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Innovative water quality monitoring: Automation of data assessment in practical scenarios

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Abstract: Thanks to important technological developments regarding water quality sensors, in-situ on-line monitoring is becoming more and more used to collect water quality information in water and wastewater systems. However, in real world applications, the remaining challenges are associated with the automation of data collection and especially data validation to ensure proper use and interpretation of the data and avoid the danger of building data graveyards. In this paper, a novel water quality monitoring strategy with a practical orientation is presented. It combines different approaches and sources of information, aimed at automatic data collection and data quality assessment. The proposed tools are successfully tested on on-line water quality time series from different applications including sewers, wastewater treatment plants and receiving waters.

Keywords: data quality assessment, fault detection, on-line monitoring; sensors, water quality.

Introduction

Nowadays, the main goal of water authorities is to guarantee good ecological status of water bodies, promote sustainable water use and protection of water resources. An overall water quality (WQ) assessment of water and wastewater systems is being required and a consistent monitoring strategy becomes crucial to achieve the environmental quality objectives. Compared to traditional grab sampling, in the last few years water authorities and water utilities have shown a progressive interest on implementing automatic in-situ monitoring systems (Table 1). High frequency data generated with those systems can be used to reach different goals: describe pollution dynamics, illicit discharge detection, resource management, modelling, integrated control of the water basin... (Langeveld et al. 2013; Winkler et al. 2002). A reduction of the total monitoring costs can also be achieved (Pressl et al., 2004).

However, due to the intrinsically challenging measurement conditions, the implementation of on-line water quality monitoring systems has inherent engineering challenges and the automation of the data analysis adds to that complexity. Currently, most of the data validation process is done by using inefficient manual procedures that becomes infeasible when huge data sets need to be analysed (Rieger and Vanrolleghem, 2008). Therefore, the development of monitoring networks that encompass ‘smart’ water-side stations leads to new technological demands to avoid data graveyards.

In this paper a novel technology for water quality monitoring that includes automation of data assessment is presented. Software tools with a practical orientation are proposed for real-time advanced data quality evaluation to identify outliers, sensor faults and improve maintenance procedures. The ultimate aim is to ensure that high quality data is being presented to the data user and to create fully documented long-term databases of meaningful water quality data. The proposed tools have been successfully tested on water quality time series collected in different water systems.

Table 1 Examples of filed online monitoring applications

	Location	Authority	Monitoring plan	Measurements/Installation
USA	Denny Way Washington	Dep. of Ecology regulation	CSO remediation	Buoy for NTU and DO on-line monitoring
USA	Aurora, Illinois	Illinois Environ. Protection Agency (IEPA)	Evaluate the impact of CSO on WQ in the Fox River	Automated samplers for WQ from 5 bridge locations, 3 storm sewer outfalls and 7 CSOs
USA	Dayton, Ohio	Miami Conservancy District	WQ monitoring of the Mad and Stillwater Rivers	Gauge stations: on-line °C, DO, pH, uS/cm, NTU, chlorophyll, blue-green algae
CANA	Ontario	Michigan Storm Water Permit	Assessment of Rouge River	WQ monitoring at 13 stations, level; flow and precipitation at 20 stations
CANA	Quebec City	Environment Canada	Monitoring the St Lawrence River	At 9 stations: automated sampler and continuous WQ
EUROPE	UK, Scotland, Wales	Environment Agency (EA)	Assessment of CSO impact in Thames River	WQ: DO, °C, pH, uS/cm, NTU, NH_4, blue-green algae and chlorophyll
EUROPE	Berlin, Germany	Water Authority of Berlin	Assessment CSOs in River Spree	Continuous flow in sewer and WQ in a bypass
EUROPE	Eindhoven, Netherlands	Waterschap de Dommel	Overall river basin assessment	Continuous WQ monitoring: Dommel River, WWTP

Material and Methods

Within the framework of the RSM30 monitoring stations (Primodal Systems, Hamilton) (Figure 1), the data evaluation module is a key component to ensure the quality of the data being collected.

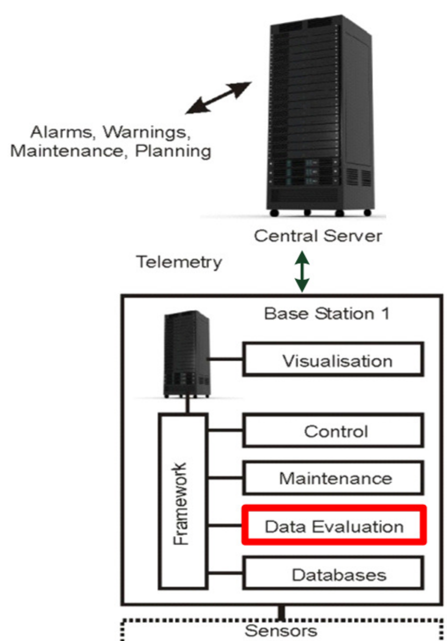

Figure 1 Primodal RSM30 monitoring station

To achieve that goal, the proposed automated tools enclose three processes (Figure 2) and their integration allows assessing the quality of the data in the short, middle and long term, reducing also the danger of building more data graveyards:

- Evaluation of sensor status data: Calibration data and other status data are used to assess the sensor measuring quality and to flag each value with a quality indicator.
- Automatic check of each single value: This "on-line" concept uses the time series information to assess the validity of the data. First, univariate methods based on forecasting of time series by using models are used to detect outliers and individual sensor faults. Second, multivariate methods that exploit the correlation between several variables are used to detect and confirm individual and multiple faults.
- Regular analysis of comparative measurements: This "off-line" concept uses reference measurements (grab samples or portable sensors) to build control charts and to detect systematic errors and poor calibration.

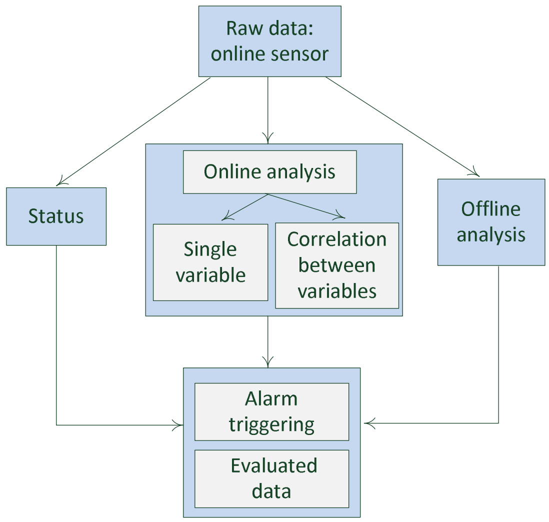

Figure 2 Data quality assessment process

Results and Conclusions

To illustrate the potential of the proposed tools Figure 3 and Figure 4 show some results obtained from the application of the data assessment approach. In Figure 3, outliers are successfully identified and removed in a TSS online time series from the inlet of the primary clarifier at the Lynnetten WWTP in Copenhagen (Denmark). The band delimited by the red and blue lines represents the prediction interval within which normal data should fall according to the calculated time series model. A large number of outliers are identified in this challenging measurement location. With an appropriate installation and maintenance efforts, the data quality performance is maintained even during the unusual rain event around December 24th and 27th 2012.

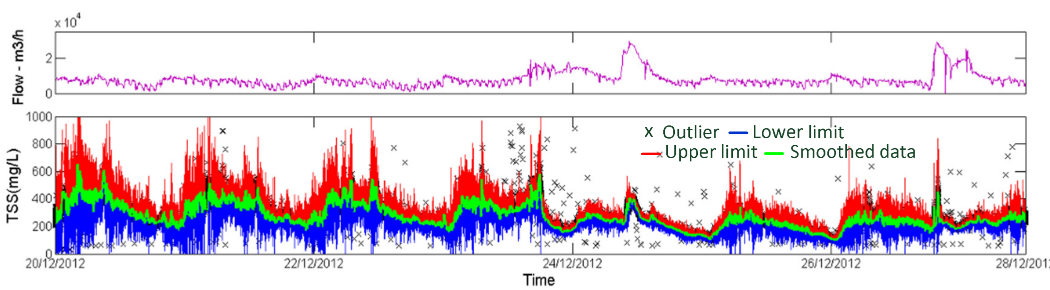

Figure 3 Online outlier detection for a TSS time series inlet primary clarifier, Copenhagen, Denmark

Figure 4 shows the results of the application of the online analysis of a DO time series collected in the River Dommel in Eindhoven (The Netherlands). Some outliers are detected outside the prediction interval. Once the outliers are replaced by their forecast value, the resulting time series is smoothed (green line) and several data features (five subplots below the time series) and their acceptability limits (red horizontal lines) are calculated for fault detection purposes. For example, around October 26th and October 28th excessive slope values are identified and the residuals standard deviation (RSD) also indicated a larger variance in the data coinciding with an important percentage of outliers or replaced data. Once all data features have been evaluated for each data point, data is validated according its degree of reliability (last subplot): 0 - valid (all test passed), 1 – doubtful (some tests failed), and 2 – not valid. About 86% of the data is considered as valid, comparing well with typical loss rates (Thomann, 2008).

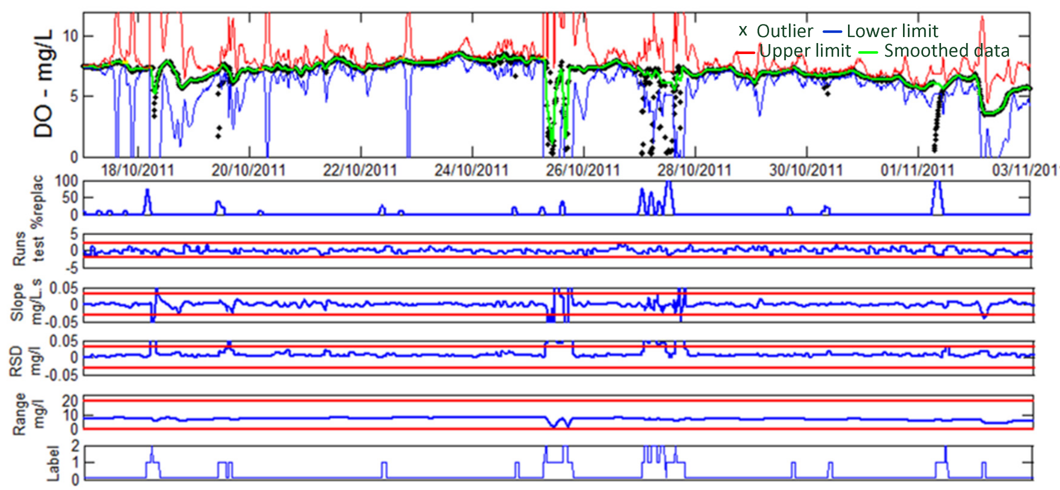

Figure 4 Online data validation for a DO time series from the Dommel River, Eindhoven

Following the scheme in Figure 2, after a fault is detected, an alarm is generated and posterior analysis is carried out to identify the fault and to apply the required corrective action in the field. Once the data is validated, the resulting time series can then be used by authorities and utilities as a basis for policy or management decisions concerning the water body and its uses, the efficacy of the treatment processes and take remedial actions if required.

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