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# WATER QUALITY MONITORING AUTOMATION OF RIVERS IN SERBIA

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**Abstract**. *This paper reports on the automatic stations for monitoring river water quality in Serbia. One automatic station observing basic parameters such as temperature, pH value, dissolved oxygen concentration and electroconductivity was established on the river Kolubara, a tributary of the river Sava. Two more automatic stations were installed on the river Tisa, a tributary of the Danube, with a higher number of parameters – in addition to basic parameters there were sensors for turbidity, ammonium ion and chlorophyll. Build-up of the early warning system is in the design phase, and consists of four automatic water quality stations on the main watercourses – the rivers Sava, Danube and Tisa.*

**Key words**: *water quality, monitoring, automatic station, surface waters*

## INTRODUCTION

The traditional approach to monitoring of river water quality consists of manual sampling in remote locations and the transport of samples to the laboratory for chemical analysis. This approach, although it is relatively non-technical and easily reproducible, is also time-consuming, has high labor costs, may be limited due to weather conditions, can give inconsistent results and does not allow the continual collection of data (Wang et al., 2004).

The examples of new technology and instrumentation are automatic monitoring stations that are already effectively used in a number of networks for monitoring the "capture" of various pollutants or temporal changes in toxicity (Mutko et al. 1997, Bols et al. 1999, Lechelt et al. 2000, Allan et al. 2006, Marković et al. 2007, Mariolakos et al. 2007, Scott et al. 2007, Strobl et al. 2008). Automatic monitoring systems have been developed by companies that manufacture devices for measuring water quality (YSI 2010) or the solutions were developed on the level of patents (Moskoff, 2004).

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Automatic monitoring is not suitable for all situations. The choice of automatic monitoring must be based on specific monitoring objectives, program resources and the suitability of sites. The selected method must match the program objectives and be technically feasible. Automatic methods may correspond more than manual ones in the following situations: high variable water quality daily or hourly, transient events that affect the quality of the water, or when it is not possible to sample manually or it is difficult to maintain the required sampling frequency (Field Manual, 1999).

The present situation in Serbia, in terms of network automation stations for monitoring surface water quality, is such that is currently operating only one automatic station on the Kolubara river (a tributary of the river Sava), located in Beli Brod. This station was put into operation in July 2008 as a result of cooperation between Serbia and Germany in the Twinning Project "Strengthening the capacities of the Water Directorate" and monitors only the basic parameters of water quality; continuous monitoring diagrams are presented on the web site of the RHMS (Mijović et al., 2009).

Also, as part of Neighbourhood Programme Serbia-Hungary, two automatic stations were installed on the river Tisa at locations Novi Kneževac and Novi Bečej. These stations operate on the principle of multiparameter probe directly immersed in river water, and measure a number of parameters. These were put into operation also in 2008 and store data in the database; however, observed parameter values are not realistic, indicating a lack of calibration of sensors in multiparameter probes, so that the results of continuous monitoring have not been made available to the public (Mijović et al. 2007, 2008).

In addition to these automated stations that have already been physically installed, although with various operational statuses, the project for an early warning system of surface water pollution, which was initiated in 2006 by the Ministry of Science and Environmental Protection under the NIP (National Investment Plan), was made in 2007 by a team from the Faculty of Technical Sciences in Novi Sad (Kulić et al., 2007). Four automatic stations were provided by this project, i.e. three ones at the inlet locations of the river Sava – at Jamena, the river Danube – at Bezdan , and the river Tisa – at Novi Kneževac, as well as an automatic station at the outlet of Serbia, i.e. at Radujevac on the river Danube. It was intended that these stations monitor several parameters - from the basic ones (temperature, turbidity, pH values, etc.) to very sophisticated ones (Daphnia toximeter, SAC 254, the measurement of radioactivity, etc.), and be modular, so that they can function as a basic measurement program, an extended measurement program, and so on.

In general, automatic stations for water quality monitoring can function on two basic principles: a) a water intake pump and sensors in the measuring reservoir, and b) a measuring probe directly immersed in the river water (Mijović & Palmar, 2009).

## AUTOMATIC STATION BELI BROD ON THE KOLUBARA RIVER

The principle of automatic station operation is based on the abstraction of river water, flow of water through the reservoir with immersed sensors that measure the parameters of the water quality and restore water into the river (Mijovic & Palmar, 2009). The measured values of the parameters are saved using a data-logger, transmitted through a GSM modem to the server in RHMS and stored in a central database.

An automatic weather station for monitoring water quality of the Kolubara river is located at 44° 22′ 16" latitude and 20° 11′ 59" longitude, elevation zero meters is 99.32 maAsl, and the distance from the mouth of the river is 39.2 km.

The installed equipment consists of a sensor for the continuous measurement of the water level, water temperature, pH value, dissolved oxygen and electroconductivity. In addition, the submersible pump was installed at the water intake location for the continuous abstraction of river water and providing water flow through the reservoir in which the sensors for measuring the above mentioned parameters of water quality are immersed, as well as a water-flow meter.

Figure 1 schematically depicts the principle of an automatic station for continuous monitoring of water quality.

The advantages of this concept of setting measuring sensors are:

1. Easier access to sensors for regular maintenance and cleaning;

2. The sensors are in flow-through reservoir, and cannot be damaged by impact or due to the presence of ice in winter;

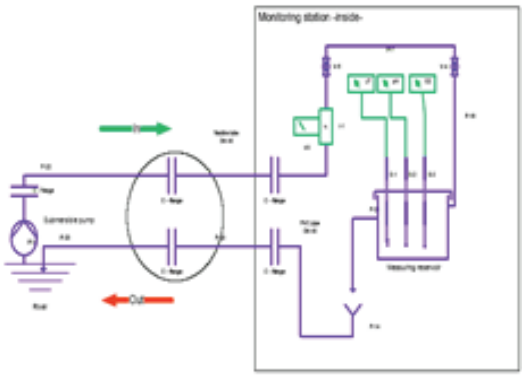

**Fig. 1**. Schematic view of an automatic station.

Figure 2 shows the interior of the station.


**Fig. 2**. The interior of the automatic station Beli Brod.

Manufacturers of embedded measuring sensors are WTW and Seba Hydrometrie (Germany), and their technical characteristics are shown in Table 1

**Table 1.** Specification of measuring equipment

| Sensor | Measuring range | Measuring principle |
|---|---|---|
| Water level, H | 0 - 10 m | pneumatically |
| Water temperature, t | 0 - 50°C | semiconductor sensor |
| pH value | 0 - 14 | electrochemically |
| Electroconductivity, $E_p$ | 0 – 1 x $10^{-1}$ S/m | measuring conductance |
| Dissolved oxygen, DO | 0 – 20 x $10^{-6}$ kg/L | membrane, Clark's principle |

**Acquisition and data transfer**

At the station, a SEBA MDS5 Datalogger has been installed with a 16-bit A/D converter. A logger has a standard 8 analog and 2 pulse input, and its own real time clock. Registration information can be time-controlled or event-controlled, depending on the parameter variation to be measured. Data storage is in a serial flash-memory with a capacity of 1MB (enough for about 480,000 measured values). The local connection to the logger is via a serial port RS232 or RS485 or USB. The logger is power supplied through the public network adapter and power consumption in the power-down mode is less than 7.5 mAh. In the case of an interruption in the external power, the logger has an internal lithium battery as a backup. The station is equipped with an MC35iT GSM/GPRS modem. Communication is made possible through the GSM service. The software package for retrieval, adjusting and control consists of the following programs: Wbedien 32, DEMASole and DEMASdb.

**Appearance on the website of RHMS**

Indicators of water quality of the Kolubara river in real time are visible on the website of the RHMS. There is a choice of parameters, at the start and the end of the observation period. Figure 3 shows the page on the website of RHMS.


**Fig. 3.** The appearance of measured parameters on the website of RHMS (RHMS website 2008)

## AUTOMATIC STATIONS ON THE RIVER TISA

### Site description

The station Novi (New) Kneževac on the Tisa River was founded in 1883; it is located on the left bank of the river, at 144.5 km from the mouth and the river basin and its area is 140,130 km$^2$. The water level station in Novi Kneževac is the part of the reporting network of hydrological stations forecast service of RHMS and is equipped with a device for remote transmission of data on the water levels (Mijović et al., 2008).

Station Novi Bečej on the Tisa River was established in 1855 and is located on the left bank of the channel Banatska Palanka – Novi Bečej at 65.0 km from the mouth of the river; the catchment area is 145,415 km2. The station is located just upstream of the dam in New Bečej so that the water levels at this station are under the direct impact of the dam.

The average flow of the river Tisa at Novi Bečej is 766 m$^3$/s, with a mean monthly minimum 95% non-provision to 123 m$^3$/s, and a maximum annual discharge of 1% probability of 3870m$^3$/s.

### Specifications

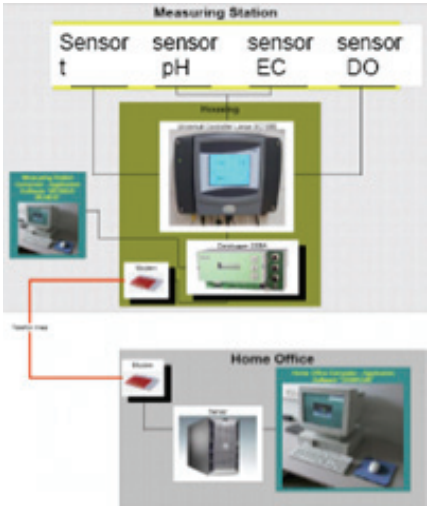


**Fig. 4.** The concept of the automatic measurement station for water quality

A multiparameter probe MPS-K16 with sensors for measuring T, pH, conductivity, dissolved oxygen, ammonium ion and chlorophyll is immersed directly into the river water and continuously records the value of these parameters. The water level was also measured (using an optional sensor). All of the measured values are collected in a central data-logger with a capacity of storing up to one month, depending on the frequency of sampling, or sent directly to the central computer via the GSM network.


**Fig. 5.** The automatic station at Novi Kneževac on the river Tisa

**Acquisition and data transfer**

Acquisition and data transfer have been solved in the same manner as described in the **Acquisition and data transfer** section of the Automatic Station Beli Brod on the Kolubara River.

The software package for station communication, examination and adjustment consists of the following programs: SEBAConfig, DEMASole and DEMASdb. The SEBAConfig program is used for checking the logger locally or remotely; its purpose is to set certain parameters of loggers or sensors. The current values of measured parameters can check or download historical data by this program. In the normal mode the memory is circular, which means that when the memory is full, the new measured values are entered instead of the oldest ones.

**Table 2.** Technical specification of the sensors (Measuring range and accuracy)

| Parameter | Measuring Range | Accuracy | Resolution |
|---|---|---|---|
| Temperature | -5….50°C | +/- 0,1°C | 0,01°C |
| Electroconductivity | 0..200 x $10^{-3}$ S | +/-1µS for $E_p$<200x$10^{-6}$S<br>+/-0,5% for $E_p$>200µS | 1x$10^{-6}$S |
| Oxygen (optical) | 0,01-25x$10^{-6}$ kg/L | +/- 0,5% | 1x$10^{-8}$ kg/L |
| Oxygen saturation | 0..400% saturation | +/-0,5% | |
| Turbidity | 0..1000 NTU | +/-0,3NTU , <10NTU<br>+/-3% , >10NTU | 0,01 NTU |
| pH value | 0..14 | +/- 0,1 | 0,01 |
| Ammonium-ion | 0,2..18x$10^{-3}$ kg/ L | +/-2 x$10^{-6}$kg/L for <40x$10^{-6}$ kg/L<br>+/- 5% for >40x$10^{-6}$ kg/L | 1x$10^{-4}$ kg/L |
| Chlorophyll-a | 0,03..500x$10^{-6}$ kg/L | +/- 0,1µg/l for<3µg/l<br>+/-3% for >3µg/l | 1 x$10^{-8}$ kg/L |

The DEMASole and DEMASdb programs make a whole, provided that the program DEMASole can be used independently. The DEMASole program is used for time-programmed downloading of data from the station as well as report generation. Reports may contain the latest values assumed or measured values of the previous day, two previous days, or some other selected period. The DEMASdb program for data storage uses some of the software for database management (RDBMS) of type Oracle, MySQL or BorlandParadox.

## EARLY WARNING SYSTEM OF SURFACE WATER POLLUTION

Within the NIP (National Investment Plan), and according to the decision of the Ministry of Science and Environmental Protection and with the approval of the Government of the Republic of Serbia in 2006, the project of building a system of early warning of surface water pollution was designed. The aim of this project was the automatic determination of quality parameters on the inlet stream sites of the rivers Danube, Tisa and Sava, and at the outlet of the Danube River from Serbia, as well as data collection and sharing via an information system (Kulić et al., 2007).

The approach in the development of automated stations in this project is based on the phase conception (EASE Project, 2002), i.e. divided into two phases, with phase I consisting of:

a) The basic measuring program,

b) Extended basic measuring program

In the second phase it's scheduled for: an extended measuring program.

The basic measuring program includes the measurement of key parameters for the sudden change in the water body. Equipment for this program covers the main physical-chemical parameters and the basic recording of measured values, and consists of:

- Measurement of the level and velocity of the water stream.
- Measurement of the physical-chemical parameters: pH, dissolved oxygen, electrical conductivity, redox potential, water temperature, turbidity.

This equipment, in addition to the detection of harmful discharge into the surface waters, can register changes in natural surface water bodies (e.g. heavy rain, flooding, etc.). Setting the primary measuring program allows us to collect much more data than is currently the case and provides a basis for further development of the system.

An extended basic measuring program in the continuous monitoring provides an early warning with the aim to inform the water users on the change of quality; the credible way to identify the probability/impact of possible contamination from chemical, microbiological, or radioactive contaminants is based on the data in the accidental or other situations in which significant changes in the water quality occurred. The program enables a complete automatic detection of unusual conditions of water as well as automatic water sampling. The following equipment is provided:

- A Hydrocarbon fluorometer,
- The total γ-radiation,
- An on-line analyzer for nitrates, phosphates, ammonia and SAC 254,
- The UV spectrophotometer,
- An algae or Daphnia toximeter,

- An automatic sampler,
- A computer for automatic analysis of data (test of abnormal events and alarm index).

**Equipment for an extended measuring program**

The extended measuring program (Phase II) supplements all measuring equipment with very powerful devices for the detection of substances or mixtures hazardous for water. Due to their complexity these devices are very expensive in terms of purchase and operating costs, and for their operation it is necessary to engage a highly qualified staff. However, their procurement can be avoided by a different organization, i.e. samples may be taken by an automatic sampler and then analyzed in a central laboratory. This measuring equipment includes:

- A GC/MS (gas chromatograph / mass spectrometer),
- A HPLC / UV (liquid chromatograph / ultraviolet spectrometer) or MS (mass spectrometer),
- A TOC analyzer (total organic carbon),
- Ion Chromatography.

This equipment is intended to detect organic micropolluters (pesticides and industrial chemicals) in very low concentrations (ppt / ppb) and with various volatility . As additional equipment centrifuges, sedimentation tanks and artificial membranes for bioaccumulation are provided.

In the second phase the equipment for optional and additional measurements is provided:

- The measurement of anions and cations by ion-selective electrodes,
- The measurement of sulfate by ion chromatography,
- The measurement of chlorinated hydrocarbons by gas chromatography,
- The measurement of heavy metals by anodic stripping voltammetry.

**Acquisition and data transfer**

As part of this equipment for each monitoring station the following are provided:

- An industrial computer (Touch Panel)
- Software for storing measurement data, display of the function time vs. measuring parameters and automatic sending of data to a base station.

The communication system is such that the data from monitoring stations are transferred by radio to the communications center and then to the control center via fiber optic or a wireless link.

In the Control Center the following equipment is provided:

- A workstation with 4 monitors
- A Microsoft Windows Server 2003 Web Edition
- A Microsoft SQL Server 2005 Standard IA64,
- WinCC System Software v6.2, RC 1024th

The system for supervisory control and data acquisition (SCADA) has the task to display values collected at monitoring stations. All of the signals are processed using the appropriate software, run on the monitors and recorded in the database.

## CONCLUSIONS

The present situation regarding the monitoring of surface waters in Serbia is characterized by the following:

- Monitoring surface water quality with manual sampling at 129 locations on 66 water streams,
- one automatic station (the river Kolubara - Beli Brod) with the system comprising of a pump and with water flow through the reservoir with sensors (in operating condition),
- two automatic stations (the river Tisa) with multiparameter probes directly immersed into the river water (operating but not functional),
- four automatic stations at the inlet and outlet of Serbia - in the design phase.

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# AUTOMATIZACIJA MONITORINGA KVALITETA VODE REKA U SRBIJI

## Svetomir Mijović, Bojan Palmar

*U ovom radu prikazane su automatske stanice za monitoring kvaliteta vode reka u Srbiji. Jedna automatska stanica za monitoring osnovnih parametara kao što su temperatura, pH-vrednost, koncentracija rastvorenog kiseonika i elektroprovodljivost postavljena je na reci Kolubari, pritoci reke Save. Još dve automatske stanice su instalirane na reci Tisi, pritoci Dunava, sa većim brojem parametara – pored osnovnih parametara postoje senzori za mutnoću, amonijum-jon i hlorofil-a. Izgradnja sistema rane najave je u fazi projektovanja, a sastoji se od četiri automatske stanice kvaliteta voda na glavnim vodotocima – rekama Dunav, Sava i Tisa.*

Ključne reči: *kvalitet vode, monitoring, automatska stanica, površinske vode*