A new concept for storm water treatment: full-scale experience in Flanders

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Abstract Current practice in Flanders (Belgium) is to limit the hydraulic capacity of the wastewater treatment plant to $6Q_{14}$. A maximum of $3Q_{14}$ is treated in the activated sludge system, the excess flow undergoes only physical treatment (stepscreen, sand trap and settling). This paper focuses on an alternative storm management operation strategy aiming at maintaining plant performance and reducing the total pollutant discharge towards the receiving waterbody. Given the observed dilution of incoming wastewater under storm conditions, the idea was put forward that higher hydraulic loadings could be treated within the biology if additional secondary clarifier volume was supplied. The new storm operation strategy would consist of treating $6Q_{14}$ biologically using the available storm tanks as additional clarifier volume. The outcome of this study clearly shows that $6Q_{14}$ can be treated biologically using the storm tank as an extra clarifier. It was shown that doing so the overall pollutant discharge was significantly reduced. The proposed strategy does not entail any extra operational costs. On the contrary it offers a potential cost saving of 244 million Euro in view of a possible future change of environmental legislation regarding storm tank spill frequencies.

Keywords Dynamic modelling; pollutant discharge; storm operation

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Introduction

River water quality in Flanders (Belgium) has been dramatically bad during the past twenty years, because of the high degree of urbanisation, the industrial and agricultural pollution and insufficient basic treatment infrastructure. Almost no watercourses met even the lowest criteria, which were set out in river master plans. In 1990 the private company Aquafin was founded and assigned with the task of the design, construction, operation and pre-financing of the necessary infrastructure for sewage treatment. Nowadays a great deal of collector sewers and treatment plants are being built or scheduled for the near future.

Current practice in Flanders is to limit the hydraulic capacity of the wastewater treatment plant (WWTP) to $6Q_{14}$ (Q_{14}=1.7 dry weather flow Q_{DWF}, corresponds to a flow level if the average dry weather flow would be spread over 14 hours instead of 24 hours). A maximum of $3Q_{14}$ is treated in the activated sludge system, the excess flow undergoing only physical treatment (stepscreen, sand trap and settling). At present environmental legislation specifies a maximum allowable spill frequency (7x/year) for the combined sewer overflows, but no similar criterion is defined for overflows coming from storm tanks. However in pursuit of minimising the environmental impact towards the receiving waterbodies and anticipating a pending extension of the spill frequency criterion towards storm tank overflows, the option of treating $6Q_{14}$ into the biological train of the WWTP, assuming the WWTP can maintain its performance, deserves further attention.

The underlying assumption in this research was, given the observed dilution of incoming wastewater under storm conditions, that higher hydraulic loadings could be treated within the biology if additional secondary clarifier volume was supplied. For increasing secondary clarifier volume without actually building new tanks one option is to operate the storm tank as an extra clarifier. This paper ultimately aims at providing an answer to the following three questions: i) can a WWTP still meet its consents when operating under $6Q_{14}$ mode, ii) does $6Q_{14}$ operation result in a lower total pollutant discharge towards the receiving waterbody, iii) what is the impact on operational costs?

Materials and methods

Simulation tools and simulation models

All simulations were run with the WEST simulator package (Hemmis NV, Belgium). To model the complex processes involved in the biological reactors the IAWQ ASM No.1 (Henze *et al.*, 1987) was used. The clarifier model used is a 10-layered Takacs model (Takacs *et al.*, 1991). Model parameters and influent fractionation were taken from previous studies if available, otherwise default parameters were used.

Plant descriptions: test plants

Table 1 summarises the main characteristics of the plant under study and Table 2 gives an overview of the average effluent concentrations versus the consents. The effluent consents for total nitrogen (TN) and total phosphorus (TP) are related to yearly averages, while the effluent consents for COD, BOD and SS are formulated in terms of 95% percentiles.

Model-based feasibility evaluation methodology

In order to evaluate the feasibility of certain alterations in the overall process strategy, dynamic simulation was used as a tool to assess potential impacts of these process alterations. For the plant under study a rain event was designed and fed to the simulator. Each rain event consists of four phases: i) a rising phase in which the flow is increasing towards its maximum flow $6Q_{14}$ and the entering load is increasing, ii) a first flush phase characterised by maximum flow and maximum loading, iii) a dilution phase characterised by maximum flow and the entering load dropping back to the design load level, iv) drop phase: return to average flow conditions and design load.

Full scale experiments

In full-scale the plant operation was monitored under $3Q_{14}$ operation mode (classical operation) and during $6Q_{14}$ operation mode. The basic process determinants (sludge concentration, SVI, temperature, aeration control,…) were similar for both periods. Under $3Q_{14}$ operation, influent, effluent secondary clarifier and effluent of the storm tank were sampled. Under $6Q_{14}$ operation, influent and effluent of secondary clarification were sampled.

Flows, DO control, sludge concentration and other basic operation determinants were followed during the campaigns. Figures 1 and 2 give a schematic process lay-out under $3Q_{14}$ and $6Q_{14}$ operation.

Table 1 Main characteristics of test plant

Plant	Design capacity (P.E.)	Actual loading (% compared to design load)			Maximum Hydraulic Capacity (m^3/day)
		BOD	TN	TP	
Ertvelde	11,000	61	119	–	16,971

Table 2 Average effluent concentrations versus consents

Plant	BOD		COD		TN		SS	
	Effluent	Consent	Effluent	Consent	Effluent	Consent	Effluent	Consent
Ertvelde	5	25	70	125	9.1	20	15	35

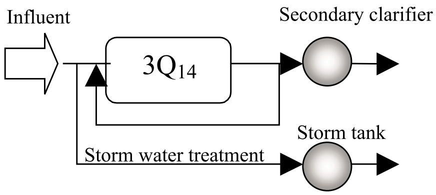

Figure 1 $3Q_{14}$ operation process scheme

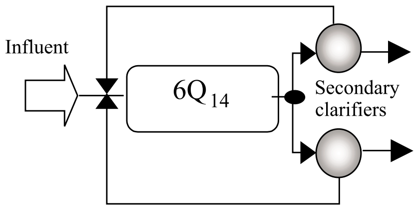

Figure 2 $6Q_{14}$ operation process scheme

The observations with an average daily flow higher than $3Q_{14}$ were classified into three hydraulic classes for both observation periods. This classification was done in order to compare the WWTP's performance for similar types of events.

Results and discussion

Model-based feasibility study

In the first step, the proposed option was evaluated using a dynamic process model. These simulation studies indicated the concept to be feasible and gave the green light to pursue full scale tests.

The WWTP of Ertvelde is equipped with a stormtank which is interchangeable with the secondary clarifier. The simulation was run using the stormtank as extra clarifier volume and adopting a SVI= 150 ml/g. A design storm of 48 h was fed to the simulator, accounting for a maximum influent flow of $6Q_{14}$ (=16971 m^3/day). A rise time and a flush time both of 2h were taken during which the flow increased and concentrations were fixed at their dry weather average values. Afterwards a dilution phase of 44 h followed in which the loading dropped back to the average loading level.

The simulation results indicate a substantial breakthrough of NH_4-N during the "flush" phase, afterwards as soon as the dilution phase starts NH_4-N levels drop back to lower values. In total the effluent consent is not violated either for nitrogen or for SS (the consents of the other water quality parameters were also met, results not shown). The design storm being fed to the system is probably an overestimation of reality, since during the "first flush" phase the loading increases up to 10× the design load.

Full scale experimental tests

At the WWTP of Ertvelde a full-scale monitoring period was run over several months. In total, 25 overflow events of the storm tank were observed under $3Q_{14}$ operation. During the $6Q_{14}$ operation period in total 25 events were observed with an influent flow exceeding the $3Q_{14}$ limit.

Effluent performance under $6Q_{14}$ operation and $3Q_{14}$ operation

During $6Q_{14}$ operation mode the effluent consents were met at all times (consent total nitrogen= 20 g/m^3; BOD=25 g/m^3; SS= 35 g/m^3). Figure 3 compares the average effluent performance for both operation modes.

Comparison total pollutant discharge $3Q_{14}$ versus $6Q_{14}$ operation

Table 3 shows the classification of the different events under $3Q_{14}$ and $6Q_{14}$ operation into three hydraulic classes. An event is defined as an observation day with an average daily influent flow higher than $3Q_{14}$.

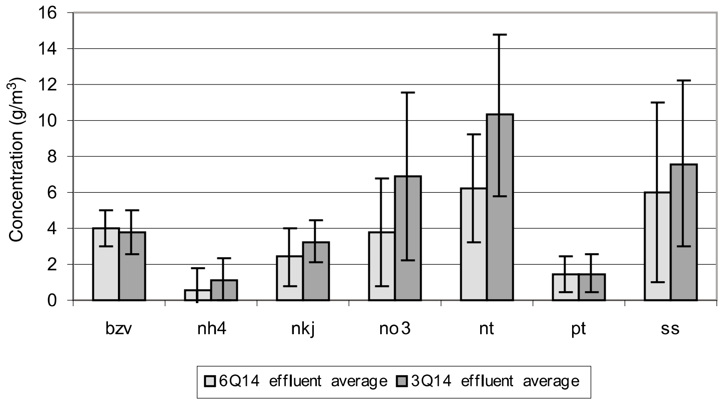

Figure 3 Average effluent concentrations $3Q_{14}$ operation versus $6Q_{14}$ operation

Table 3 Classification of events into hydraulic classes for both operation modes

Hydraulic class	Number of observations	
	$3Q_{14}$ operation mode	$6Q_{14}$ operation mode
3–4 Q_{14}	9	8
4–5 Q_{14}	4	9
5–6 Q_{14}	12	8

To quantify the impact of $6Q_{14}$ operation in terms of total pollutant discharge the reduction percentage of total pollutant discharge of $6Q_{14}$ operation was calculated relative to the $3Q_{14}$ operation mode:

Reduction percentage (%) =

$$\frac{[\text{pollutant discharge } 3Q_{14} \text{ operation}]-[\text{pollutant discharge } 6Q_{14} \text{ operation}]}{[\text{pollutant discharge } 3Q_{14} \text{ operation}]} \times 100$$

Figure 4 gives an overview of the average reduction percentages for each of the basic quality parameters for the different hydraulic classes. Summarising, one can state that for BOD, COD, suspended solids and total nitrogen a substantial reduction in total pollutant discharge is obtained by switching to $6Q_{14}$ operation mode. These reduction percentages range between 10 and 80% depending on the water quality parameter considered. The highest reduction percentages are obtained for suspended solids (80%); nitrogen and BOD reduction percentages mount up to 40%; COD reduction is in the range between 10 and 25%.

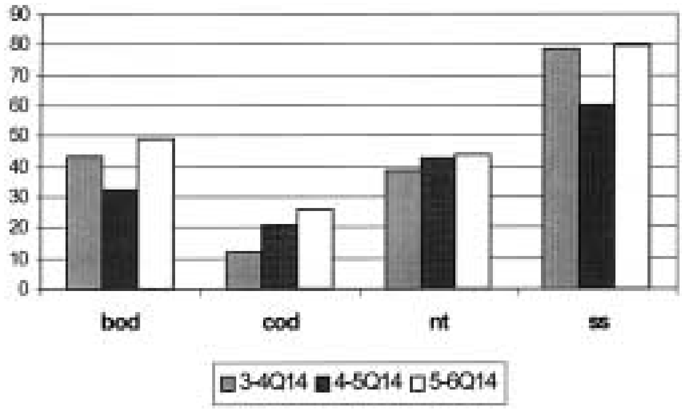

Figure 4 Average reduction percentages in total pollutant discharge by switching to $6Q_{14}$ operation

It was also investigated whether or not $6Q_{14}$ operation would imply extra operational costs. But full scale tests show that there is no significant difference between $3Q_{14}$ and $6Q_{14}$ operation where energy costs or sludge production are concerned.

Potential savings

It has been calculated that for the whole region of Flanders an extra storage capacity of 1,300,000 m^3 would be needed to comply with an extension of the spill frequency concept towards the storm tanks. This represents a total investment of 244 million Euro if the classical $3Q_{14}$ operation concept is maintained. By adopting the $6Q_{14}$ storm operation strategy the same objective is reached without any extra investments.

Conclusions

Full scale tests confirmed that effluent consents could still be met when adopting the specified $6Q_{14}$ operation mode. Furthermore it was demonstrated that by applying this $6Q_{14}$ operation strategy the overall pollutant discharge was significantly reduced compared to the classical $3Q_{14}$ operation mode. This extra pollutant discharge reduction ranged from 10 to 80% depending on the water quality parameter under consideration. Viewing the relative importance of the stormtank overflow discharge into the total pollutant discharge balance of the integrated wastewater system, a significant reduction can be obtained in pollutant discharge on the overall wastewater system by selecting the $6Q_{14}$ operation mode. The proposed strategy does not entail any extra operational costs. On the contrary it offers a potential cost saving of 244 million Euro in view of a possible future change of environmental legislation regarding storm tank spill frequencies. The application of this strategy is not limited to Flanders, but is applicable to any country with a similar type of sewer system (combined and flat) and similar characteristics of the sewage.

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