EXPERIENCE AND ORGANISTATION OF AUTOMATED MEASURING STATIONS FOR RIVER WATER QUALITY MONITORING

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ABSTRACT
Automated Measuring Stations (AMS) for river water quality monitoring have been used on the Belgian Zwalm river, to generate on-line measurements of water quality variables. Although a high degree of automation has been implemented at the levels of measurement, maintenance & control, data communication and data management, the resulting data series easily inherit errors and uncertainties. To ascertain confident series, organisation and standardisation at the different levels is needed. The experience of one year of measurement gives a lot of insights in the strong and weak points of AMS. Generating a data set with AMS is easy, but ascertaining the confidence of the data requires human supervision and follow-up.

KEYWORDS
Automated Measuring Stations; on-line measurements; rivers; water quality monitoring

INTRODUCTION

Automated Measuring Stations (AMS) are supporting tools for water quality survey, control strategies and computer model simulations as they measure quickly and frequently several water quality variables. Also, Fronteau (1999) concluded that low frequency sampling - such as the monthly sampling performed by the Flemish EPA - are not sufficient to calculate reliable water quality indexes and thus to give an accurate view of the river water quality.

The paper presents the experience of one year of measurements with three measuring stations on the Zwalm river in Belgium.

DESCRIPTION OF THE AUTOMATED MEASURING SYSTEM

The measuring system

For the given AMS, the river water is pumped through a hydraulic loop that is placed inside a closed cabin (figure 1). At the entrance of the loop, the turbidity is measured and a bypass to the sampling system is available. After filtration (100µm), temperature, conductivity, pH, dissolved oxygen and redox potential are measured in the loop. Ammonia and nitrate are measured with ion-selective electrodes in small reservoirs that are filled at regular times and to which buffer solutions are added. The sensors are connected to transmitters where the signals are transformed to 4 -20 mA signals that are sent to the data logger. Solar radiation, precipitation and water level are measured in situ.

Data transmission and management

The logging time step is set by the user. At every time step, an ASCII string with all measurements and alarms is formed and stored in the data logger. The logger has an autonomy of 10 days for a sampling interval of 10 minutes. Two data strings are combined to form one "Short Message Service (SMS)" message and are automatically sent to a central using the Global System of Mobile Communication (GSM). In the other direction, SMS messages can be sent to give a command, for instance to send all data or to start the sampler. In the central computer, the data are daily automatically backed up and imported into a relational database.

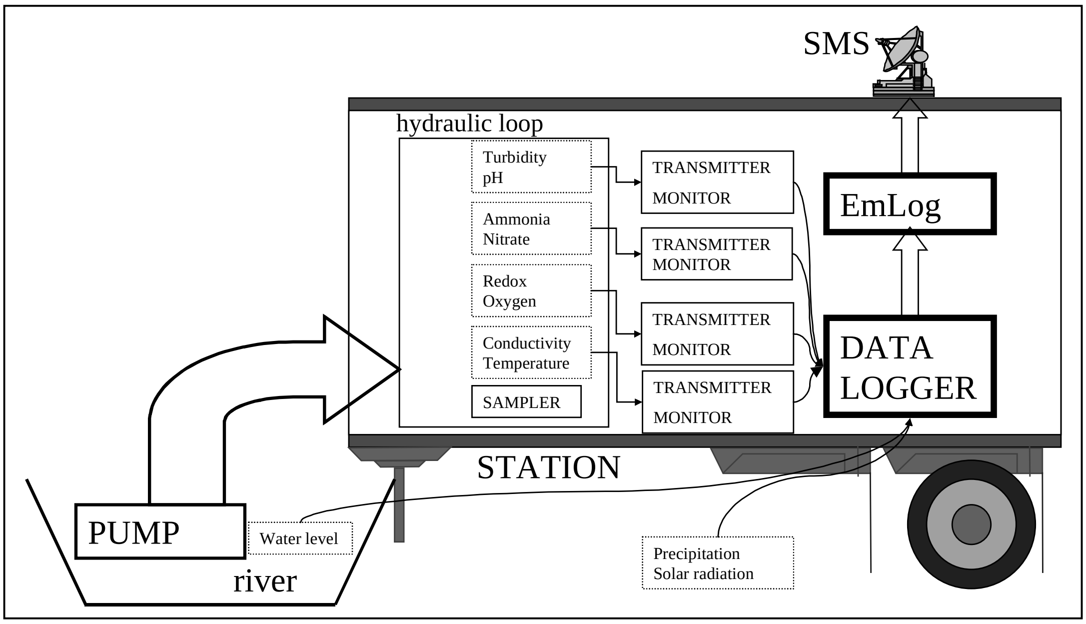

Figure1. Scheme of the measuring station

Maintenance & control

The station requires a weekly control and maintenance visit by two team members. Automated maintenance is limited to the rinsing of the filter and the electrodes. With this respect, one of the main problems with the AMS was related to the adhesion of silt and clay on the electrodes and even clogging of the system, due to very high concentrations (1500-2000 mg/l) of very fine suspended solids in the water during floods on the Zwalm river. The 100 µm filter, placed to retain the suspended solids, does not retain those highly adhesive fine clay particles. These conditions are rather extreme but far from exceptional in Southern Flanders. The original system, whereby filtered water was used to rinse the system, was not able to remove those particles and had to be replaced by injection of air under pressure (every 15 minutes). This improved the situation, but didn’t solve the problem completely.

Remote control of the functioning of the system is facilitated by the generation of alarms in case of malfunctioning of the sensors (signal out of range), low flow or pressure in the loop or low air temperature in the cabin.

VALIDATION

One of the main challenges for AMS is to operate according to standard guidelines. Standard methods for this type of monitoring can be found in APHA (1995) and ASTM (1990). When different error sources can act simultaneously on the output, the validation and calibration of a station is a complex problem. The latter is especially true during the start-up period of an AMS.

Calibration errors (Bols, 1999)
The quality control with respect to the calibration is based on the use of control sheets and on the analysis of the calibration characteristics.

Control chart. A control chart, also known as Shewhart chart (NMKL, 1990), aims at the detection of systematic errors by comparing the total error to the random error. Careful and repetitive measurements of the concentration of a standard solution with an electrode allow for the determination of the standard deviation $\bar{s}$ and mean value $\overline{X}$ of the measured values. The control charts consist of a mean-value line, two warning-lines at $\overline{X} \pm 2\bar{s}$, and two limit-lines at $\overline{X} \pm 3\bar{s}$. The lines coincide with a probability that random errors lie between them with a probability of respectively 95 % and 99.7 %. At every visit, the sensors are controlled with standard solutions and the measured values are filled in the chart as shown on figure 2. Full calibration is needed when either one measurement lies outside the limit-lines, 2 successive measurements lie outside the warning-limits, 7 consecutive points lie above or below the mean value-line or 7 consecutive points have a continuously increasing or decreasing course.

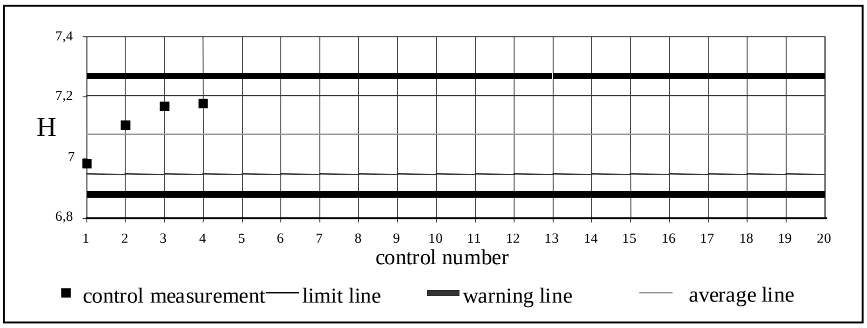

Figure 2. Control chart for pH electrode on standard solution pH7 (Bols, 1999)

Calibration characteristics. The electronic signal of a sensor is transformed to a concentration through a linear calibration curve. After calibration, the slope and intercept of the curve are compared to historical values. The latter allows for a follow up of the evolution of the response of the electrode and may e.g. show signs of ageing of an electrode, for instance when the slope reduces to unacceptable values. It is also important to check the linearity of the calibration curve by plotting the electronic signal versus the standard concentration value for several concentrations.

Interference
The influence of *temperatur*e on electrodes is known and is automatically compensated. Originally, temperature sensors incorporated in the sensors were used to this purpose. It was found out, however, that the measured temperature was influenced by the temperature inside the cabin, as the sensors were only partly in the water. Separate temperatures sensors were therefore installed and used for compensation.

Another problem was the sensitivity of the oxygen electrode to *pressure* variations within the loop. The electrode had to be moved from the loop to a branch under atmospheric pressure.

Error on response time
The analysis of the response times for the given system was critical, due to the need to rinse the system at regular times. It was therefore decided to freeze the measurements during the response time after the rinsing cycle.

Errors in the measurement procedure

Examples of problems that may occur with respect to the measurement conditions deal with clogging of the system and the fouling of membranes with sludge. The gradual clogging of the filter or of the loop or a failure of the pump may lead to (quasi) stagnant water in the measuring system, resulting even in anaerobic conditions. It is therefore imperative to monitor the flow and/or pressure in the system, so that erroneous data due to such phenomena can be eliminated from data set. As the formation of a sludge layer or bio-film on the membranes of the electrodes is a gradual process, it is not easy to generate an alarm. The best is to avoid such conditions, through automatic cleaning of the sensors and the filter and by manual cleaning during the regular maintenance visit

EVALUATION AND CONCLUSIONS

Only after about one year of activities, the first reliable data series are being collected. Buying an AMS is like buying a new house: one should first have bought one to have the necessary experience to buy one.

The use of a hydraulic loop in a sheltered environment facilitates the maintenance and calibration as compared to multi-probe systems that are put in the river. However, in rivers with high sediment concentrations, filtering, clogging and fouling of membranes is a severe problem. Also, the position of the sensors in the loop must be studied carefully with respect to pressure effects, sedimentation and simply the required position (vertical or horizontal) for the well functioning of the sensors.

As a final conclusion, it can be stated that AMS can provide time series of important water quality variables with reasonable accuracy, provided an extensive follow-up. While it probably cannot be expected to obtain with ASM the precision that can be obtained under controlled laboratory conditions on samples, ASM offer the advantage of continuous monitoring. Their usefulness should therefore be evaluated in view of the objectives of the measurements.

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