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ADVANCED RIVER WATER QUALITY MONITORING STATIONS AT THE MORAVICA RIVER IN SERBIA

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Abstract. *The overall objective of this project is the immediate enhancement of the water quality management in Serbia as an example of excellence for the South East Balkan region. Therefore, close links between the local and regional economy and the Serbian Higher Education sector will be created through technology and knowledge transfer. New technologies like GPRS Technology to realize data transfer from distance hydro measure stations will be introduced in the water quality monitoring management. Outcomes of the project are a measurement program for Advanced River Water Quality Monitoring, a pilot station and operator staff for the realization of the monitoring scheme, devices including GPRS-Technology for the monitoring scheme, a monitoring station to conduct a test run, a quality management scheme, training measures for operators of monitoring stations, analyzed data from measurement program and dissemination and networking measures like a final international conference. The project is funded within the scope of the Tempus Program (Tempus Cards Structural and Complementary Projects) of the EU.*

Key words: *River water, water quality monitoring, water quality management, on-line distance measurements.*

1. INTRODUCTION

Based on a longer co-operation between Bauhaus Universität Weimar, Germany and the University of Nis, Serbia, an application for a project entitled Construction of Pilot Devices for Advanced River Water Quality Monitoring was submitted for the Tempus Cards Programme Structural and Complementary Projects and agreed for October 15st,

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2005 to October 14th, 2006. Partners are the Serbian Water Authority JVP „Srbijavode" Beograd, VPC „Morava", Nis, Serbia, the Graz University of Technology, Austria, the DWA Deutsche Vereinig. f. Wasserwirtschaft, Abwasser u. Abfall, Hennef, Germany, the EWA European Water Association, Hennef, Germany, KNOTEN Weimar GmbH, Weimar, Germany, and the Municipality of Sokobanja, Serbia. The full project programme provides activities as follows:

Determination of measurement tasks: Ensure water quality, identifying and monitoring sources of pollution and special distribution of contaminations, comply with various international agreements, integrate quality assurance activities, transformation to Serbian conditions.

Identification of Pilot Stations, suitable Installation strategies and Operators: with help of local authorities, have to meet the requirements of developing monitoring schemes.

Construction of Devices: according to the measurement task plan, practical realization in respective pilot monitoring devices and a complete new system for data transfer including user-friendly software.

Set up Monitoring stations: developed devices will be installed at an identified pilot monitoring station, the station should operate according to the developed measurements program.

Operator Training: Development of curriculum and modules for training measures, executing of operator training in Graz and in Nis and as correspondence courses in the English language in part via e-learning platform.

Data use: Multi-user water systems could be regulated in rational way by knowing hydrological and water quality data. Data will be transferred by using GPRS technology.

Dissemination and Networking Activities: postgraduate and vocational correspondence courses on ARWQM should be organized. Operator manual, project meetings, workshops, a series of publications published in special journals, an internet portal, and a final symposium are (or are to be) realized.

Quality control scheme: monitoring to control the overall project quality can be identified as the systematic and continuous collecting, analyzing, and using of information for the purpose of management control and decision-making.

Project management: it comprises reporting to the EC, financial management, supervision of the milestone concept, maintenance of the web-platform, and main quality and project management activities including main project administration work.

Determination of measurement tasks

Water quality management in Serbia/EU in comparison to requirements according to Serbian law

EU Policy, in one of its fields, is conducted through directives, which represent normative part of European legislation. Since mid-70s numerous important directives have been adopted, which are related with the issue of surface and ground waters. Complete new approach to the water management was made starting with1996 when several important directives have been adopted. The most important among them is "Water framework directive" (WFD), adopted on 23 October 2003. This directive consists of long term vi-

sion (until 2015) and represents complex, overall approach to the issue of water exploitation and protection. From that side it is crucially important in terms of politics, economy, and social aspect.

Problem with protection from the pollution is in close connection with technological and industrial development, which has as circumstance creation of legal regulative in this area. Creation and implementation of such regulative regarding water protection from the pollution as modern social creation has very wide influence and importance for regular and efficient functioning of water protection mechanisms. Beside this, if we take under consideration more expressed sense that protection against pollution is one of the basic pre-conditions for survival of life, then the obligation of each individual is to treat water as good of overall interest. Inevitable involving of the state in the water protection, had in Serbia the history as follows (Genesis of Legal Water Protection in Serbia):

- Kingdom of Serbia
  - 1878 Law on waters and their use,
  - 1905 Law on regulation and use of waters.
- Republic of Yugoslavia (SFRJ)
  - 1965 Law on waters.
- Republic of Serbia
  - 1967, 1975, 1989 and 1991 Law on waters.

Apart from the Constitution and Laws on waters, legal regulative regarding water protection is regulated through Law on Environmental protection, Law on communal work, and sub-laws related to those areas. In Serbia, water protection is assured through: legal acts, water-management base, water-management approval for objects and plants, which can affect quality and quantity of waters, water-management license, building of equipment for cleaning of polluted waters, forbidding of certain materials or adding of others, administrative, punitive and other protection measures. In frame of Republic Hydrometeorology Service, there is a Department for water quality control. The main activities of this Department are as following:

a. **Systematic research of surface and ground waters quality in territory of Republic of Serbia**:
   Research of surface and ground waters quality in territory of Republic of Serbia is conducted according to the Programme on Systematic research of waters quality. Such programme has been adopted at the beginning of every year by Serbian Government and it defines scope, type, and frequency of water quality controls. Systematic research of surface and ground waters quality, which is, according to the Law on Waters, responsibility of Hydrometeorology Service, covers the following topics: Sampling and physical-chemical, microbiological, bacteriological and radiological water analysis, sampling and chemical analysis of river's mud and mud in accumulations. Analysis covers up to 66 physical-chemical-biological parameters.
b. **Assessment of water quality status**:
   Data collection, analysis and drafting of interim and annual reports as well as reports upon requests of beneficiaries, Ad hoc monitoring of water quality demanded by accident pollution, research of the waters cut by state boarders, in frame of international water-management co-operation with Hungary and Romania, overview of technical documentation for building of new and reconstruction of the existing

objects, preparation of instruments, chemical substances and necessary tools for conducting of sampling and other chemical analysis on site, and supervision of mentioned duties, drafting of guidelines and standard operational procedures for field work.

2. IMPLEMENTATION OF WFD IN SERBIA IN THE FRAMEWORK OF OUR PROJECT

Serbia is just one step away from the preparatory phase on drafting of legislations on Emission Limit Values for water (ELV). At the beginning, base of it would be group of boundary values defined by the so called "daughters" of Directive 76/464/EEC. That means it will be necessary to define a timeframe in which the industry will achieve ELV for each type of pollutants. Data collection about technologies which are implemented in our country is important as well as their comparing with requirements of BAT (best available techniques) standards.

Enforcement of Directive on waters will be conducted through two phases.

Phase 1: Framework for cooperation (Adaptation of legal frames to WFD, defining of institutional frame, responsible institution, defining of coordination mechanisms),

Phase 2: GIS and mapping and characteristics of river basins (Defining of typology and referent conditions for surface water, Identifying of artificial and strongly modified water bodies, Identifying and description of ground water bodies, Identifying of pressures on surface and ground waters, Implementing of economic analyses about water exploitation, Establishment of register of Protected Areas).

Determination of measurement tasks

It is particularly important that the objectives of a water quality monitoring program be clearly stated and recorded. The very act of writing them down generally results in careful consideration being given to the possible options. Written objectives help to avoid misunderstandings by the project participants, and are an effective way of communicating with sponsors, and to provide assurance that the monitoring program has been systematically planned. They are also important when the program is evaluated to determine whether or not the objectives are being met.

The following is a list of typical monitoring objectives that might be used as the basis for design of sampling networks. The list is not intended to be exhaustive, merely to provide some examples.

- Identification of baseline conditions in the water-course system,
- Detection of any signs of deterioration in water quality,
- Identification of any water bodies in the water-course system that do not meet the desired water quality standards,
- Identification of any contaminated areas,
- Determination of the extent and effects of specific waste discharges,
- Estimation of the pollution load carried by a water-course system or subsystem,
- Evaluation of the effectiveness of a water quality management intervention,
- Development of water quality guidelines and/or standards for specific water uses,
- Development of regulations covering the quantity and quality of waste discharges,
- Development of a water pollution control program.

Identification of pilot stations

List of potential pilot stations & selection criteria

The necessary prerequisites for pilot station selection were existence of conflict interest of local authorities (municipalities Sokobanja and Aleksinac), conflict between interests in water usage (enterprises vs. local communities), with many circles of interest. The distance from Nis, as a center for data collection was also not neglected. The existence of potential point pollutant (Coal mine "Citluk") with waste water treatment plant was influenced factor. The candidates for pilot station(s) were the following river basins:

I. River Toplica (A_{basin} = 2180 km^2, L_{flow} = 130 km, q_{mean}= 12 m^3/sec);
II. River Krajkovačka reka (A_{basin} = 125 km^2, L_{flow}=32 km, q_{mean} = 0,60 m^3/sec);
III. Moravica river ($F_{basin.}$ = 606 km^2, L_{flow} = 57 km, q_{mean} = 5 m^3/sec).

The complete applied list of (weighted) factors used for choice of pilot station location, ordered in "Decision matrix for identification of pilot station" contained: (1) Distance from research center (under 50 km), (2) Area of river basin (up to 600 km^2), (3) Flow lenght (up to 60 km), (4) Strictly identified point pollutant, (5) Existing WWTP, (6) Water class changes in between 25 km river flow, (7) Water reservoire (multi-purpose accumulation) on the river flow, (8) Using water for water supply and waste water disposal, (9) Conflict of multiple interest of administrative bodies, (10) Conflict of interest inside of administrative borders, (11) Interest of communities for environmental problems, (12) Reachibility of measurement stations whole year long, (13) Availability of parallel measurement possibilities (at least two laboratories along the river).

Based on given criteria and (weighted) evaluation, the basin of river Moravica has been chosen for location of pilot station, and point pollution was outflow from WWTP of Citluk coal mine, discharging to Izgara creeck, which forms, together with Tisovik creek, river Moravica. The detailed description of Moravica river basin could be found in project reports, and on the site www.gaf.ni.ac.yu/ARWQM. The map of Moravica river basin is given on Fig. 1.

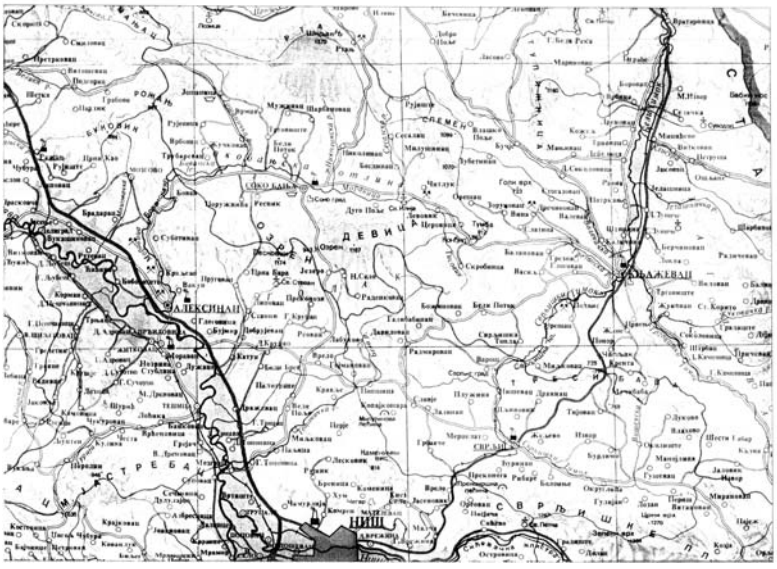

Fig. 1. River Moravica basin

Definition of basic data set for WQ assessment

As with all freshwater systems, river quality data must be interpreted within the context of a basic understanding of the fluvial and river basin processes which control the underlying characteristics of the river system. Similarly, the design of the monitoring network, selection of sampling methods and variables to be measured must be based on an understanding of fluvial processes as well as the requirements for water use. Water quality can be described by a single variable or by any combination of more than 100 variables. For most purposes, however, water quality can be adequately described by fewer than 20 physical, chemical, and biological characteristics.

The selection of variables will depend on the program objectives and on both existing and anticipated uses of the water and will also be influenced by the ability of an organization to provide the facilities, and suitably trained operators, to enable the selected measurements to be made accurately. Full selection of variables must be made in relation to assessment objectives and specific knowledge of each individual situation. A further very important question is also the required frequency of data mining to get specific knowledge about the variability of a process since only few variables are measurable with a high frequency and without great cost. The simplest combination of variables is temperature, electrical conductivity, pH, dissolved oxygen (DO), and total suspended solids (TSS). More complex programs may analyze up to 100 variables, including a range of metals and organic micro-pollutants. Moreover, analysis of biota (plankton, benthic animals, fish and other organisms) and of particulate matter (suspended particulates and sediments) can add valuable information. Determining the hydrological regime of a water body (velocity, discharge, water level, suspended matter dynamics) is an important aspect of a water quality assessment. Discharge measurements, for example, are necessary for mass flow or mass balance calculations and as inputs for water quality models.

Basic data set for water quality assessment

Accepted data set for continuous water-quality monitoring is given in Table 1.

Table 1. Accepted data-set

Basic	Optional
• discharge/velocity/water level	• turbidity & TSS
• temperature	• ammonia
• pH	• chloride
• dissolved oxygen	• chlorophyll
• conductivity & TDS (Total Dissolved Solids)	• biosensor

Optional data set of manual sampling and analysis water quality variables is: redox potential, nitrogen and phosphorus compounds, biological oxygen demand, major ions (sodium, potassium, calcium, magnesium, carbonates and bicarbonates, chloride, sulphate), metals and fecal coliform.

A common system configuration for data collection is the four-parameter water-quality monitoring system, which collects temperature, pH data, specific conductance, and dissolved oxygen, although systems can be configured to measure other properties such as ammonia, chloride, turbidity or chlorophyll, and Daphnia (water fleas) biosensor. The sensors that are

used to measure these water properties require careful field observation, cleaning, and calibration procedures, as well as thorough procedures for the computation and publication of final records. Producing an accurate final record requires thorough procedures for the computation, publication, and archiving of the data. To obtain the most benefit and best interpretation from the collected data series a time-near observation is urgently recommended.

Data transfer from distant hydro measure stations using GPRS

GPRS (**G**eneral **P**acket **R**adio **S**ervice) is a mobile data service available to users of GSM (**G**lobal **S**ystem for **M**obile Communications) mobile phones. It is often described as 2.5G. That is a technology between the second and third generations of mobile telephony. It provides moderate speed data transfer, by using TDMA (**T**ime **D**ivision **M**ultiple **A**ccess) channels in the GSM network. First it was standardized by ETSI but now that effort has been handed onto the 3GPP. Today one of the most important application of a GPRS technology is data transfer from distant places.

Construction of device for ARWQM - hardware/software support of typical stand-alone measure station (Integraf 1008G)

INTEGRAF 1008G is a compact universal regulator, based on micro-controller Philips 80C552, meant for acquisition, regulation, governing, automatisation of processes, and production systems and used for supervising and control, simply in any field where is necessary to use micro-controller governing. It is a high performance microcontroller suitable for instrumentation, industrial governing, automatisation of industrial, waterworks or agricultural equipment.

Basic functions

On the basis of collected data (input analogous and digital signals) and data processing (scaling, calculating technical values with built in algorithms), controller is able to administer outputs completely independently. Monitoring of measuring values, state of regulation circuits, distant assigning and accessing to regulation parameters is available thanks to real-time connection of controller and PC.

(Technical characteristics: Power 220V, Consumption 5V/12V, Analogous inputs: 8, Input signal 4-20 mA, Resolution 10 bit, Digital inputs: 8, Communication: GPRS, GSM, RS232/485, Speed: 19200 bit/sec, Comm. Line: 1200 m without amplifying signal, NVRAM: 128x8, Bus connection: real time clock, Hand terminal, led display, LCD display, LED indicator, Communication controller). The structural scheme of INTEGRAF 1008G is given in Fig. 2.

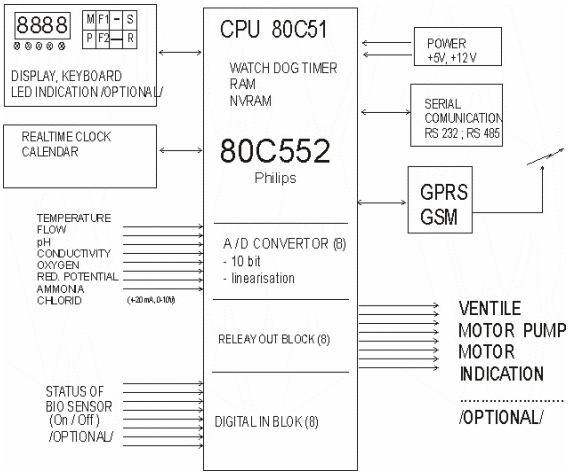

Fig. 2. Structural block scheme of INTEGRAF 1008G

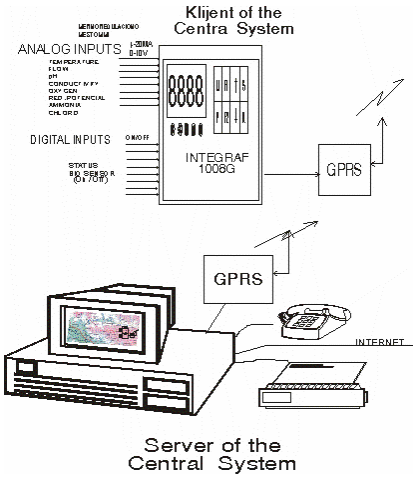

Fig. 3. Block-scheme of ARWQM system

Server Application Software of the Central System

Application software for PC written in C programming language for Windows environment/platform is used for gathering and processing data received from microprocessor controller. The software can be also used for governing objects in systems, with certain algorithm, on the basis of processed result of measuring parameters, given by microprocessor controller.

Application software along with micro-controller software, Client of the Central system, INTEGRAF 1008G and communication software for communication between microcontroller through GPRS modem and PC, Server of the Central System, make a unique software package of Central System for gathering, processing and data supervision on

purpose of automation and increasing of system reliability. The software package allows connecting several systems for tracking and governing into unique system for data acquisition, central control, and automatic regulation. The scheme of the system is given in Fig. 3.

Operator Training

To train among others the operator staff for the pilot station and further stations, the development of a curriculum on "Water quality management" is under way. A learning modules for training measures of about 175 pages will be developed until July 2006. Table 2 displays the structure:

Table 2. Structure of module "Water quality management"

Chapter 1	Introduction	Chapter 8	Advanced instrumental analyses
Chapter 2	Water quality	Chapter 9	Analytical quality assurance
Chapter 3	Designing a monitoring programme	Chapter 10	Microbiological analyses
		Chapter 11	Biological monitoring
Chapter 4	Resources for a monitoring programme	Chapter 12	Hydrological measurements
		Chapter 13	Sediment measurements
Chapter 5	Field work and sampling	Chapter 14	Use and reporting of monitoring data
Chapter 6	Field testing methods	Chapter 15	Moravica river basin as case study
Chapter 7	Physical and chemical analyses		

The training measures for the operator training are planned as combination of contact lessons and correspondence courses in the English language. It will be presented to the target audience in August/September and supported by an e-learning platform.

3. CONCLUSION

Since the project is in operation, the current state is presented and no final result can be expected yet. Further work steps are the practical set up of the pilot station, operator training, the data use and the dissemination and network activities. A final symposium under the auspices of the European Water Association (EWA) will be held in October in Nis, Serbia, to present the results.

REFERENCES

1. Australian Guidelines for Water Quality Monitoring and Reporting – Summary 2000, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, October 2000, ISBN 09578245 1 3, ISSN 1038 7072.
2. Richard J. Wagner, Harold C. Mattraw, George F. Ritz, Brett A. Smith: Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting, U.S. Geological Survey, Water-Resources Investigations Report 00-4252, Reston, Virginia, 2000.
3. Deborah Chapman (ed.): Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition, © 1992, 1996 UNESCO/WHO/UNEP, ISBN 0 419 21590 5 (HB) 0 419 21600 6 (PB).
4. Jamie Bartram and Richard Ballance (eds.): Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes, Published on behalf of United Nations Environment Programme and the World Health Organization, © 1996 UNEP/WHO, ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk).

5. H. Granbohm, J. Wilkund: GPRS: General Packet Radio Service, Ericsson Review, vol. 76, no. 2, pp. 82-88, 1999.
6. ETSI, ETSI GSM standard, www.etsi.org
7. M. Gospić: GPRS systems for data-transfer using GSM network: survey, Yu Info 2001, Kopaonik, March 2001 (in Serbian).

KONSTRUKCIJA PILOT-UREDJAJA ZA UNAPREDJENI MONITORING KVALITETA REČNE VODE NA RECI MORAVICI U SRBIJI

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Opšti cilj ovog projekta je poboljšanje menadžmenta kvaliteta vode u Srbiji kao primer izvrsnosti za region Jugoistočne Evrope. Biće kreirane bliže veze izmedju lokalnih i regionalnih preduzeća i visokoškolskih ustanova u Srbiji transferom tehnologije i znanja. Nove tehnologije, kao što je GPRS, biće primenjene radi transfera podataka sa udaljenih mernih stanica i upotrebljene za menadžment monitoringa kvaliteta vode. Rezultati projekta su program merenja za ARWQM (Advanced River Water Quality Monitoring), pilot stanica i edukovana posada stanice za realizaciju plana merenja, uredjaji uključujući GPS-tehnologiju, monitorska stanica sa testiranjem rada, šema menadžmenta kvaliteta, obuka osoblja monitorskih stanica, analiza podataka programa merenja i diseminacija i umrežavanje, kao što je finalna medjunarodna konferencija. Projekt je finansiran u okviru Tempus programa (Tempus Cards Structural and Complementary Measures) Evropske Unije.