Grid-based wide area water quality measurement system for surface water

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***Abstract* - The development of a surface water monitoring network is a critical element in the assessment and protection of water quality. We developed a prototype of easy to install technology by which the different surface water (e.g. rivers, lakes) quality indicators can be measured. The project pilot area is the Sajó river with 5 monitoring station. Thanks to the modular design of the sensor-tube, the equipment can measure from 1 to 7 indicators. The wide area measurement system (WAMS) communicate via the GPRS network. System design are detailed presented in the paper. Finally the measured results are discussed.**

Keywords - IoT, WAMS, GPRS, water quality, embedded system

I. INTRODUCTION

Water is used in various activities, such as consumption, agriculture and travel, which may affect water quality. Therefore, the water quality monitoring is necessary which includes several chemical parameters. Some of these are: pH, redox potential, conductivity, dissolved oxygen, ammonium and chloride ion amount. [1] [2]

The water quality problems of surface water bodies are predominately caused by organic and nutrient material loads. More than 90% of the River Basin Management Plans (RBMP) assessed indicated that agriculture is a significant pressure in the basin, including diffuse or point source pollution by organic matter, nutrients, pesticides and hydro-morphological impacts.

The RBMP gives the diffuse Nitrogen and Phosphorous load of each surface water body identifying the load from agricultural waste water body identifying the load from agricultural, waste water treatment plan, urban and other areas to the water body. There is need to improve existing system for monitoring water bodies, given that laboratory methods are too slow to develop an operational response and does not provide a level of public health protection in real time. Improve and expand monitoring and assessment tools to ensure a statistically robust and comprehensive picture of the status of the aquatic environment for the purpose of further planning. [3]

The project reviews new innovative technologies with the focus on the on-line monitoring and control.

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 programs,

• evaluating the effectiveness of management actions.

Preliminaries

At the University of Miskolc we developed a container-based water quality investigating station in the year of 2010. Several conventional water quality measuring device and a newly developed robot analyzer has been installed into the container. The water supply system carried out by a water-pump which is inside the container. The measured data was transmitted to the central server station via GPRS. In this project we used an Omron PLC to control the water quality measurement process. A personal computer was used for data acquisition and logging. For the communication with the server station the PC was responsible also.

A Robotic Water Analyzer placed into container are able to make continuous measurements and collect data even at extreme weather conditions. Measuring station is able to make automatic on-line measurement of main components of wastewater during 24 hours a day 7 days a week. The mobile station made sampling of wastewater every 2 hours. [2] [3]

The Robotic Water (RWA) is a Hungarian development. The RWA developed was adjusted which is suitable to carry out real time measurements on NH_4^+-N, NO_3^--N, PO_4^{3-}-P concentrations in the treated waste water and surface water. The measurements of the parameters are carried out on the basis of photometry with use of minimum amount of chemicals. The accuracy of the RWA measurements was controlled by cross checking the data with standard laboratory measurements. The measuring system was used at Hungarian waste water treatment plant. The primary objective of the RWA was to monitor the changes in orthophosphate-P concentration of the treated sewage water.

The online analyzer measurement results were compared with standard laboratory carried out. The measurement parameters were focused orthophosphate-P concentration

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determined, as a high concentration will cause eutrophication of the water.

The RWA technology is basically a cost effective, universal, automatic liquid handling robotic device equipped with sensor(s) for process water analytical purposes. [3]

II. Concept of the New Measuring System

The aim of this project was to monitor the quality of surface waters with an easy to install mobile technology. A new concept was conceived. It has been designed that two people can easily install.

As figure 1 shows the system is consist of 3 main parts. These are:

- the communication column,
- the pipeline between the column and water
- and the submersible sensor-carrier (sensor tube).

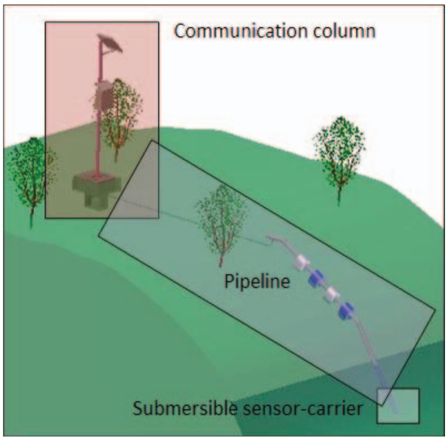

Fig. 1, Monitoring station concept

Communication column

The communication column (Fig 2) holds the solar panel, the instrument box and under the ground housed the accumulator protected from the environmental conditions (e.g. low temperature in winter). 50W solar panel and 60Ah accumulator was used in this project.

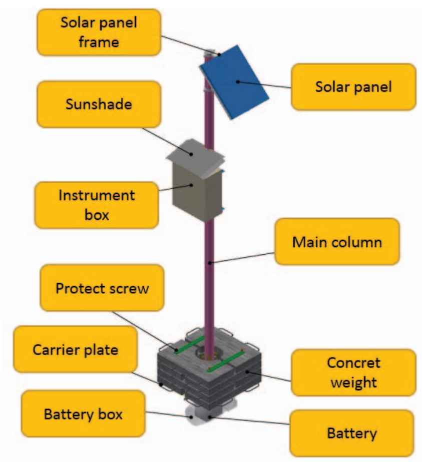

Fig. 2, Communication column parts

The column is responsible for communication on the one-hand with other measurement columns, on the other-hand with a server station via GPRS network.

The maximum length of the pipeline is about 50 meter. The big advantage of this system is that it is easier to install compared to other similar systems.

Submersible sensor-carrier

Glass electrodes was used for the quality measurements of water. It housed in a custom-designed sensor tube with the signal processing unit and level-interface electronics (Fig 3).

In the head of the carrier body 6 different water quality sensor and a submersible water level detector can be placed. The non-used sensor-places could closed by dummy plugs. The signal processing unit and the level interface electronics was placed in the body of the sensor tube.

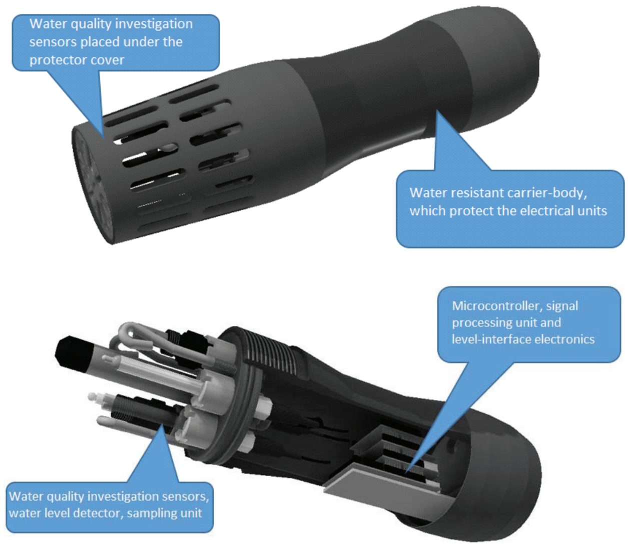

Fig. 3, 3D design of submersible sensor-carrier

The modular sensor tube was designed to connect the following electrodes and sensors:

- Submersible Level Transmitters (SBLT2-10-40)
- Redox potential sensor (ORP 01860676 01 0 1336)
- pH sensor (HI 1001)
- Conductivity and temperature sensor (1887155 01 0 1349)
- Dissolved oxygen sensor (451-741 014/DJ/S8)
- $NO3^-$ Nitrate Ion-selective electrode (E-531-ise-NO3)
- Cl^- Chloride Ion-selective electrode (E-531-ise-CL)

For the successful measurements required to calibrate the electrodes. The system can receive calibration data via the Bluetooth module in the instrument box.

A unique android application was developed for mobile phones to calibrate the electrodes. Linear and exponential (for the ion-selective electrodes) calibration was used in the system. It was calculated real-time by the CPU unit.

Electrical design

Arduino Mega 2560 (CPU) was used in the measuring system. These are communicating via UART (Fig 4). One of these is placed in the instrument box on the column. GPRS and Bluetooth board was connected to it. . It was responsible for

- the reliable and secure communication with the remote core server via GPRS VPN,
- data acquisition via UART communication with the another Arduino in the sensor tube and
- calibration data interface via the Bluetooth module.

The second Arduino was placed in the sensor tube with the following responsibilities:

- analog and digital signal processing,
- raw data scaling,
- communication with the upper Arduino (CPU).

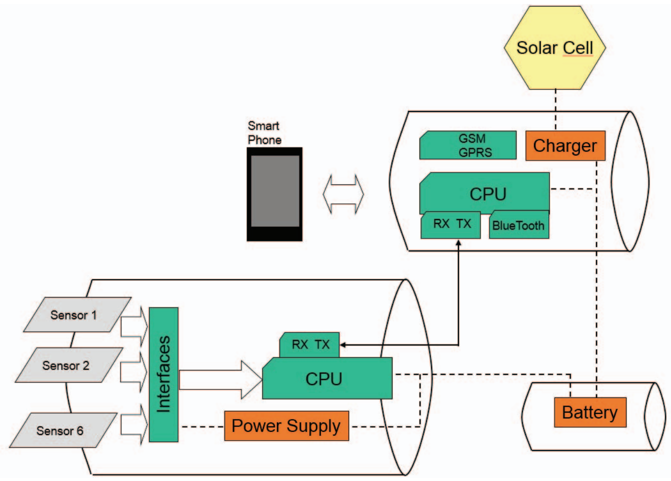

Fig. 4, Electrical design and wiring

Unique voltage/signal level-interface electronics was developed for each electrode. The level-interface electronics was placed in a main board that is connected to the Arduino (Fig 5). The main board is responsible for power transmission to the electronics and to connect the unified analog signal (0-5V) to the correct analog input of the Arduino.

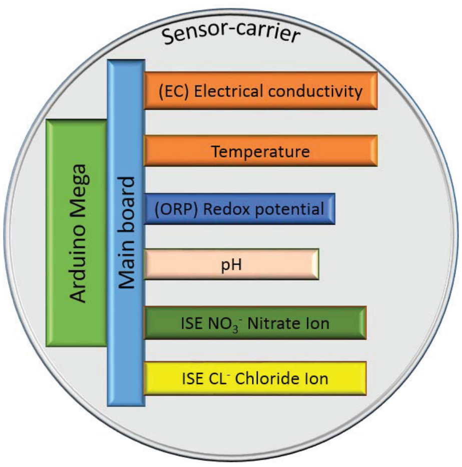

Fig. 5, Electrical design in the sensor carrier

Probably the simplest circuit is the pH electrode interface (Fig 6). It is a classic analog amplifier with high input impedance for glass electrode. It has no moving parts and can be used in the full range of pH (From 0 to 14).

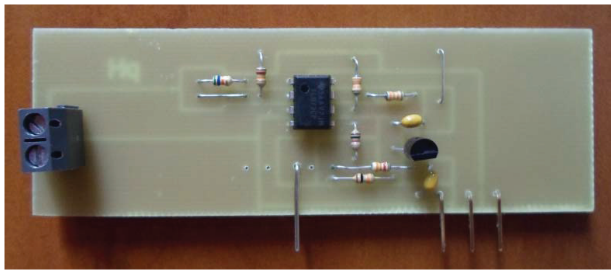

Fig. 6, pH electrode interface circuit

Temperature compensation was used in the system. In order to correct the pH value of a sample to the calibration temperature, the following formula was used in the software.

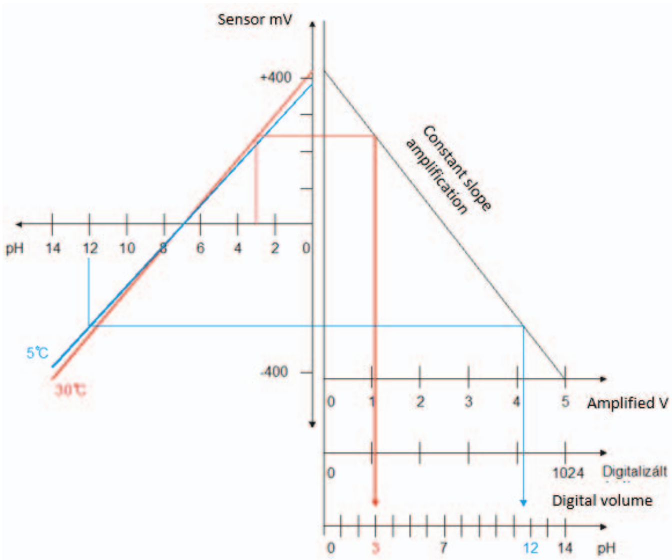

Fig. 7, pH signal amplifier with constant slope

Most pH sensors are designed to produce a 0 mV signal at 7.0 pH, with a (theoretically ideal) slope (sensitivity) of -59.16 mV / pH at 25°C. Figure 7 explain the constant slope amplification of a pH electrode. Temperature compensated pH was calculated by the next form:

$$S(Tsample) = S(Tcal) * \frac{T(sample) + 273.15}{T(cal) = 273.15},$$

where S is a slope of the electrode, T is temperature [°C] and cal is calibration.

With the new calculated slope S(Tsample) from the mV signal, the pH of the sample can be calculated at sample temperature T(sample). A linear relationship is assumed between sample pH and temperature.

The ORP sensor has a range of –2,000mV to + 2,000mV. The measuring range of an EC sensor is between 200uS and 2000uS.

III. Measurements and Results

In this section some of our measurements will be presented. The following examples are measured between April 3, and April 8, in 2015.

Figure 8 shown the water level calculated from the pressure. The horizontal axis shows the date, the vertical axis shows the water level in meters.

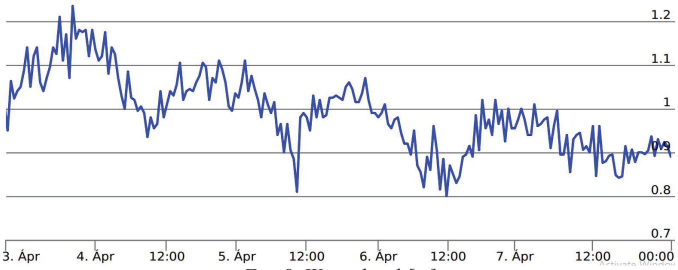

Fig. 8, Water level [m]

The next diagram (Fig 9) shown the nitrate ion concentrate of the river. NO3- is an ion-selective electrode with exponential scaling. Vertical axis represents the nitrate level in ppm.

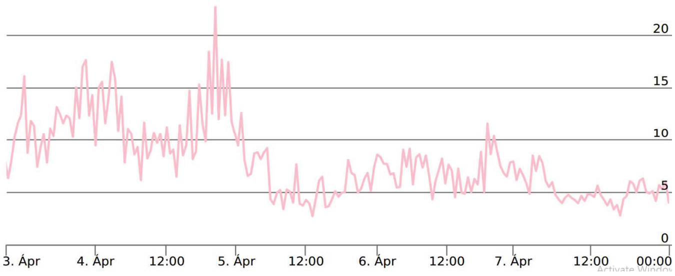

Fig. 9, nitrate level [ppm]

Almost all natural waters contain chloride ions. In small amounts they are not significant. In large concentrations they present problems. Figure 10 shows our chloride ion measurements.

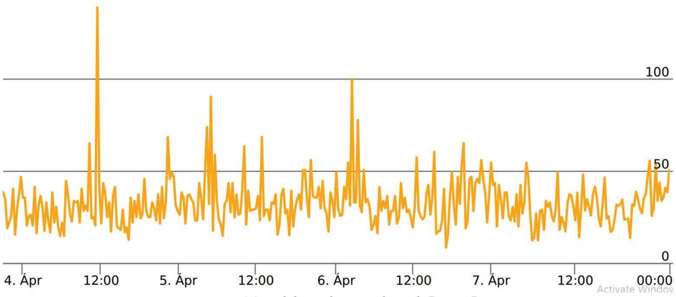

Fig. 10, chloride ion level [ppm]

ORP (Fig 11) is typically measured to determine the oxidizing or reducing potential of a water sample. It indicates possible contamination, especially by industrial wastewater.

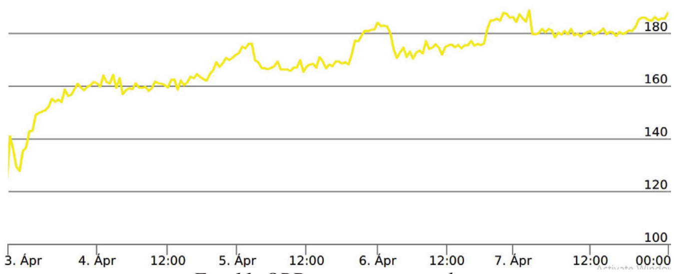

Fig. 11, ORP measurement values

Electrical conductivity (EC) estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. Figure 12 shows the EC measurement results.

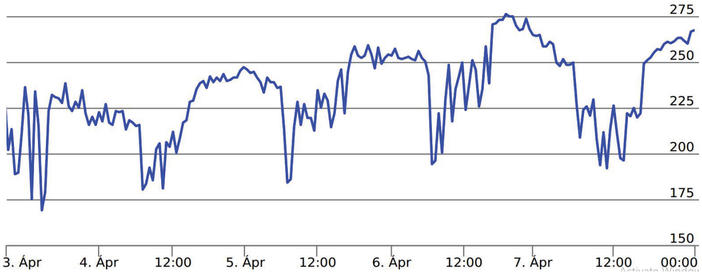

Fig. 12, EC measurement values

The pH value is a good indicator of whether water is hard or soft. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 to 8.5. Figure 13 shows our measurement from the Sajó River.

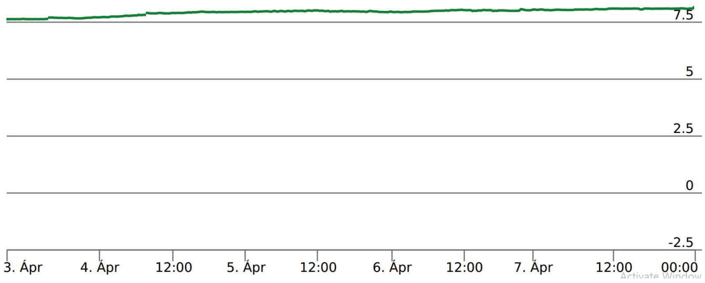

Fig. 13, pH measured from the Sajó River

IV. Conclusion

The system presented in this paper is suitable to monitor the main quality indicators of surface water. It is modular and easy-to-install. It provides a forecast of the possible spread of contamination. GPRS was used for communication that is available in most parts of Europe.

For the microcontrollers and other electric circuits used in this system the 50W solar panel and the 60Ah accumulator are adequate.

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