10 years spectrometry based P-RTC in Wuppertal - experiences and enhancements

10 ans de P-RTC basé sur la spectométrie à Wuppertal - experiences et améliorations

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RÉSUMÉ

Il est rare que soit mis en œuvre un système de contrôle global en temps réel sur les réseaux d'assainissement urbain. La plupart du temps, des structures isolées sont contrôlées localement à partir de la mesure du niveau de l'eau et du débit, et leur principal objectif est de parvenir à un niveau élevé d'utilisation des capacités. Si, afin de permettre une conservation efficace de l'eau, les aspects qualitatifs doivent jouer un rôle plus important, il est nécessaire de disposer de systèmes de contrôle tenant compte de la pollution. Durant 10 ans, des structures individuelles ont subi des contrôles portant sur la pollution dans la ville de Wuppertal, en Allemagne. Actuellement, 8 structures dans le réseau des égouts de la ville sont surveillées et contrôlées par des capteurs UV-Vis. Pour aboutir à la possibilité d'un contrôle global, depuis 2013, la structure de débordement dans le plan d'eau récepteur sur le principal réservoir d'eau (42.000 m³) est également contrôlée. Les données de 7 débordements sur les 8 structures et le principal réservoir d'eaux pluviales sont comparées. Ces données historiques servent à développer une nouvelle stratégie améliorée de contrôle global. L'analyse des données vise à déterminer si des processus dynamiques doivent être suivis ou si les différences spécifiques de la zone du bassin versant sont importantes, récurrentes et assez spécifiques pour appliquer une stratégie basée uniquement sur les données historiques. Les résultats présentés dans cet article ont été établis dans le cadre d'un projet de recherche du BMBF intitulé « La ville en tant que système hydrologique soumis au changement. Mesures en vue d'un système de gestion adaptable pour les ressources en eau urbaines » (SAMUWA).

ABSTRACT

The implementation of global real time control systems in urban drainage networks is rare. Commonly, single structures are controlled locally based on water level and flow rate measurements with the primary objective is to accomplish a high degree of capacity utilization. If, in order to enable efficient water conservation qualitative aspects are to play a larger role, pollution-based control systems are required. For 10 years individual structures have been locally pollution-based controlled in Wuppertal. Currently, 8 structures across the city's sewer system are monitored and controlled by UV-Vis sensors. To elicit the possibility of a global control, since 2013 also the system's overflow structure into the receiving water at the main storm water tank (42.000 m³) is monitored. The data of 7 overflow events at the 8 structures and the main storm water tank are compared. This historic data serves to develop a new improved global control strategy. By the data analysis it is intended to clarify if dynamical processes are to be followed or if the catchment area specific differences are large, recurrent and specific enough to implement a strategy based on historic data only. The results presented in this paper were established as part of a BMBF- research project entitled "The city as a hydrological system in the course of change. Steps towards an adaptable management system for urban water resources" (SAMUWA).

KEYWORDS

CSO control, long term online-monitoring, spectrometry based real time control, storm water separation, UV-Vis spectrometer

1   INTRODUCTION

The main receiving water body (River Wupper) in Wuppertal flows through the centre part of the city, which is dominated by a hilly topography with a valley where the river is located. As in various urbanized areas, numerous tributaries have become part of the urban drainage system during industrialization. In North Rhine-Westphalia, Germany, current legislation demands that runoff from distinct areas has to be treated differently, depending on the landuse of the corresponding surfaces (MUNLV NRW, 2004). Decentralised structures or central storage rooms are possible treatment measures but for this case the most efficient solution is a P-RTC (Hoppe et al., 2011).

Classical real-time control (RTC) strategies for sewer systems often facilitate the activation of available (in-line) storage volume based on water levels and flow measurements (e.g. de Korte et al., 2009). If the control objective is to divert less polluted stormwater runoff into the next receiving water body and more polluted runoff to the Wastewater Resources Recovery Facility (WRRF) it is still difficult to successfully operate the system based on hydraulic measurements only. The caused problems could be avoided by a pollution-based real-time control (P-RTC) system (Fuchs and Beeneken, 2005; Gruber et al., 2006; Hoppe et al., 2011).In Wuppertal's sewer system clean river water from tributaries is mixed with polluted surface runoff. To separate the more polluted stormwater runoff from the less polluted flow fractions, a P-RTC system was developed and installed. It has been implemented in 8 storm water diversion structures (SDS 1-8). After 4 years of measurement, the P-RTC has been continuously operated since May 2009 in eight structures (Figure 1). Further information on the basic idea and set-up can be found in Hoppe et al., 2011. As parameter representative for storm water pollution turbidity is used, which can be measured accurately by photometric technics and which, by means of calibration and correlation, also enables the determination of total suspended solids (TSS_{eq}) (e.g. Lacour et al. 2009; Langeveld et al., 2005). By defining a threshold value for TSS_{eq} (currently 100 mg/L) the polluted runoff can be selectively diverted into the main intercepting sewer (MIS). At the end of the MIS a main stormwater retention tank (MST) is a situation that represents at the same time the only overflow structure of the total MIS.

A major issue in dynamic P-RTC strategies is the availability of accurate data provided in a sufficient frequency (Van Daal-Rombouts et. al, 2013). During the operational phase of the above described set-up repeatedly problems occur regarding measurement equipment failures, sensor drift, etc.. Because of this the quality and available length of accurate data for further investigations the development of a more sophisticated (global) P-RTC system is still limited. This study has the aim to extend and improve the available measurements and to thoroughly analyse the already available data as basis for a future statistical global RTC.
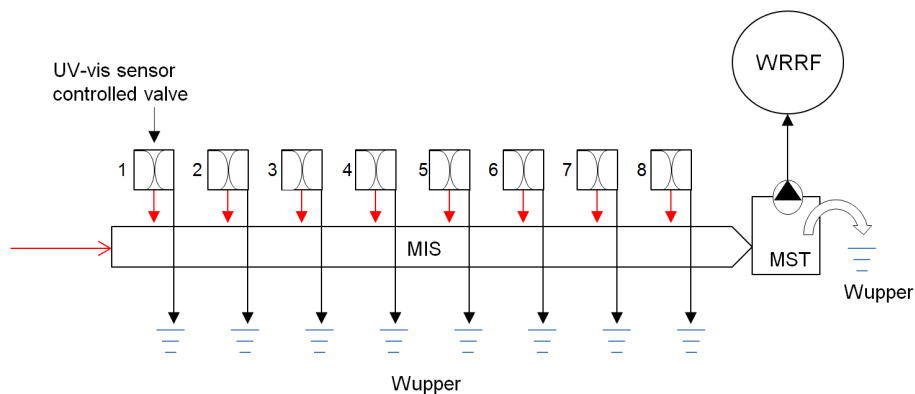

Figure 1: Scheme of the local control system at 8 storm water diversion structures (SDS) in Wuppertal

2   METHODS

2.1   Measurement devices

In 2013, an additional spectrometric probe (UV-vis) was installed at the overflow of the MST (storage volume ~4,000 m³) located at the end of the MIS. In Germany the sewer network is categorized as a potentially explosive area. According to Directive 94/9 / EC, only sensors considered as equipment "Intended for use in potentially explosive atmospheres" (ATEX) are allowed. Among sensors for the detection of turbidity or TSS_{eq} only the S::can sprecto::lyserTM meets this criterion. At all structures

S::can sprecto::lyserTM UV-Vis submersibles probes (optical path length 5 mm) are installed. The S::can's 4-20-mA-signals are directly transferred to the control system; only at the MST the recorded data is manually read-out. At all structures additional sensors measuring hydraulic variables are installed. The standard set-up at each structure consists of a spectrometric sensor and at least a flow or water level sensor, respectively. All structures are equipped with cameras.

2.2   Data analysis

Overflow events at the MST are used to identify events at the SDSs. An event at a SDS is determined if the measured concentration at this structure rises above the background concentration and reaches again the background concentration after a certain time. To guarantee that all identified events belong to the same rainfall event, a SDS event is only counted if it lasted not more than an hour longer than the recorded combined sewer overflow (CSO) at the MST. Since, the installation of the additional S::can sprecto::lyser^{TM} at the MST, all together 7 CSO events could be observed. Caused by equipment failure only 5 overflow events at SDS 1 and SDS 4, 4 overflow events at SDS 8 and no overflow event at SDS 5 could be recorded simultaneously with the recorded CSOs at the MST. For the first analysis of the obtained data only an outlier validation was performed, further data validation will be carried out.

3   RESULTS

The monitoring results show a large variation of the TSS_{eq} concentrations of the SDSs, see Figure 2 as example for an event recorded on December 19th 2015. The high concentration at the SDSs occurred before the beginning and at the beginning of the CSO at the MST. However, the event mean concentrations (EMC) at the CSO structure were during 5 out of 7 events higher than the EMC at the SDSs (see Figure 3). These findings can provide a basis to adjust the control algorithm. Generally, during the CSO events the high pollution occurs with high flow rates. At SDS 6, the pollutograph for TSS shows the same characteristics regarding timing and peaks as the hydrograph for the July 19th event (see Figure 2).
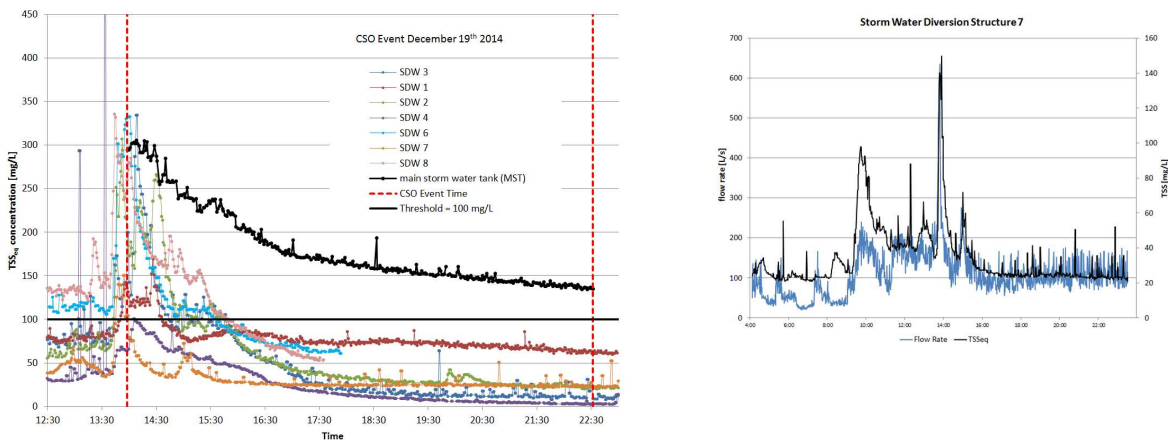

Figure 2: left: TSS_{eq} measurement at a CSO event (19 July 2015), 7 SDS
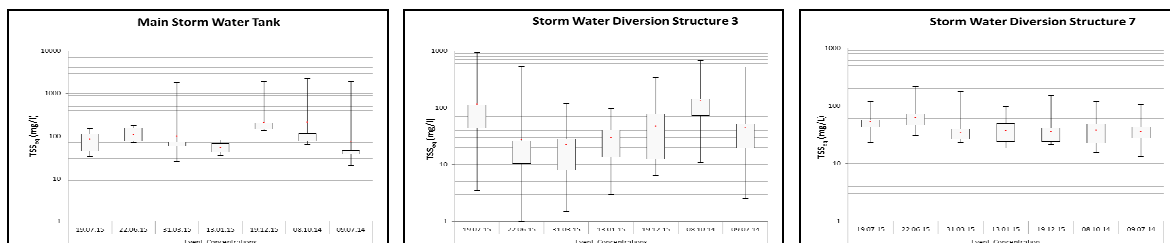right: CSO event (19 July 2015) at SDS 6

Figure 3: Boxplot of event concentrations of 7 CSO events at the main storm water tank
left: main storm water tank, middle: storm water diversion structure 3 (high variation); right: storm water diversion structure 7 (low variation).

4 DISCUSSION AND CONLUSION

The implemented online sensors and the chosen P-RTC strategy have enabled an optimized use of the sewer system's (treatment-) capacity. But a successful operation demands a high-level on maintenance. Well defined strategies are needed to deal with operational problems linked to the online sensors, the uncertainties of the online measurements and the sometimes limited outcomes (cf. Gruber et al., 2006; Lepot et al., 2013).

The SDSs show variety degrees of pollution presumably because their location in different sub-catchment areas. Whereas the patterns between 5 of the 8 SDSs show certain similarities, at 3 SDSs no characteristic patterns are found. However, the measurements at the MST show that with the local P-RTC at the SDSs the mean event concentration is higher at the MST than at all SDSs for 5 out of 7 events. This is a clear indication that the operation of the local P-RTC strategy successfully decreases the environmental impact caused by stormwater discharges. To further develop the RTC strategy more events have to be evaluated to extend the number of stormwater events with reliable measurements. At this point the analysis reveals that dynamic non-recurring processes have a great impact. Highly polluted storm water is discharged to the treatment plant but still high loads of TSS enter the receiving water because of high volumes with concentration below the chosen threshold. Furthermore, the individual SDSs have been ranked by their occurring pollution. This ranking can be used for adapting the maximum flow connected to the MIS at the structures with high concentration and for adjusting the TSS thresholds at the structures with low concentrations.

To increase the significance of the measurements the influence of the sensor calibration and the resulting uncertainties have to be taken into account. This will allow a more precise calculation of the total loads and will increase the comparability of different events at different locations.

5 ACKNOWLEGDEMENTS

LIST OF REFERENCES

De Korte, K., van Beest, D., van der Plaat, M., de Graaf, E., and Schaart, N. (2009). *RTC simulations on large branched sewer systems with SmaRTControl.* Water Science and Technology, 60(2), 475–482.

Fuchs, L. and Beeneken, T. (2005). *Development and implementation of a real-time control strategy for the sewer system of the city of Vienna.* Water Science and Technology, 52(5), 187–194.

Gruber, G., Bertrand-Krajewski, J. L., de Beneditis, J., Hochedlinger, M., and Lettl, W. (2006). *Practical aspects, experiences and strategies by using UV/VIS sensors for long-term sewer monitoring.* Water Practice and Technology, 1(1).

Hoppe, H., Messmann, S., Giga, A., and Gruening, H. (2011). *A real-time control strategy for separation of highly polluted storm water based on UVVis online measurements from theory to operation.* Water Science & Technology, 63(10), 2287–2293.

Lacour, C., Joannis, C., Gromaire, M.-C. and Chebbo, G. (2009). *Potential of turbidity monitoring for real time control of pollutant discharge in sewers during rainfall events.* Water Science and Technology 59 (8), 1471–1478.

Langeveld, J. G., Veldkamp, R. G. and Clemens, F. (2005). *Suspended solids transport*: an analysis based on turbidity measurements and event based fully calibrated hydrodynamic models. Water Science and Technology 52 (3), 93–101.

Lepot, M., Aubin, J. B., and Bertrand-Krajewski, J. L. (2013). *Accuracy of different sensors for the estimation of pollutant concentrations (total suspended solids, total and dissolved chemical oxygen demand) in wastewater and stormwater.* Water Science and Technology, 68(2), 462–471.

MUNLV NRW (2004). *Anforderungen an die Niederschlagentwässerung im Trennverfahren.* RdErl. D. Ministeriums für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz – IV-9 031 001 2104 vom26.5.2004.

Van Daal-Rombouts, P., Langeveld J.G., Clemens, F.H.L.R. (2013). *Requirements for quality of monitoring data for water quality based RTC.* 7th International Conference on Sewer Processes and Networks (SPN 7). Sheffield, U.K.