Innovative technology for integrated water quality measurement

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Abstract

With the release of the EC water framework directive, water quality management will become a trans national issue on a catchment scale, requiring exchange of water quality data between governing boards and water authorities of the different member states. One issue for water quality management is to have sufficient and comparable information about the water quality and the impacting factors and effectiveness of measures taken. Based on novel technologies, a modular monitoring station suitable for continuous application in sewers, wastewater treatment plants and surface water bodies has been designed. The monitoring stations serve as the backbone of a water quality pilot network, that is currently tested at different locations in Austria. The network also includes a central data base server, where the collected data is processed consistently and stored in a standard format. The water quality network design shows new perspectives with respect to continuous and consistent water data collection and processing, which is a prerequisite for decision making in water quality management.

Keywords

EC water framework directive, integrated water management, river monitoring, sewer monitoring, water analysis, water quality network, WWTP load control

INTRODUCTION

One crucial issue within water quality management as required by the EC water framework directive (Directive 2000/60/EC) is to have sufficient and comparable information on water quality and the impacting factors as well as effectiveness of measures taken (trend monitoring). Today local and national authorities operate a number of laboratories and research facilities which provide the requested water quality data, at most based on laboratory analysis on a monthly scale for a monitoring purpose.

Water quality management is a process of making decisions based on the available information. Thus, the information demand is in strong interaction with the decision to be made, subsequently different problems require different levels of information with respect to parameters, accuracy and resolution in space and time. Thus, the current practise of water quality monitoring is not sufficient to support water quality management. In addition, in order to increase exchange and use of information, standardisation of the applied methods for water analysis and data processing – also very important – a standard data format has to be promoted.

The demand for information also raises the question, which parameter is indicative for the respective problem. For example, organic pollution can be expressed by a large number of parameters: BOD, COD, DOC, TOC, SAC etc.
Even if it is agreed upon one specific parameter to describe the organic pollution in water, it is difficult to compare two values for management purposes. For example, 100 mg/l of COD measured at a combined sewer overflow have a significant different impact on water quality than 100 mg/l of COD measured in the effluent of a WWTP, due to the completely different composition of these waters and subsequently the biodegradability.
In contrast, in order to build an information network, it would be valuable to determine specific parameters that can be used to express the organic pollution independent of the addressed problem. It also has to be considered, that the acceptance of a specific parameter is often not only a question of the validity and scientific acceptance but the dissemination, availability, robustness and ease of use.

In 1998 a research cooperation between the Vienna University of Agricultural Sciences, Graz University of Technology, Vienna University of Technology and Depisch civil engineers was founded in order to investigate innovative forms of measurement and processing of water quality data. In a first project phase the impact of agricultural land use and a municipal wastewater treatment plant on the river Poellau were used to exemplify the possibilities of various innovative measurement techniques. Later the project was extended to include a detailed investigation of the processes within a treatment plant (Depisch, 2000).
The project presented here is a continuation of these studies. The main focus of this phase is the design and operation of a water quality network which is suitable to support decision making on a catchment scale. Therefore a modular monitoring station was designed, which is suitable for application in sewers, wastewater treatment plants and surface water bodies. Special emphasis was put on the uniform design of the monitoring stations which supports a given set of sensors, measurement devices and aims at a consistent data collection. A central database was designed to collect the data from all stations within the network and process all data in a standard format. The telemetric network has two tasks: Data will be presented and continuously updated on a project homepage and remote control and maintenance on demand is possible.
The monitoring stations will be operated over a period of one year.

WATER QUALITY NETWORKS

Water quality data on a catchment scale

On a catchment level scale a large number of subsystems interact with each other and have a resulting impact on the water quality and quantity. For combined sewer systems management of the sewer networks influences the load into the connected WWTP and subsequently the load discharged into the receiving water body after treatment. Design and operation of the wastewater treatment plant limit the maximum hydraulic and organic load that can be treated, which defines the volume of stormwater that has to be retained in the sewer network or that is to be discharged without treatment in case insufficient stormwater storage volume is available. Depending on the investigated area, the impact of stormwater discharge may be insignificant compared to the load from surface runoff.
For example in Austria, the central Vienna WWTP treats around 20 % of the total wastewater amount of wastewater in Austria, thus, design and operation of the plant and the connected sewer network have a significant impact on the load discharge from urban drainage not only of the Vienna region, but also of entire Austria. On the other hand, investigations by Zessner and Kroiss (1999) showed that the yearly load variations of nitrogen in the river Danube at Vienna is larger than the entire nitrogen load discharge from all wastewater treatment plants in Austria within one year. In

the same study two flood events in July 1997 at the river Danube were investigated, showing that during a period of six days around 3,000 tons of phosphorous were transported which corresponds to 36 % of the yearly phosphorous load of the Danube at Vienna. For comparison, the yearly phosphorous discharge of the central Vienna WWTP is around 180 t/a.

For a small receiving water body being part of a larger catchment area, the influence of a single wastewater treatment plant can be dominant (Franz et al., 1996), on a larger catchment scale the influence of the same treatment plant maybe insignificant. Subsequently, the information requirements for water quality management is also strongly influenced by the selection of the catchment scale.

Finally, technical availability is a major factor which influences the type and resolution of the accessible water quality data. The costs for labour intensive laboratory methods are a limiting factor for the application of these types of quality analysis. The cost of on-line analysis is generally not influenced by the measuring frequency, but the required maintenance effort. For a water quality network it may be necessary to operate monitoring stations in remote areas, therefore, issues like energy consumption of the sensors and auxiliary equipment and the required service intervals may become the deciding factor which type of water quality data is measured on-line.
In addition, often sensors prevail, which do not deliver a required parameter, but a surrogate or aggregate parameters that proved to work reliably. Simple physical measurements are often preferred over complex chemical analysers, which may deliver high precision but are complicated to operate and require a lot of maintenance. After all, the main goal is to get the required information sufficiently and reliably with the lowest possible effort.

The modular water quality monitoring station
The above mentioned considerations were included in the design of a monitoring station which can serve as the backbone of a water quality network. The main goal was that the monitoring station can be applied in surface water, sewers and WWTP´s in an uniform assembly. The selection of the applied sensors was based on the requirements of the different monitoring locations and experience within the group concerning the reliability and precision of available sensors. Each station is equipped with a powerful industrial PC suitable for exterior installation. The station PC serves for control of the monitoring station and intermediate data storage. All sensors are directly linked to the station PC via a bus-interface, or in one case via an analogue input without an intermediate signal transformer. This significantly reduces the number of signal transformers and connecting lines, which reduces the time required for station installation and prepares the ground for a mobile state-of-the-art monitoring station. All sensors are controlled and operated via the station PC.

All the selected sensors are compact in size, can be installed directly in the water and do not require sample preparation or periodic refill of chemical reagents. Some limitations have been observed with respect to the availability of Ex-proof sensors, which are required for application in sewer networks. This circumstance resulted in the installation of a measurement container for the sewer monitoring station, where the non-Ex-proof sensors are installed. All but one sensor are equipped with an automatic cleaning system using pressurised air or water. Besides standard parameters like dissolved oxygen, pH and conductivity focus is given on the continuous monitoring of nutrients and organic compounds.

For ammonium monitoring a ion-sensitive in-line sensor was chosen, since it is an comparably low-cost sensor requiring relatively low maintenance when applied within a WWTP (Rieger et al., 2002). No experience with this sensor is yet available within the research group with respect to application in raw wastewater or surface water. An advantage of this sensor type is that two electrodes can be fitted into one probe head, which enables easy change to other ion-sensitive electrodes, like for example chloride or bromide.

For continuous monitoring of organic compounds a submersible UV-VIS-spectrometer will be applied. Experiences with this instrument have already been made through applications with riverbank filtrate (Langergraber et al., 2001) and at different measurement locations within wastewater treatment plants (Winkler et al., 2002). An advantage of this instrument is that a large number of parameters – for example CODeq, BODeq, turbidity and nitrate – can be measured simultaneously with only a single instrument.

The water quality monitoring network

A central data server is connected to all monitoring stations via a dial-in connection using a TCP/IP-protocol. The central server periodically connects to the field stations for data transfer. The collected measurement data is processed by means of plausibility algorithms and then stored in a central data base. Data aggregation algorithms are automatically applied on the raw data sets, the results are stored separately in the central data base.

An identification list of all measured parameters is administrated in the central data server. This list provides a unique identification of each measurement signal collected within the network. Second, each sensor is identified by a unique serial number, the sensors list is administrated in the central data server. Based on this two lists the configuration and installation of a field station can be carried out, station specific properties are defined during the installation procedure and stored in a configuration table in the station PC. After finishing the station configuration the configuration table is transferred to the central data server.

With the configuration information from each station a data monitoring tool is set up in the central data server, which provides all required information for unique identification of any given measurement signal of the network including the valid settings (for example measurement range or calibration settings) for a specific period including sensor identification. The automatic administration of these configuration data is essential for evaluating long time series of measurement data.

MEASUREMENT LOCATIONS

Combined sewer overflow

In combined sewer systems the ratio of wastewater to stormwater can reach up 1:100 during heavy rain events (Butler, D., Davies, J. W., 2000). For economical reasons it is unfeasible to build sewers that large, that such peak flows can be transported along the full length of the sewer. Therefore special structures are integrated in sewer systems, which divert flows above a certain level out of the sewer system and into a natural watercourse or buffer these flows in special tanks. After the rain event the stored stormwater is returned to the sewer system. The simplest of these structures are called combined sewer overflows (CSO), which have only a diverting and no buffering effect. CSOs are designed with the intention of retaining as many solids as possible in the sewer system.

One monitoring station will be installed at a combined sewer overflow in Graz, later in the project another station will be installed at a CSO in Vienna. Currently, the monitoring station in Graz is under construction, which includes considerable efforts for the required infrastructure (sensor installation in the overflow chamber, measurement container and connecting lines).

The selected catchment in Graz serves a population of 13.000 inhabitants and has a total catchment area of 102 ha. The spill channel of the CSO discharges in the river Mur which, at Graz, has an average flow of 117 m³/s. Figure 1 gives an overview of the measurement location and lists the installed equipment. A video camera and lighting is built in the chamber complementarily to observe the overflow events.

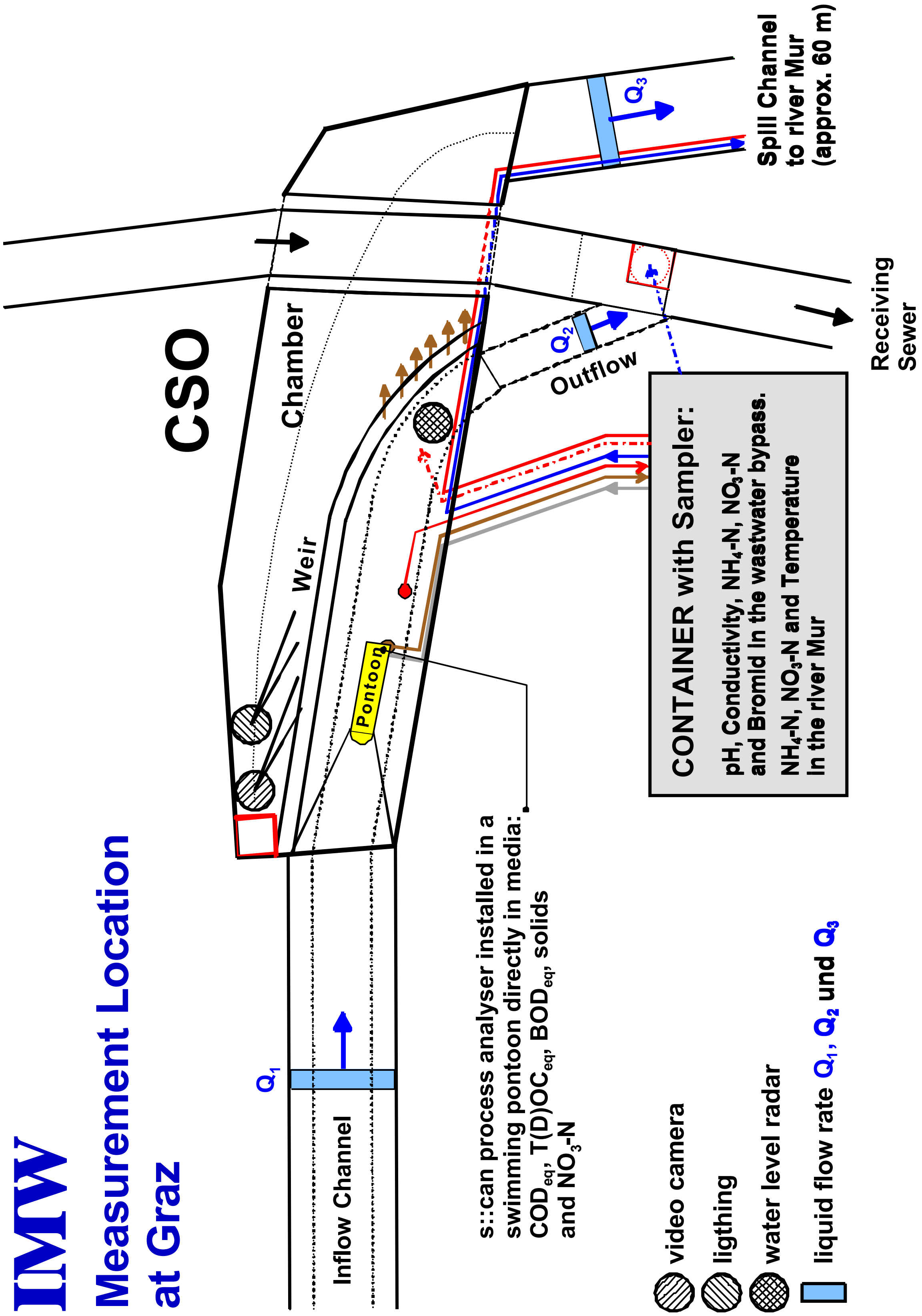

Figure 1: Layout of the CSO monitoring station at Graz

In the sewer channel an UV-VIS spectrometer situated in a swimming pontoon is installed directly in media. Most sensors will be installed in a measurement container, sample supply is by means of a small peristaltic pump (2-3 l/min) which is installed in the overflow chamber.
For flow measurement a water level radar is installed, which also triggers the video recorder and an automatic sampler in the case of an overflow event. For measuring the inflow and outflow of the chamber three flow meters will be installed.
The automatic sampler will be operated with a high sampling frequency, in order to get a sufficient number of samples during the first flush of the overflow event. Analysis of the samples will be carried out in order to evaluate the on-line measurements. In order to have identity of samples, the inlet hose of the sampler will be fixed to the swimming pontoon.
Besides it the measurement of NH_4-N, NO_3-N and temperature in the Mur is planed complementarily for monitoring the discharges of CSOs upstream the measurement location.

Wastewater treatment plant
One goal of the project is to provide continuous monitoring of the activity of nitrifying bacteria by means of continuous oxygen uptake measurement. The oxygen uptake rate (OUR) is an excellent indicator of the activity of an activated sludge system. Assuming no inhibition, it is additionally an indicator of the plant load.
Nitrifying bacteria are characterised by a low growth rate and high sensitivity against milieu changes – like a decline of the pH-value, the temperature or the occurrence of inhibiting substances. Nevertheless, a negative impact on the nitrification population is not immediately shown in the plant performance, especially if plant monitoring is based on analysis of daily composite samples.
With the help of continuous OUR-monitoring the diurnal variation of the nitrification activity can be shown and put into perspective with other plant data like flow, load and temperature dynamics. Monitoring of the nitrification activity will be carried out by two different methods. One will be measurement of the maximum oxygen uptake rate due to nitrification (OUNmax), in the presence of excess ammonium. The second is to monitor the dosage of NaOH-base in order to keep the pH-value constant during the nitrification process.
Both methods will be carried out by means of a ball type in-situ respirometer. This instrument was chosen, since it is directly installed in the tank and subsequently does not require an installation for sludge supply. It is equipped with an aerator, a mixer and the following sensors: Temperature, pH, conductivity, dissolved oxygen and MLSS. Dosage of substrate, NH_4Cl, ATU, NaOH and automatic pH-control is carried out by peristaltic pumps controlled by a PLC-controller.

Application of sensors within wastewater treatment plants has increased over the last years, but still some reservations concerning the use of on-line measurements can be observed. This is caused by a number of factors, like the cost, the required maintenance effort or sometimes insufficient training of the operating personnel. As a result, dynamic data availability is limited.
Therefore, one monitoring station will be installed at the influent of a wastewater treatment plant. The measured parameters include ammonium, pH, conductivity and UV-VIS-absorbance. These measurements provide a comprehensive information of the plant load dynamics and possible peak loads. They provide a valuable data base to detect the causes of operational disturbances and subsequently for operation optimisation. Finally, such data is also very helpful if an extension of an existing plant is to be designed, since from such data the load variations can be derived and subsequently the required equipment can be designed accordingly.

Danube river downstream the central Vienna WWTP
One monitoring station will be installed at the river Danube, downstream of the central Vienna WWTP. The automatic measuring system will deliver data distinguished from traditional monitoring.

In particular it is planned to point on following aspects:

- sensitiveness during trend detection
- interrelationship of cause and effect
- interference of local conditions (especially mixing aspects, sewage plume, homogeneity of the cross-sectional flow area)
- periodicity of data
- differentiation between background load and selective influence

The measurement location was chosen in order to observe the influence of this large WWTP on the river water quality. It is currently extended from 2.5 Mio. to 4 Mio. PE in capacity (Mueller-Rechberger et al., 2001), the extended plant will start operation in 2005. The monitoring campaign will provide reference data for later measurements after the start of the operation of the new plant.

During and after the monitoring campaign, an interpretation of the stored data with reference to the stability of the used sensors and the expressiveness of the chosen parameters is to be done. One deliberate fact in addition is a continuous data set, to observe possible and expected changes in the water quality. Trend detection and identification is very difficult by monitoring huge water bodies like big lakes or fast flowing rivers. Especially, due to the extension of the central Vienna WWTP it is very important to measure the observed parameters continuously to ensure no accidental differences in the data by using only selective measurements.

A small measurement container (Figure) will be installed, which accommodates auxiliary equipment like a compressor or the station PC. All used sensors are installed directly in the Danube river, the connection lines are protected by strong pipes reaching directly into the river.
The following parameters will be measured: Conductivity, temperature, dissolved oxygen, ammonium, nitrate, pH, redox potential, and UV-VIS spectrum.
For data transmission a GSM-connection was chosen. Initially, it was planned to operate the station by solar power supply, but it turned out that the total power demand of the monitoring station would have required a considerably large panel area. Therefore, it was decided to switch to mains connection.

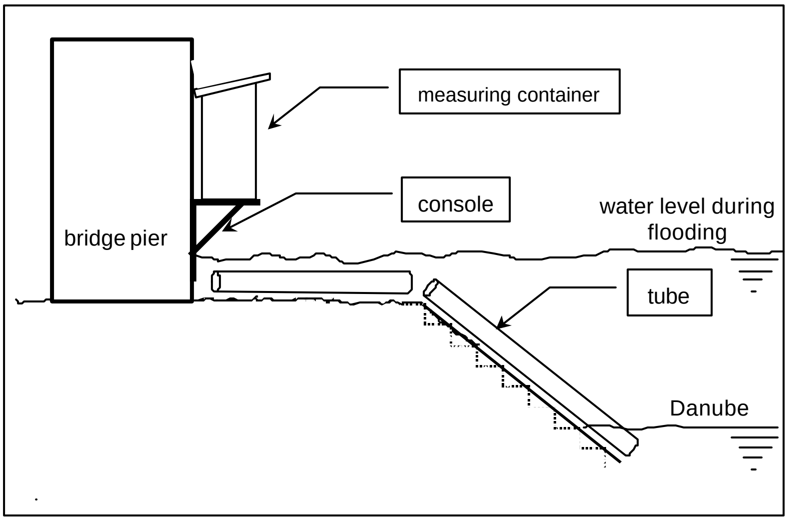

Figure 2: Principle layout of the Danube river monitoring station

CONCLUSIONS

Data demand is always a question of the investigated subject, specific problems have different requirements with regard to the measured parameter, accuracy and resolution in space and time. In contrary, trans national cooperation with respect to water quality management – as it is required in the EC-WFD – and subsequently exchange of water quality information will work only, if the available water quality data is based on standardised measurement methods and standardised data formats. In the presented project a water quality network is introduced, which is based on modular monitoring stations suitable for application is sewers, wastewater treatment plants and surface water bodies. The station concept reduces the requirement for auxiliary equipment to a minimum, only for the sewer monitoring station a sample supply to a container is needed, since some of the required sensors are not available in an Ex-proof version. Nevertheless, all sensors can be installed directly in the liquid and do not require sample preparation or periodic refill of chemical reagents. Each station is equipped with an industrial PC, which serves for control of the sensors and intermediate data storage. A central data server periodically collects the data from the monitoring stations within the water quality network. The data are processed by automatic plausibility checks before they are stored in a standard format in the central data base. The presented water quality network is an example for continuous and consistent data collection and processing, which could strongly improve cooperation with respect to water quality management on a catchment scale.

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