Utilization of activated sludge plants for enhanced treatment of combined sewage

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ABSTRACT

A process is introduced which utilizes secondary clarifiers for the treatment of combined sewage. Under storm water conditions, surplus sewage bypasses the aeration tanks after primary treatment and is directly introduced into the secondary clarifiers. The hydraulic capacity of existing activated sludge plants can be increased without additional tank volume. Particulate matter as well as dissolved compounds are removed to a high extent. Investigations on a full scale treatment plant (100,000 p.e.) show that the effluent quality is comparable with full biological treatment, even if the hydraulic loading is increased by 50%.

Key words | activated sludge process, combined sewage, enhanced treatment, secondary clarifier

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INTRODUCTION

Activated sludge systems are typically designed to process 2–3 or more times the dry-weather flow with high efficiency. During wet weather (rainstorm or snowmelt), the combined storm water runoff and sewage usually exceeds the capacity of the final clarifiers and overflows through an outfall into the receiving waters with minimum, or no, treatment. Since the wastewater treatment standards increased within the last 20 years, the emissions from the combined sewer overflows (CSO) became relevant.

One possibility to reduce the CSO discharge into the receiving water is to increase the maximum wastewater flow to the wastewater treatment plants. The common practice, e.g. in Europe, is to operate aeration tanks at mixed liquor suspended solids concentrations of 3–6 kg/m^3. Under these conditions, the capacity of secondary clarifiers is limited by the sludge loading rate and not by the hydraulic loading rate or surface overflow rate (SOR). In the United States, the MLSS concentrations in the aeration tanks are usually lower than in Europe, which allows operating the clarifiers with peak surface overflow rates of 2 m/h or more.

With well designed clarifiers, low concentrations of effluent suspended solids (<10 mg/L average) can be obtained (Parker *et al*. 1996, 2001). Müller & Krauth (1998) report on an automatic control strategy to limit the storm water inflow to the aeration tank according to the actual treatment capacity, with the ammonia concentration in the nitrification zone and the sludge blanket level in the secondary clarifiers as control parameters. Measures to cope with overloading of the secondary clarifiers are presented in Nyberg *et al*. (1996). Peters *et al*. (2007) present an assessment of different measures to minimize river impacts during storm water events for a catchment in Berlin, Germany.

This paper presents full scale experiences with enhanced treatment of combined sewer overflow (CSO) in secondary clarifiers.

doi: 10.2166/wst.2008.744

PROCESS DESCRIPTION

The maximum flow of treated wastewater under storm water conditions is enhanced by charging the secondary settling tanks with surplus wastewater.

If the wastewater inflow to the wastewater treatment plant exceeds the limit for the sludge loading of the final clarifiers, the surplus wastewater flow bypasses the aeration tank and is fed into the feed-channel to the secondary clarifiers. By means of this bypass, the hydraulic loading can be enhanced whereas the sludge loading of the clarifiers is not affected. The activated sludge and the storm water bypass are mixed in the feed-channel and in the flocculation zone of the secondary clarifier. A high portion of the organic load of the bypass is adsorbed onto the MLSS and thus removed from the wastewater, whereas the bypass water flow does not increase the sludge transfer into the secondary clarifier.

In case storm water is treated in a final clarifier, not only suspended solids are removed, but also a removal of colloidal and dissolved material takes place. These components are recycled with the return sludge to the aeration tank for biological treatment. The treatment efficiency achieved with this process can beat that of CSO basins.

The process can be applied as follows. According to the capacity of the screens and the grit chambers, all the incoming wastewater is treated mechanically to remove the coarse material. If the wastewater flow exceeds the maximum value for biological treatment, the surplus wastewater bypasses the aeration tank and is fed into the inflow to the clarifiers (Figure 1). This process has been operated at Wulkaprodersdorf WWTP (Austria) for many years (Svardal *et al.* 2007).

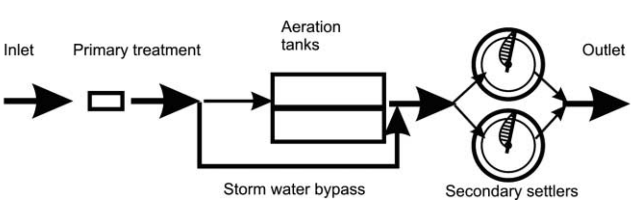

Figure 1 | Flow scheme for the storm water bypass process.

FULL SCALE INVESTIGATIONS

Application at Wulkaprodersdorf treatment plant

The wastewater treatment plant Wulkaprodersdorf/Austria has successfully been operated with this process in order to reduce the total emission into the Wulka River. The Wulka is the main tributary to Lake Neusiedl, which is a very shallow lake on the border between Austria and Hungary. There had been problems with eutrophication in the past. On the average, the effluent of the treatment plant contributes about 15% to the flow of the Wulka River. The effluent of this plant has a high impact on the water quality of the Wulka and the Lake Neusiedl. The effluent standards for the treatment plant are very strict (Table 1) compared to the European guidelines (EEC 1991), and have to be kept also under storm water conditions. Key data of the plant are given in Tables 2, 3 and 4.

At the treatment plant Wulkaprodersdorf, the wastewaters of 22 communities of the Wulka valley, the wastewater of a vegetable canning factory, many vineries and the leachate of a landfill are treated. A scheme is shown in Figure 2. The mechanical stage consists of screens (6 mm) and an aerated grit chamber. There is no primary sedimentation.

Then, the wastewater flows directly into two aeration tanks (7,500 m^3 each) with surface aeration (horizontal shaft aerators), which are connected in series. The mixed liquor is fed to two circular sedimentation tanks. The third, old sedimentation tank is kept as a reserve tank but is usually not in use, because of its low depth of 2.4 m only. Typical operation parameters are summarized in Table 3.

Table 1 | Effluent limits for Wulkaprodersdorf WWTP in the daily composite sample and minimum removal efficiency in the yearly average

Parameter	Effluent limit	Annual removal efficiency	EU Urban WW Directive
BOD_5	10 mg/L	95%	25 mg/L/70–90%
TOC	15 mg/L	85%	
COD	50 mg/L	85%	
NH_4-N	3 mg/L		
Total N		80%	15 mg/L/70–80%
Total P	0.5 mg/L		2 mg/L/80%

Table 2 | Plant properties of Wulkatal WWTP

Aeration tanks with surface faerators	Total volume 15,000 m^3
2 circular secondary clarifiers	Total volume 13,680 m^3, Ø 45 m
Water depth in clarifiers	4.3 m
Water depth reserve tank	2.4 m

Table 3 | Operation parameters of Wulkatal WWTP

MLSS	5–7 kg/m^3
Sludge volume index	70–170 mL/g
Volumetric BOD loading	0.15–0.30 kg BOD_5/(m^3.d)
F/M ratio	0.02–0.05 kg BOD_5/(kg MLSS.d)
Solids retention time SRT	20–30 days

Table 4 | Key data from Wulkaprodersdorf WWTP (average values from 2005–2006)

Parameter	Influent load	Effluent concentration
Dry weather flow	19,000 m^3/d (220 L/s)	
COD	6,300 kg/d	20 mg/L
TOC	2,200 kg/d	7 mg/L
Total N	407 kg/d	1.5 mg/L
NH_4-N		0.2 mg/L
Total P	51 kg/d	0.2 mg/L

The inflow distribution is shown in Figure 2 in detail. The incoming wastewater flow ranges from 100–300 L/s under dry weather conditions. Under stormwater conditions, the flow increases up to 1,000 L/s. A maximum flow of 600 L/s is fed into the aeration tanks, whereas the surplus flow is bypassed to a small tank (60 m^3), which is utilized for the even distribution of the flow to the secondary clarifiers and for the dispersion of the storm water bypass in the mixed liquor.

Treatment performance

A detailed monitoring of the treatment plant was performed over two years, in order to assess the performance of the stormwater bypass treatment with the secondary clarifiers. Fifty five storm water events with bypass treatment were observed. The efficiency of the bypass treatment and the achieved effluent quality are presented.

In order to estimate the purification potential of this process concerning the stormwater bypass, the following assumptions have been made.

(a) The effluent concentration that would have been obtained without bypass operation is not known. Therefore it has been assumed that the effluent concentration under storm water conditions without bypass operation resembles the measured concentrations including the bypass. This assumption certainly

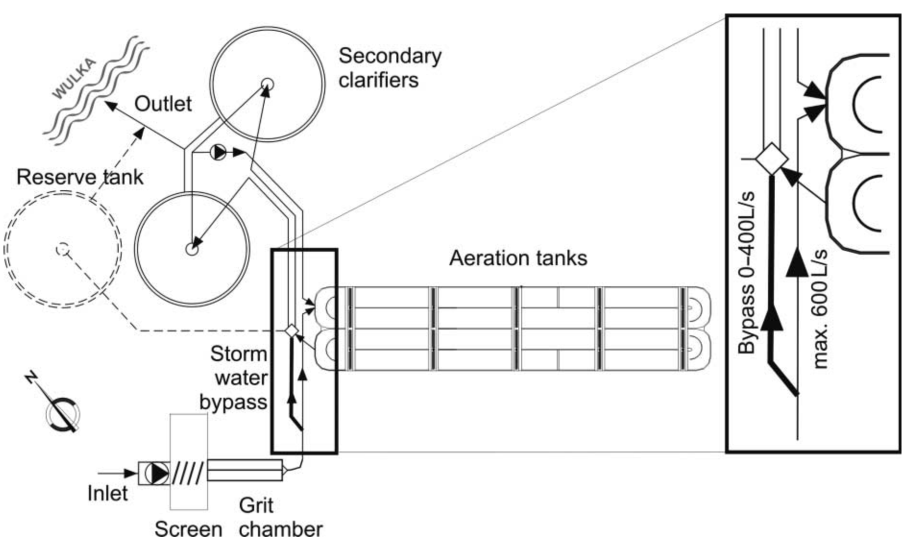

Figure 2 | Scheme of Wulkaprodersdorf WWTP.

somewhat overestimates the removed pollution load of the process with storm water bypass.

(b) After the storm event, the investigated experimental period used for the balancing was elongated to the next morning. It is assumed that by this means a possible pollution load stored in the clarifiers is included in the balance.

For the assessment of the removed pollution load under storm water bypass conditions, the measured loads of the effluent are compared with the theoretical emission load without storm water bypass. This theoretical load is calculated as the sum of the estimated effluent load without bypass treatment and the load of the storm water bypass. The calculation of the influent and effluent loads is based on 2-hour-composite samples. On the basis of the available data, 49 events could be evaluated.

Figure 3 shows the daily COD loads for 49 storm water events. Grey bars indicate the COD effluent loads of the plant as measured. The white bars indicate the effluent load that would have occurred without bypass treatment, and the black bars on top of the white bars indicate the measured COD load in the storm water bypass. The top values of the black bars correspond to the theoretically emitted COD load without storm water treatment. For all these events, it can be stated that about 900 kg of COD were removed from the bypass on the average. Table 5 gives an overview for the efficiency of the storm water treatment in the secondary clarifiers for typical wastewater parameters.

The efficiency of the storm water treatment in the secondary clarifiers exceeds by far the performance of primary treatment, which is usually applied for CSO, and is comparable to full biological treatment.

Depending on the ratio of storm water bypass to aeration tank effluent a certain amount of dissolved pollution (NH_4-N) is recycled to the aeration tank as return sludge flow, and undergoes biological treatment. For the documented events, this portion was calculated to about one third of the bypass load.

Based on lab-scale investigations it was found that absorption to the sludge flocs is relevant for removal of COD and particulate matter (Nikolavcic *et al.* 2006), but of minor relevance for ammonia. The removal efficiency for ammonia as given in Table 5 indicates that other processes are also important. The concentrations in the effluent are generally below 2 mg NH_4-N/L. As the mixed liquor overflows weirs on its way to the clarifiers, it is supposed that some oxygen is introduced and ammonia from the bypass is nitrified and later denitrified to a certain extent.

During storm water operation of the plant, the effluent concentrations of the organic compounds were always

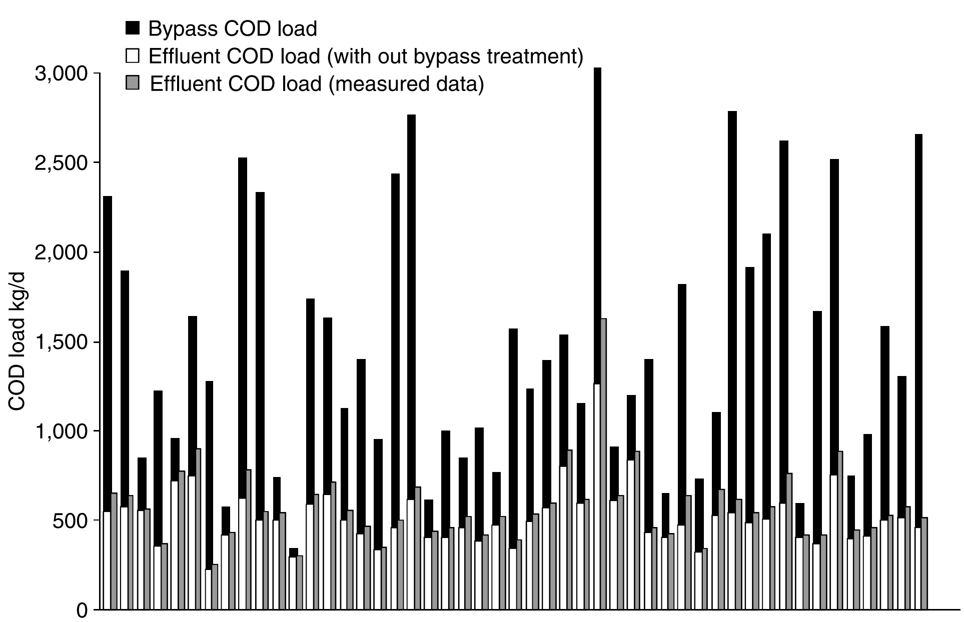

Figure 3 | Daily COD loads for 49 storm water events.

Table 5 | Mean bypass loads and removal efficiency for 49 events of storm water treatment at Wulkaprodersdorf WWTP in 2005 and 2006

Parameter	Flow	COD	NH_4-N	Total N	TSS	Total P
Bypass load	4,080 m^3/d	980 kg/d	21 kg/d	49 kg/d	1,088 kg/d	76 kg/d
Minimum		75%	16%	38%	92%	25%
Average		92%	88%	78%	98%	79%
Maximum		98%	98%	96%	99.9%	97%

below the limit of 50 mg COD/L. The maximum effluent concentration in the daily composite samples was 33 mg/L in 2005 and 27 mg/L in 2006 respectively.

The average effluent concentration for total suspended solids (TSS) during storm water operation was 4 mg/L. The maximum value of all the 2-h-composite samples from two years of investigations was 23 mg TSS/L in the effluent.

The concentrations of NH_4-N are crucial for keeping the effluent limit of the plant. Table 6 gives the quantity of events with storm water treatment according to the maximum NH_4-N effluent concentration in the 2-h-composite samples. The maximum value of all samples was 6 mg NH_4-N/L.

During 7 of the 55 documented events, the effluent concentration exceeded 2 mg NH_4-N/L. A comparison between the 2-h-composite samples and the recorded values from an online-probe in the effluent section of the aeration tank showed that the ammonia concentration in the aeration tank was too high in five cases due to insufficient aeration. Optimising the control strategy for oxygen in the aeration tank can help to keep the ammonia concentration low.

In two cases, ammonia in the effluent was above 2 mg/L due to storm water bypass treatment, the respective values are 2.7 mg/L and 2.4 mg/L in the 2-h-composite samples, and 1.7 mg/L and 1.9 mg/L in the daily composite samples. The stormwater treatment in the secondary clarifiers put no risk on keeping the effluent limit of 3 mg NH_4-N/L in the daily composite samples.

Table 6 | Number of events according to the maximum NH_4-N concentration measured in 2-h-composite samples of the effluent

Max. NH_4-N effluent concentration	n.a.	0–1 g/L	1–2 mg/L	2–6 mg/L
Number of events	1	34	13	7

CONCLUSIONS

The two years of investigation at Wulkaprodersdorf WWTP (Austria) show that conventional secondary clarifiers can be utilized for enhanced CSO treatment with very good results. The performance of this process exceeds that of the common practice of CSO treatment by far and is comparable to full biological treatment.

Keeping the effluent limits was not at risk due to the storm water bypass. However, the maximum hydraulic load could be increased by 50%. The maximum observed value for NH_4-N in the effluent was 6 mg/L, and caused only by inaccurate control of the oxygen supply.

This process for enhanced CSO treatment can be applied at conventional activated sludge plants without additional tank volume. In case that the capacity of the influent pumps and the primary treatment is not yet at the limit, only a bypass channel or a pipe to the effluent of the aeration tank is required to treat additional storm water in the secondary clarifiers. If a certain quality loss in the treatment plant effluent can be accepted under wet weather conditions, the overall emissions into the receiving water can be reduced remarkably.

ACKNOWLEDGEMENTS

These investigations were cofinanced by the European Union Interreg IIIc project SiTaR.

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