AUTOMATED MEASUREMENT STATIONS FOR RIVER WATER QUALITY MONITORING

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ABSTRACT

The recent technological developments in analysis and sampling systems as well as the need for high resolution datasets for integrated water quality modelling have led to the increased application of Automated Measurement Stations (AMS) in river water quality monitoring projects.

However, the investment and maintenance costs of AMS are high and therefore considerable prior research is essential before defining, ordering, buying, setting up and running AMS (Goethals et al., 1999). Moreover, still a lot of operational problems are inherent to these systems. This often leads to inaccurate and unreliable measurements. To optimise the application of AMS an in depth integrated quality control study is essential. Most of the problems find their origin at sensor level, but also other parts within the measurement process may be affected by technical problems so that every aspect of the measurement process must be controlled (Goethals et al., 1999).

SETTING UP THE AMS AND FIRST VALIDATION

In this study, an application of AMS for monitoring river water quality is evaluated. In 1998, the University of Gent and the Free University of Brussels bought three identical AMS (Fig. 1) for river water quality monitoring. A pump placed in the river continuously supplies water to the station. Inside the cabin, part of the water is filtered and brought in contact with several sensors that measure the following variables: pH, dissolved oxygen (DO), redox potential, temperature, conductivity, ammonium-concentration and nitrate-concentration. Turbidity, water-level, short wave radiation and rainfall are also measured, making a total of eleven on-line logged variables. All these measurements which are collected in a central datalogger can be stored for several days or sent directly via an SMS-message through GSM to a central computer at the VUB. On top of this, a refrigerated sampler with 24 bottles allows to take samples for additional laboratory analyses.

The objective of this study is to optimise the performance of the AMS. In the first place, this means getting accurate and reliable measurements. Second, it means that a quick and easy working method is obtained. The optimisation is carried out on three levels (Bols, 1999).

First of all, procedures and manuals have been worked out for the functioning, the calibration and the maintenance of each sensor and for the handling of the entire station. This must lead to a readily understandable, quick and standardized manner of managing the AMS.

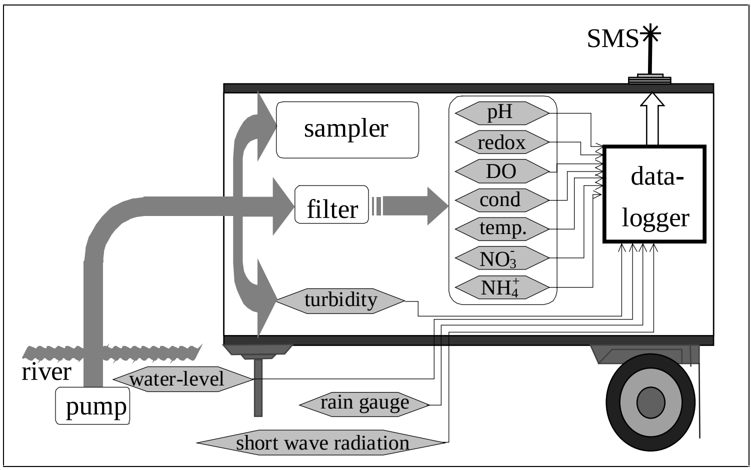

Fig. 1. Schematic representation of the AMS

Secondly, a method has been developed for total quality control of the measurements based on Bothe (1997). This is done by monitoring the sensor's calibration characteristics and by means of control charts. These two methods focus on two fundamentally different aspects of the measuring process so that they are complementary. Monitoring the calibration characteristics like the slope of the calibration curves, allows continuous evaluation of the health-state of the sensor and is a more general, long term quality control strategy. Control charts allow the user to determine the minimal maintenance for a certain confidence level of the on-line measurements and also helps the user to decide when to intervene in the measurement process based on measurement references. This is done by experimentally determining the bias and the standard deviation through repeated measurements of standard solutions. To apply the control charts for on-line measurements instead of the usual off-line measurements, the procedures that are normally used had to be adapted. More specifically, adaptations had to be made regarding the number of control measurements needed to obtain the bias and the standard deviation. Although both methods have their weaknesses, they should allow the user to have a reasonably accurate idea of the quality of the measurements. However, the ultimate quality-control tool is the frequent validation of the measurements. This is explained in the next paragraph.

The third level of the optimisation of the AMS is the validation of the different sensors. The validation is done by repeatedly comparing the measurements of the on-line sensors with the measurements of portable or laboratory sensors. The results of the sensor validation are shown in Fig. 2. This shows the range of the errors in terms of percentage together with the indication of the mean of the measured errors. From this, it is obvious that, except perhaps for the pH sensor, the sensors have too high errors. Especially the nitrogen sensors and the temperature sensor have enormous errors with up to 1000% for the ammonium sensor.

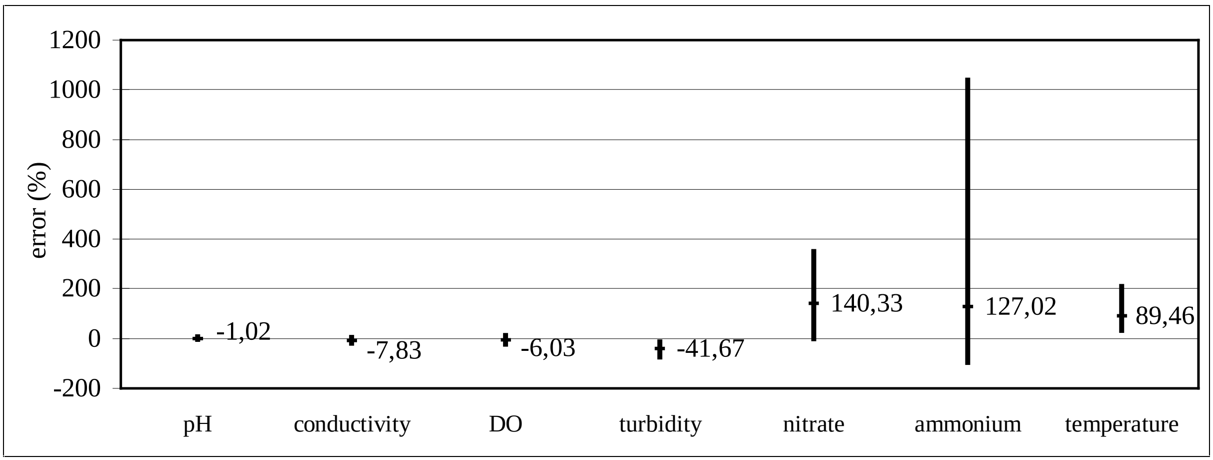

Fig. 2. Range of errors in terms of percentage of the first validation with indication of the mean of the errors

PROBLEM SOLVING AND SECOND VALIDATION

Because of the large errors that occurred during the validation, the functioning of each sensor was studied in more detail. Several fundamental causes of errors were found and solved. Because it is not possible to give an overview of all problems that were encountered, only two examples are highlighted.

The first example is the temperature sensor. The temperature was originally measured with the built-in Pt-1000 sensor of the conductivity electrode. The Pt-1000 sensor normally is very precise and accurate. However, as can be seen in Fig. 2, the errors on the temperature measurement were very large with a mean error of around 90%. The problem with the temperature sensor was that it didn't measure the temperature of the pumped water, but the temperature of the inside of the conductivity sensor which was influenced by the air temperature. This problem was solved by immersing a separate Pt-1000 sensor directly in the water.

The second example concerns the washing system of the filter and the sensors. The filter was originally backwashed every 5 minutes with filtered water while the sensors were not washed at all. This system was not efficient because the filter clogged very rapidly and the sensors were often covered with sludge that could pass the 0,1 mm filter (clay particles). This had an effect on all the sensors and caused wrong measurements because the water had a too low flow and because the sensors measured the variables within the deposited sludge instead of the river water. Moreover, it also caused a rapid deterioration of the sensors. The washing system with water was replaced by a system with injection of compressed air during the washing cycles, in which, apart from the filter, also the sensors are washed separately.

After these and many other adaptations, a second validation was carried out of some sensors. The results are shown in Fig. 3. As with the first validation, results are given as the range of measured error in terms of percentage. On the left, for each sensor, the results of the first validation are shown. The results of the new validation are shown on the left for each sensor. When compared to the results of the original validation, it is obvious that the range of errors has diminished and that the precision of the measurements has increased (except for pH). A closer look, however, shows that for most sensors, there is still a considerable amount of error. This means that the measurements are still not accurate. For now, only the temperature sensor is accurate enough.

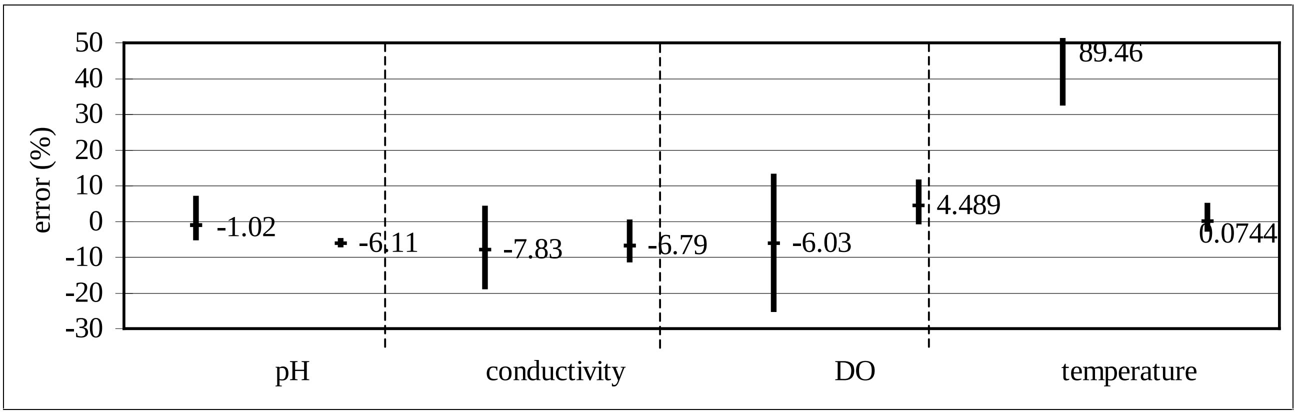

Fig. 3. Range of errors in terms of percentage of the first and the second validation with indication of the mean of the errors

It can be concluded that the objectives of the study are only partially achieved. Especially the nitrate and ammonium measurements are completely useless. Moreover, the causes of these errors are unclear. Other variables, like turbidity, redox potential, rainfall, short wave radiation and water level have not been investigated sufficiently, due to technical problems and lack of time. The measurements of pH, dissolved oxygen and conductivity still suffer from systematic errors that are higher than the ones that usually occur with comparable sensors. Further research is thus needed to obtain reliable measurements from the other sensors.

CONCLUSIONS

From this evaluation, it can be concluded that problems can arise at every level. Also, it has to be noted that many problems are linked to each other, which makes the upgrading even more difficult. In this view, it is essential to make the right choice of equipment supplier who can prevent problems and reacts efficiently to suddenly arising problems. Another point of importance is the intelligence and the degree of automation of the AMS. This is largely absent with the AMS under study. Especially the possibility to perform automatic quality control of the measurements is completely lacking. Current manual quality control is very labour-intensive and requires a lot of time. A smart system is essential because it can lighten the pressure on human labour so that more attention can go to special tasks and problem solving. Finally, depending on the application, it may not be necessary to have continuous measurements of all eleven sensors. It is better to have few variables that are accurately and reliably measured than a lot of variables that are inaccurate.

Although the methods, problems and solutions, discussed here are specifically applicable to this type of AMS, our experience can also be valuable for other systems. Most of the problems are not isolated cases but also occur at other on-line applications. Also, practical problems with on-line measurements are not often described in literature. From this, one might conclude that it is often required to first perform prior research and acquire sufficient experience before reliable measurements can be realized.

ACKNOWLEDGEMENT

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