official Gazette RS 30/10),
- Law on Meteorological and Hydrological Activity (Official Gazette RS 88/2010),

- Rulebook on the determination of surface and groundwater bodies (Official Gazette of the RS 96/2010), and
- Rulebook on parameters of ecological and chemical status of surface waters and chemical parameters and the quantitative status of groundwater (Official Gazette 74/10).

In the Rulebook on Determination of Water Bodies of Surface and Groundwater, an overview of all surface water bodies - watercourses is given, of which there are 493 in total, followed by heavily modified and artificial water bodies. However, more than 55% of the surface water bodies in Serbia are still not covered by continuous monitoring. (Žarković, 2018) This results in a lack of monitoring of their quantitative and qualitative status.

Conclusions

Water quality monitoring is a continuous monitoring of hydrological, quantitative and qualitative characteristics of surface waters: physicochemical, radiological, hydrobiological and microbiological properties of river ecosystems, including water, sediment, suspended sediment and bioindicators. In all these cases of quality control, using standard test methods, one of the main goals is to mass balance the pollution in the local and regional context or water load in the complete catchment area.

Based on all of the above, it can be concluded that all interested entities for a particular river basin should participate in the process of establishing a monitoring program. The monitoring network is designed depending on the information requested.

The monitoring program, as well as its implementation plan, covers many aspects, such as field measurements, sampling (sample collection, preparation, storage methods, and sample transportation), chemical and microbiological analysis and data collection.

Water quality monitoring objectives, objectivity, and quality standards are set to assess the quality of water resources, characterize ecological status, and establish conditions for dedicated water use and water quality management. Laboratory data defines when these conditions will be met and when the water is of acceptable quality for appropriate uses. If laboratory results indicate a violation of quality standards, action must be taken to control and identify the source of the pollution.

Sampling may be continuous, in the case of stationary monitoring stations that perform continuous automatic recording of certain quality parameters, referred to as long-term monitoring. If this sampling is going on continuously, then it is referred to as environmental monitoring. It describes the status of water quality in wider areas and over a longer period of time.

Monitoring carried out over a short period of time is usually for a study, project or related to a specific problem in order to define and find a solution, and is referred to as short-term monitoring.

The ultimate goal of monitoring is to collect and provide information on water quality to stakeholders in organised manner.

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