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Research note

Strom Water Management: An Energy Efficient Bypass Technology

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P A P E R I N F O

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A B S T R A C T

The water quality in a river is influenced by discharge from the sewerage network. Through increased efficiencies of the wastewater treatment plants, the main deterioration comes from combined water overflow. In view to a reduction of the discharge from combined water outflow the increase of the influent to a wastewater treatment plant can be an efficient solution. The main bottleneck on the waste water treatment plant is the final clarifier with the limited capacity regarding sludge discharge from the biological stage. Through bypassing the aeration with combined water and a direct feed of the combined water into the final clarification the specific sludge volume loading, which is significant to the efficiency of the final clarification, will not be raised. But the adsorption capability of the aerated sludge, the sedimentation effect of the final clarification and the partial recirculation over return-sludge can be used for an elimination of suspended solids, COD, ammonia and phosphate from the combined wastewater. In large-scale tests in Wilhelmshaven (160,000 PE) removal efficiencies for the elimination in the bypass of 75 % of COD, 60 % of ammonia and 89 % of suspended solids were reached. In comparison with conventional procedures for combined water treatment (e.g. storage volumes, soil filter) the bypass technology has got the possibility to achieve a highly efficient and economical combined water treatment by using the capability of existing clarifiers. In the frame of the presentation the basics for this advanced solution will be explained and the results from the technical application will be demonstrated.

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INTRODUCTION

After the extensive development of wastewater treatment plants and the considerable improvement of water quality the combined sewer storm water overflow becomes increasingly important due to ecological impacts. For the impairment of combined water load removal components can be installed. This will reduce the discharge loads, like additional storage tank volume in the catchment area or soil filters [1].

An increased supply of combined water towards the wastewater treatment plant [e.g. > two times dry weather peak flow Q_t] could reduce the storm water runoff discharge. Through an increased feed of combined water to the wastewater treatment plant a discharge from combined systems will not be avoided, but the frequency can considerably be reduced. In particular discharge is avoided at less intensive precipitations, where only small dilution occur and concentrations of the discharge system are accordingly high.

There is a possibility to treat combined water with an increasing degree in the wastewater treatment plant through bypassing of an additional stream of combined water around the biological units which is directly fed to inflow of the final clarification.

Concept for bypass feed

The role of the final clarification in the aeration process is the separation of the aerated sludge and storage of the aerated sludge in the course of load variation. A relevant design value for the final clarification is the specific sludge volume rate $q_{SV,R}$ [L/m³·h]. There is a clear coherence between the specific volume rate and the concentration of solids in the effluent of leaving the clarification unit TS_E [mg/L].design of the clarifiers is based on relation given by DWA-A 131 [2], which often results in specific volume rate around $q_{SV,R}$ = 180 L/m³·h. In comparison to the effluent of an aeration tank (inflow to the final clarification unit) the combined process water has very low solid content.

Through bypass the combined water can be fed right after mechanical pre-purification (screen/sieving, grit removal, primary treatment/flotation) via bypassing the aeration and directly feeding into the final clarification unit. We have called this technology [3].
"Mina-Process" ("Mischwasserführung direkt in die Nachklärung"; which is translated as: "combined water fed directly into the final clarification"). The low solids content in the bypass (e.g. 100 mg TS/L; in the effluent

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of the aera-tion e.g. 3,500 mg TS/L) resulted in the specific volume loading of the final clarification to be only marginally impaired through the bypass feed. The hydraulic load of the final clarification unit increases according to the relation given by the bypass flow Q_{By}. e.g. a bypass $Q_{By} = 1 \cdot Q_t$ and an inflow to the wastewater treatment plant during combined with water flow of $Q_O = 2 \cdot Q_t$ results in an increase factor of the surface loading rate f_{qA} of

$$f_{qA} = \frac{q_{A,By}}{q_{A,m}} = \frac{Q_{By} + Q_O}{Q_O} = 1.5\,[-] \quad (1)$$

fqA = increase factor of the surface loading caused by the additional bypass of combined water

qA,m = surface loading rate of the final clarification of the combined water formation without bypass (m/h)

qA,By = surface loading rate of the final clarification of the combined water formation inclusive bypass (m/h)

Q_O = inflow to the aeration tank (m³/h)

QBy = flow-through of the bypass (m³/h)

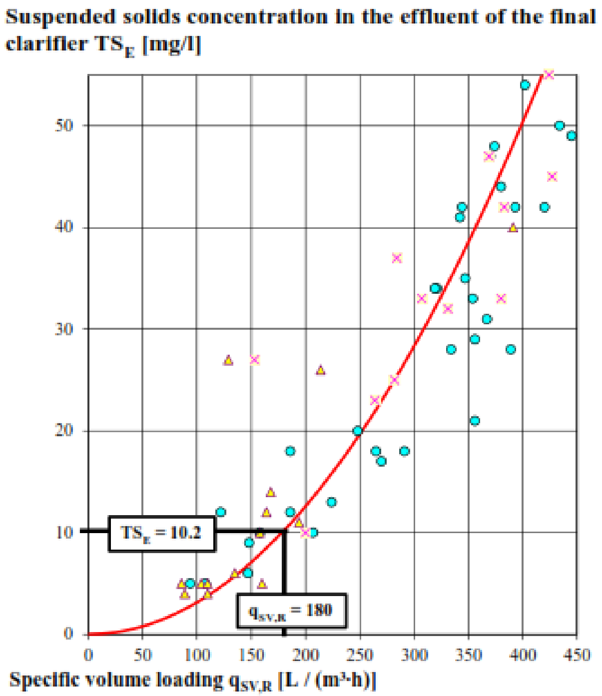

Figure 1. Solids content TS_E in the final clarification effluent

MATERIAL AND METHODS

The bypass feed leads to a dilution of the solids content at the inlet area of the final clarification unit. The settling velocity of the sludge flocs depends on the solids content. With increasing solids content the sedimentation of the sludge flocs is getting worse because of the hindering settling of the flocs. This is perceptible by the viewing the sedimentation curve, which shows the settling velocity as a function of the solids content. Similar sedimentation curves are used for detailed hydrodynamic simulations of settling tanks.

Taking as a starting point shown in the sedimentation curve, a decrease of the TS concentration from 3,500 mgTS/L to 1,750 mgTS/L leads to an increase in the settling velocity V_S by a factor three (see Figure 2). Through the dilution using bypass the hydraulic load will increase, also the sedimentation velocity of the suspended solids increase. Therefore a compensation of the impact of an additional hydraulic load through the combined water bypass takes place.

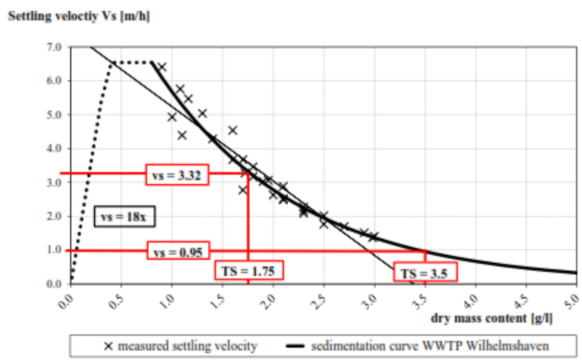

Figure 2. Empirical calculated sedimentation curve of the sedimentation velocity VS, WWTP Wilhelmshaven (160,000 PE)

Besides the hydraulic influences the impact of solids in the bypass feed should be take into account by consideration of solved components (COD, N, P). In this case the high adsorption capacity of the frequent low loaded aerated sludge should be counted as system advantages.

Considerable amount of biodegradable organic substances should be removed by the aerated sludge in a short contact time. The maximum bypass feed is generally defined by the limited elimination of total ammonia (NH_4-N). For the decision making about the application of the Mina-Process, the current capacity of the final clarifier, the hydraulic capacity of the wastewater treatment line and the general storm water management concept of the catchment area have to be considered.

Large-sale realization of the bypass feed

An appropriate concept for the combined water bypass which is directly feed to the final clarification (Mina-Process) has been implemented at the wastewater treatment plant of Schönfeld in the Erzgebirge [39,000 PE] [4]. The bypass with an adequate flow to $1.Q_t$ is split after the primary treatment and depending on the NH_4-N load (reference: NH_4-N at the effluent of the primary treatment) it is either lead to the last nitrification stage or into the effluent of the aeration tank. The bypass feed is still in an operational test and is accompanied by a research project.

In 2005 and 2006 a number of 49 cases of stormwater runoff events in large-scale use of the bypass technology at the Wulkaprodersdorf wastewater treatment plant (Austria) were analyzed and evaluated [6]. The average value of the elimination rates of the wastewater organic loads in the combined water bypass system for suspended solids, COD, phosphate and total nitrogen have reached to 98, 92, 79 and 78 %, respectively.

Large-sale tests for the mina-process on wilhelmshaven wastewater treatment plant

It is helpful for a specific test of the bypass strategy to accomplish a parallel operation with a clarifier having bypass feed and one clarifier without bypass feed. This was executed at the wastewater treatment plant of Wilhelmshaven.

Two final clarifiers are connected to one aeration tank. The tests for the bypass feed were implemented in one clarifier. The other final clarifier acted as reference or was off from the operation line (out of service) for increasing the organic load. The tests were executed in two stages for A) hydraulic examination and the elimination of suspended solids; B) for the examination of the COD and NH_4-N removal efficiencies.

For analyzing hydraulic influences of the bypass feed (test A) the bypass stream was taken from the effluent of the final clarification then was fed to the inflow of the final clarification. For analyzing the removal efficiencies of NH_4-N and COD (test B) the effluent of the primary treatment unit was used as the bypass stream.

Test A was executed and repeated for five times. The aim of the test was to assess the hydraulic operation performance of the clarifiers under bypass feeding. The solids content of the inflow, the effluent and the return sludge were analyzed as operating variables. Continuous online-measurements of the sludge level and the turbidity of the effluent were also analyzed.

The inflow to the final clarifier test basin shows a comparably higher loading than the reference basin (see Figure 3).

The dilution at the inflow of the final clarification is affected through recycling the effluent (see Figure 4) while the suspended solids in the effluent are only slightly increased (see Figure 5). The test B was operated during combined water inflow (see Figure 6).

The ammonia concentration in the test-clarifier effluent has increased by applying the bypass feed. The average of the elimination degree of the bypass ammonium reached to 60 % which is clearly higher than the efficiency, that is estimated by the theoretical hydraulic efficiency of the executed tests to be 21 %. There are obviously occurring further nitogen removal processes during the flow of the combined water through the final clarifier (e.g. nitrification, adsorption) which are documented also by other researches [5,6].

The COD concentrations of 200 to 400 mg/L in the bypass caused only a marginal increase of the discharge values. That shows that through the adsorption ability of the aerated sludge an extensive elimination of COD occurred. The average value for the removal efficiency of the COD in the bypass according to the executed trials has reached to 75 %.

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Appraisal and outlook

The realized tests with the combined water bypass feed directly into the clarifier (Mina-Process) show that additional combined water can be fed to the final clarification without a significant deterioration of the operating performance. To reach the same effect in the sewer system using other methods high invest for the storage volumes, the installation of a soil filter, or other techniques would be necessary.

Figure 3. Quantity in the final clarification inflow with bypass feed (test basin) and without bypass feed (reference basin), Test A.

The execution of an economic and energy efficiency evaluation depends on the initial condition of the final clarification, the hydrological and hydraulic conditions of the sewer system. This evaluation has to be carried out on a case to case basis.

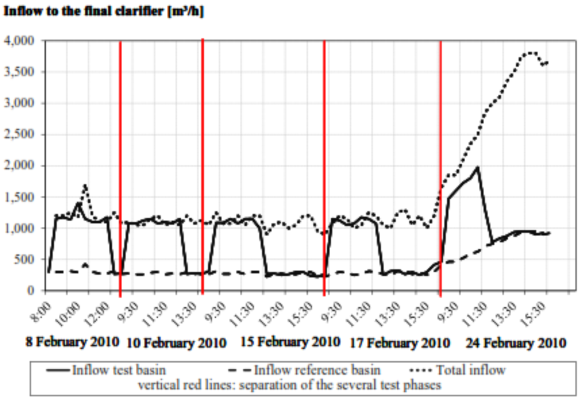

Figure 4. Quantity in the final clarification inflow with bypass feed (test basin) and without bypass feed (reference basin), Test A.

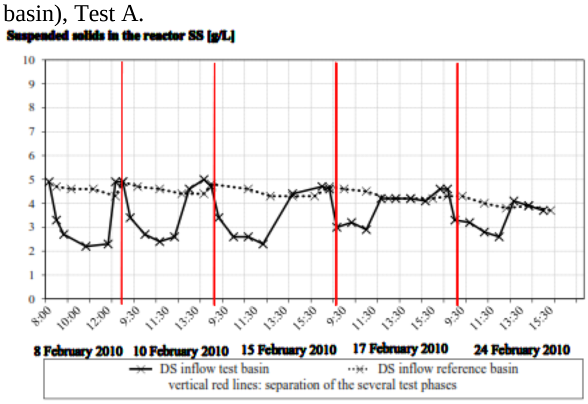

Figure 5. Suspended solids concentrations in the final clarification inflow with bypass feed (test basin) and without bypass feed (reference basin), Test A.

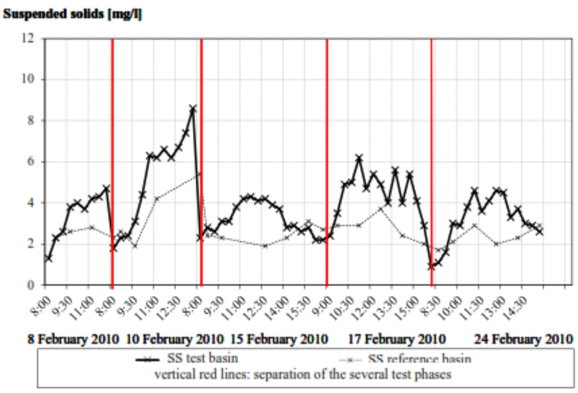

***Figure 6**. Suspended solids in the final clarification discharge with bypass feed (test basin) and without bypass feed (reference basin), Test A*

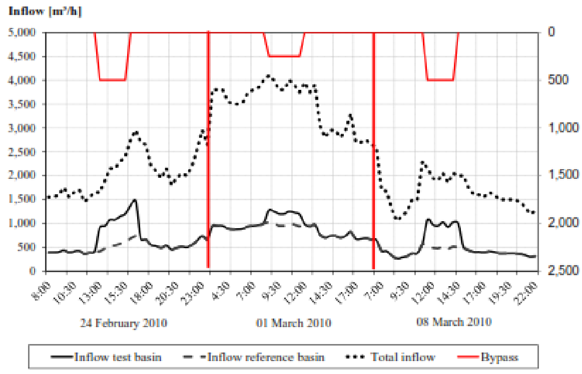

Figure 7. Inflow quantity to the test-clarifier and reference basin by feeding with the effluent of the primary sedimentation (Test B)

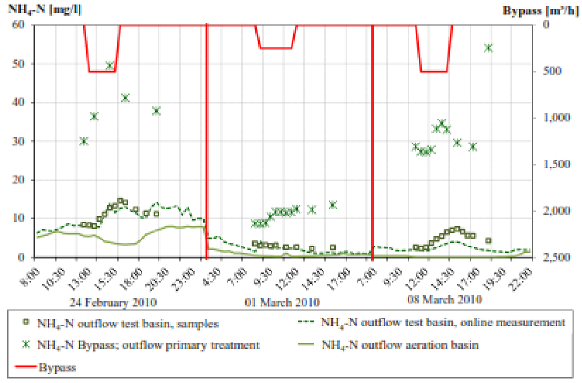

Figure 8. Ammonia concentration in bypass and final clarification discharge

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Persian Abstract

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چکیده

کیفیت آب در یک رودخانه تحت تاثیر تخلیه آب از شبکه فاضلاب به داخل رودخانه است. با افزایش بازده تصفیه فاضلاب در تصفیه خانه‌ها، مشکل اساسی از سر ریز این تاسیسات ایجاد می‌شود. در این راستا کاهش تخلیه این سر ریزا به محیط زیست می‌تواند راه حل مناسبی برای این مشکل باشد. محدودکننده اصلی در سیستم‌های تصفیه شفاف ساز نهایی است که ظرفیت پایینی دارد. با استفاده از جریان‌های کنار گذر می‌توان به نحو مطلوبی این محدودیت را جبران کرد. در این مقاله بر روی تاثیر این روش بر بازده سیستم های تصفیه متداول و تاثیر آن بر روی اکسیژن خواهی شیمیایی، فسفات و جامدات جریان خروجی تحقیق به عمل آمده است.