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Integrated real time control of SST operation at WWTP Eindhoven: design and gain

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ABSTRACT

At the wastewater treatment plant (WWTP) Eindhoven in the Netherlands a new control for the operation of the storm water settling tank (SST) bypass of the biological treatment has been implemented taking into account the in-sewer storage of the connected catchment areas. Based on the integrated principle that the SST discharges should be either minimised (no chance of CSO spilling) or maximised (change of CSO spilling), to minimise the pollution of the surface water. The average theoretical gain of the new control, based on 35 months of measurements, was estimated to be a 40% reduction in discharged volume. Preliminary results for the practical gain, based on 4 months of measurements, show a decrease of 49%. The event mean discharge has increased from 39 to $45 \cdot 10^3$ m^3. The new SST control therefore functions as intended: it prevents unnecessary discharges, while increasing the discharged volume when the SST is operated.

KEYWORDS

Effect evaluation, Integrated RTC, Monitoring, Storm water settling tank.

1 INTRODUCTION

Integrated real time control is an increasingly accepted method for optimising the functioning of wastewater systems, see e.g. Schütze and Muschalla (2013). The majority of studies that have been published are theoretical, either being based on fictional systems or on modelling exercises only (e.g. De Korte *et al.* (2009), Lacour and Schütze (2011), and Joergensen *et al.* (2014)). A few studies start to emerge that go into the practical details of applying RTC, and are based on real cases (e.g. Fradet *et al*. (2011), Beeneken *et al.* (2013) and Seggelke *et al.* (2013)).

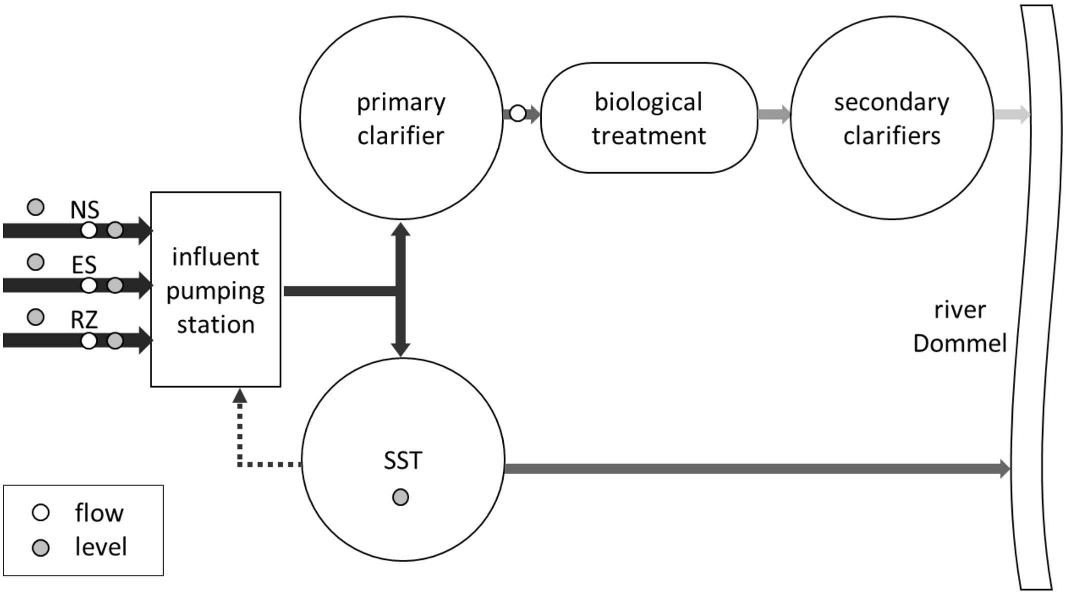
This study deals with the wastewater system of Eindhoven, that is extensively monitored and studied over an extended period of time (research project Kallisto, see Langeveld *et al.* (2013) for details). Based on an analysis of the available measurements and expert knowledge on the system functioning, an alternative control for the operation of the storm water settling tank (SST) at the wastewater treatment plant (WWTP) of Eindhoven has been designed and implemented. Such SSTs are a common feature of WWTPs in both the Netherlands and Germany. In this paper the old and new control for the SST are described, as well as the expected gains of the new control. Also a quantitative evaluation of the effects of the new control in practice based on measurements is presented.

2 MATERIALS AND METHOD

2.1 WWTP layout and measurements

The WWTP of Eindhoven in the Netherlands treats the wastewater from 3 catchment areas: Nuenen-Son (NS), Eindhoven Stad (ES) and Riool Zuid (RZ). The WWTP consists of 3 identical treatment lines containing a primary clarifier, a biological tank and 4 secondary clarifiers. At high inflows a SST can be operated to first store and later discharge partly settled wastewater to the river directly, see Figure 1. Continuous (1 minute interval) water level measurements are performed in the catchment areas, in the influent chambers and in the SST. Continuous flow measurements are performed for the influent from the catchments and the flows towards the biological tanks.

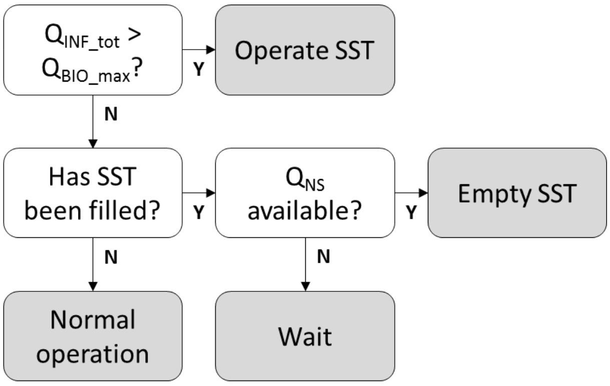
Figure 1: Schematic representation of the measurement locations and layout of WWTP Eindhoven, consisting of 3 influent flows, 3 identical treatment lines and 1 bypass through a SST.



2.2 Old SST control

The old control for the SST is based on a set point for the maximum capacity of the biological treatment (Q_{BIO_max}) only. Once the total influent flow (Q_{INF_tot}) surpasses Q_{BIO_max} the SST is taken into operation. As soon as Q_{INF_tot} falls below Q_{BIO_max} the SST is taken out of operation. The emptying of the SST depends on the available capacity in the influent flow of NS (Q_{NS}). A flow diagram of the old SST control is shown in Figure 2. Additionally the WWTP operators can change the set point for Q_{BIO_max} or operate the SST manually.

Figure 2: Flow diagram of the old SST control.



2.3 New SST control

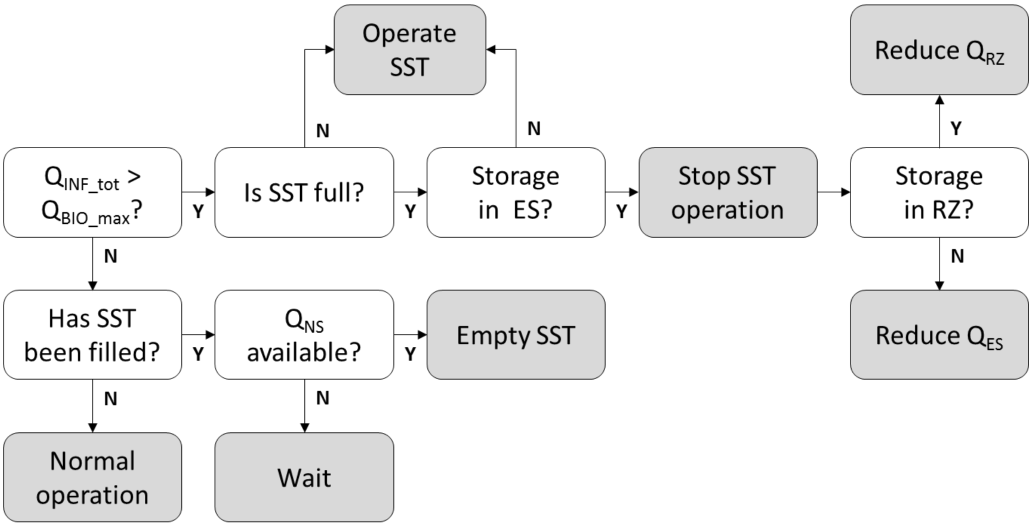
Data analysis revealed that the SST discharged more than twice as often as the combined sewer overflows (CSOs) from the connected catchment areas. The influent flows were regulated such that the connected sewer systems are always emptied a fast as possible (high Q_{INF_tot}). Together with the old control that is based on the operation of the WWTP only, this leads to frequent operation of the SST. It does not take into account the need for such high influent flows from the sewer systems perspective. At the same time the SST (and thus the WWTP) is not always operated at full capacity when CSOs are likely to occur in the catchments, leading to more pollution discharged to the surface water than needed.

The sewer systems' functioning has been incorporated in the new control of the SST by taking water level measurements from the catchments into account. A flow diagram for the new SST control can be found in Figure 3. The principle remains that the SST should only be operated as Q_{INF_tot} surpasses the set point for Q_{BIO_max}, and the general control of influent pumps is untouched. The main additional requirement is that the SST can only discharge once the CSOs in catchment area of ES are prone to spill. When there is no such risk, when the water level in the influent chamber of ES stays below 13.30 m AD, Q_{INF_tot} will be limited to Q_{BIO_max}. Based on the actual available in-sewer storage this is achieved by reducing the influent flow from either ES or RZ (Q_{ES} or Q_{RZ}). In this final step the emptying of ES is prioritised over RZ because of differences in the available storage and the impact of discharges from CSOs from the catchments.

The new control has been designed in cooperation with the WWTP operators to ensure practical feasibility, keeping the options to lower the set point for Q_{BIO_max} and the manual operation of the SST. However, caution is advised in using these when CSO spilling in the catchments is expected. The wastewater discharged by the SST is partly settled, while the CSOs in the catchments are not equipped with any type of treatment facility.

The control has been tested by simulating the effect of the control on multiple measured rain events and was implemented in November 2014.

Figure 3: Flow diagram of the new SST control.



2.4 Effect evaluation

From the available measurements, the functioning of the new SST control can be estimated on a theoretical basis as well as determined quantitatively. For this purpose 35 months (January 2012 - November 2014) of measurements are used to characterise the performance of the old SST control and the theoretical gain. Since the implementation, 4 months (December 2014 to March 2015) of measurements have become available to characterise the performance of the new SST control.

From the measurement periods with the old and new SST control the following characteristics have been determined and will be used to evaluate the effect of the new SST control:

- number of events that the SST was taken into operation,
- number of events the SST discharged,
- total discharged volume per event (V_{SST}),
- event mean capacity of the SST discharge (Q_{SST}),
- event mean Q_{INF_tot} during an SST discharge, and the period when the SST was (partly) filled,
- event mean $Q_{BIO\_\mathbf{max}}$ during an SST discharge, and the period when the SST was (partly) filled.

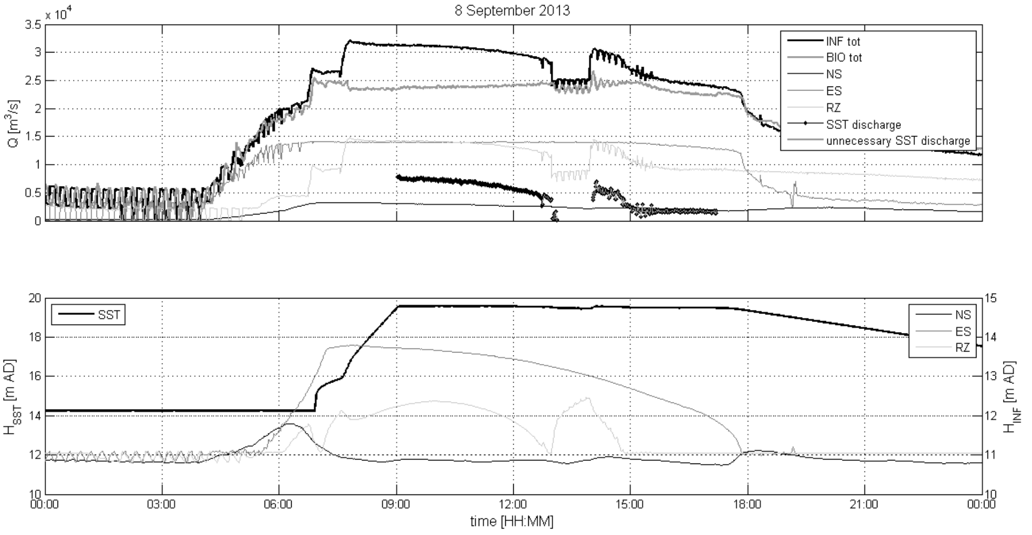
To estimate the theoretical gain, additionally, the unnecessarily discharged volume (when the water level in the influent chamber of ES was below 13.30 m AD) is calculated for the old SST control period. For the estimation of the practical gain the volume that would have discharged using the old control, based on the 35 months of measurements, will be used.

3 RESULS AND DISCUSSION

3.1 Theoretical gain

Figure 4 shows a representative example of a measured SST discharge event. The top part displays measured flows, together with the discharged flow under the old SST control and the modelled discharged flow that can be avoided using the new control. In the bottom part the levels in the SST and influent chambers are given so that the functioning of the new control can be checked intuitively. The SST is taken into operation at high flows and water levels from ES and to a lesser extend RZ. Once the SST is filled it discharges from approximately 9:00h onwards. Q_{ES} and Q_{RZ} remain high to empty the catchments as fast as possible, succeeding for RZ around 13:00h, the SST is taken out of operation by reducing Q_{RZ}. This leads to a new rise in the water level of RZ and renewed operation of the SST around 14:00h. The water levels in both ES and RZ stay well below 13.30 m AD, indicating no spilling of the CSOs in the catchments. Therefore there was no need to increase the capacity of the WWTP by operating the SST. All SST discharges from 14:00h onwards were unnecessary.

Figure 4: Example of a theoretically unnecessary discharge of the SST.



In the evaluated 35 months of historical data, the SST was taken into operation 93 times, 59 of which it discharged. The combined discharged volume for all 59 events amounts to $2.3 \cdot 10^6$ m^3. The discharged volume per event was $39 \pm 103 \cdot 10^3$ m^3, using 95% confidence intervals. All characteristics listed in the previous paragraph can be found in Table 1.

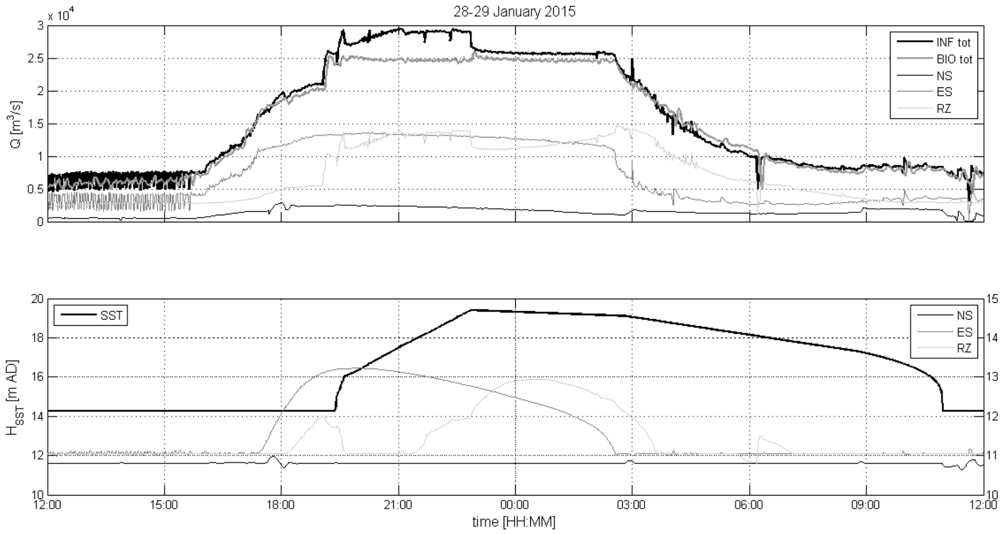
The unnecessarily discharged volume per event is calculated to be $16 \pm 29 \cdot 10^3$ m^3. This amounts to a theoretical reduction for the discharged volume of on average 40%, or over $300 \cdot 10^3$ m^3 per year.

The calculation method of the theoretical gain could result in an overestimation of the unnecessarily discharged volume, as it is assumed that no more water is discharged by the SST in the new control as soon as the water level in the influent chamber of ES drops below the limit of 13.30 mAD. In practice this is achieved by reducing the influent flow, which will in turn affect the water levels in the catchments and influent chambers, possibly leading it to rise above the limit. This would then lead to the renewed operation of the SST. This feedback is not taken into account. This effect is estimated to be small. Once the water levels have been above 13.30 mAD, they will only fall below that level once it stopped raining. A reduction in the pumping capacity will generally not result in a rise in water level but a reduced decline. Only significant amounts of rain will make the water level rise enough to trigger a renewed operation of the SST.

3.2 Functioning new SST control and practical gain

From December 2014 onwards the new SST control has been applied. Figure 5 shows an example of the SST operation using the new control. The top part of the figure displays flows: the total and individual influent flows and the flow to the biological treatment. In the bottom part the water levels in the influent chambers and the SST are displayed. The SST is taken into operation during significant rises in water level in both ES and RZ. Around 23:00h the SST is full and the water level in the influent chamber of ES is lower than 13.30 m AD. Therefore Q_{INF_tot} is limited to Q_{BIO_max} to prevent SST spilling. This was achieved by reducing the flow from Q_{RZ} as the emptying of ES was prioritised over RZ when in-sewer storage was available in both catchments.

Figure 5: Example of the SST operation under the new control.



During the 4 months the new SST control has been in operation, 11 events in which the SST was filled occurred. Relative to the months of data available, the filling frequency is similar to that of the old SST control. This is as expected, as the operation of the influent pumps and the moment of filling of the SST was not changed. 3 events out of the 11, lead to a SST discharge. The total discharged volume comprised $136 \cdot 10^3$ m^3. The discharged volume per event amounts to $45 \pm 52 \cdot 10^3$ m^3. All characteristics for the new SST control can be found in Table 1.

Comparing the new SST control to the old shows a strong decrease in the number of SST discharges (27 to 63% of SST filling events lead to a discharge), an increase in the event mean discharged volume through the SST (45 to $39 \cdot 10^3$ m^3) and an increase in all event mean flows. This shows that the new SST control functions as intended: It prevents unnecessary discharges as can be found from the decrease in the number of events. At the same time, when the operation of the SST is required, the event mean discharged volume is higher as are the event mean Q_{INF}, Q_{BIO} and Q_{SST}. So more water is (partly) treated at the WWTP, leading to less untreated discharges from the CSOs in the catchments.

Table 1: Characteristics determined from the measurement data under the old and new SST control. Uncertainties are given in 95% confidence intervals.

		old SST control	new SST control
nr [-]	months data	35	4
	SST operations	93	11
	SST discharges	59	3
event mean flow during SST operation [10^3 m^3/h]	Q_{INF}	18.6±8.5	23.4±4.7
	Q_{BIO}	17.1±6.7	21.0±3.4
event mean flow during SST discharge [10^3 m^3/h]	Q_{INF}	25.8±9,7	29.5±1.9
	Q_{BIO}	22.4±8.0	24.3±0.7
	Q_{SST}	3.4±3.9	5,2±2.6
V_{SST} [10^3 m^3]	total	2,277	136
	event mean	39±103	45±52

Using the statistics from the old SST control, the expected total discharged volume that would have occurred using the old SST control for the 11 times the SST was operated during the new SST control period was calculated to be $269 \cdot 10^3$ m^3. The new control therefore leads to a practical reduction of the discharge of 49%.

The results indicate that the new SST control functions as expected and a significant reduction in the discharged volume has been achieved. Caution in interpreting the exact numbers is necessary however, since the control has been operational for only 4 months. This leads to a small measurement basis for firm conclusions, not only because the number of events is small for the application any kind of statistics but also for example due to the variability in rainfall.

4 CONCLUSIONS

A new SST control at the WWTP of Eindhoven has been designed to optimise the operation of the SST taking into account the in-sewer storage of the connected catchment areas. Based on the possibility of CSO discharges from the catchments, the SST discharges should be either minimised (no chance of CSO spilling) or maximised (change of CSO spilling) to minimise the pollution of the surface water.

The average theoretical gain of the new control was estimated to be a 40% reduction in discharged volume. Preliminary results for the practical gain show a reduction of 49%. The event mean discharge has increased from 39 to $45 \cdot 10^3$ m^3. This shows that the new SST control functions as intended: it prevents unnecessary discharges leading to a reduction in total discharged volume, while increasing the discharged event mean volume when the SST is operated.

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