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Eske Hilbrands, Nina Altensell, Christian Massing, Jens Ante, Helmut Grüning, et al.. Evaluation of a state-of-the-art-adaptation of a downflow baffle with respect to the discharge of floating particles out of a storage and overflow tank by using CFD. Novatech 2023, Jul 2023, Lyon, France. hal-04185036

HAL Id: hal-04185036

<https://hal.science/hal-04185036v1>

Submitted on 22 Aug 2023

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Evaluation of a state-of-the-art-adaptation of a downflow baffle with respect to the discharge of floating particles out of a storage and overflow tank by using CFD

Évaluation d'une adaptation d'une cloison siphonide selon l'état de la technique actuel par rapport à la décharge des matières flottantes d'un bassin de décharge en utilisant CFD

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RÉSUMÉ

Dans ce projet, l'effet d'une cloison siphonide, qui n'est pas construit selon l'état de la technique actuel, sur la décharge des matières flottantes d'un bassin de retenue et décharge est examiné. La simulation numérique en dynamique des fluides (CFD) est utilisée pour analyser les caractéristiques du flux et évaluer si une modification de la cloison siphonide selon l'état de la technique actuel peut réduire la décharge des matières flottantes sur le déversoir latéral. Les investigations sont présentées pour une charge hydraulique représentant la médiane d'une simulation à long terme. Des trajectoires des particules flottantes are examinées qualitativement pour deux particules artificielles polystyrène et plastique. La distribution des temps de séjour des particules est analysée par rapport à la sortie aux pompes installés, au déversoir et au soutien dans le bassin. Les investigations indiquent un court-circuit hydraulique des particules légères directement au départ du bassin, pourquoi des particules avec une densité similaire à celle de l'eau sont déchargées via le déversoir latéral. Une modification de la cloison siphonide selon l'état de la technique actuel ne réduit pas la décharge des matières flottantes significativement. Sur la base des résultats, il est recommandé d'installer une nouvelle grille après le déversoir latéral au lieu d'optimiser la cloison siphonide pour réduire la décharge des matières flottantes. L'utilisation de CFD s'avère très utile pour prendre des décisions judicieuses et fondées afin d'optimiser des bâtiments existants.

ABSTRACT

In this study, the effect of a non-state-of-the-art downflow baffle to the discharge of floating particles over the side weir of a storage and overflow tank is investigated. By using Computational Fluid Dynamics (CFD) flow characteristics are evaluated. It is assessed, if a reconstruction of the downflow baffle according to the state of the art reduces the discharge of floating solids over the weir. The investigations shown here refer to one specific hydraulic load representing the median of a long-term simulation. In the simulation, particle tracks of floating solids are investigated qualitatively for two artificial particles: plastic and polystyrene. Residence time distributions of particles are analyzed with respect to the exit over installed pumps, side weir, and detention in the tank, respectively. The results of the numerical investigations reveal is a hydraulic short circuit for very light particles directly behind the inlet of the tank. Besides that, especially particles with a density close to water are discharged over the side weir. A constructional optimization of the existing downflow baffle according to the state of the art does not reduce the discharge of floating solids significantly. Based on the results, it is recommended to install a new screen behind the overflow structure instead of optimizing the existing downflow baffle to reduce the discharge of floating particles. CFD proves to be very useful in making knowledge-based decisions to optimize existing structures.

KEYWORDS

CFD, discrete phase model, downflow baffle, floating solids, side weir

1 INTRODUCTION

1.1 Background

In waste water management, downflow baffles in front of overflow weirs have already been common practice to hold back floating particles, especially to preserve receiving waters in case of high hydraulic loads. Construction of downflow baffles in front of weirs is generally regulated in the rules of the German DWA Standards (i. e. DWA-A 166 (DWA, 2013a)), where guidelines for distance to the bottom and the weir as well as construction of the weir (vertical flow) and length of the downflow baffle are included. Particles with a density $< 1000 \text{ kg/m}^3$ float onto the water surface and are held back by the baffle. Nevertheless, several investigations have already shown that flow characteristics cannot be generalized for all tanks regarding construction and additional components as baffles, especially with respect to the reserve of particles (e. g. Yan (2013), Vosswinkel et. al (2012)).

1.2 Task and objective of this study

Research subject of this study is a storage and overflow tank built in 1992 in the German city of Wuppertal. The installed downflow baffle there does no longer fulfill current technical guideline DWA-A 116 :2013 (distance to side weir; baffle immersion depth). Total volume of the tank is about 4080 m^3 ($l \cdot w \cdot h_m$: $30 \text{ m} \cdot 17 \text{ m} \cdot 8 \text{ m}$). In this study, it is evaluated, if a reconstruction of the downflow baffle according to the state of the art is (significantly) useful regarding the detention of floating solids. The storage and overflow tank is investigated with Computational Fluid Dynamics (CFD) to qualitatively assess the extent to which it poses a risk to receiving waters in terms of particle discharge over the side weir. The investigated tank serves as a storage tank in a huge, combined sewer system and at the same time for pumping (polluted) water towards the wastewater treatment plant or – in case of hydraulic surcharge – discharging the water over the overflow weir towards the receiving water. The sewer system in Wuppertal is described in Fricke et al. (2013).

2 MATERIALS AND METHODS

2.1 Simulation Software

Flow characteristics in the tank are analyzed by using Computation Fluid Dynamics, which uses numerical analysis and data structures to solve even complex, non-linear problems of fluid flows. The software package of ANSYS, Inc. is used (version 2021R2). CFD is based on the conservation of continuity and energy. Simulations are performed for a steady-state hydraulic load, using a $k\text{-}\omega\text{-SST}$ turbulence model and enhanced wall treatment.

2.2 Data Basis

Existing planning documents are used to build a three-dimensional model of the tank. Hydraulic scenarios are defined with existing model data of polluting load and long-term simulations as well as precipitation data. Data of the year 1999 is considered as representative regarding frequencies of heavy rainfall and flow volume. The scenario with an inflow to the tank of $Q = 5.100 \text{ l/s}$ is considered to be representative because it is the median within all hydraulic loads of the long-term simulation. Inflow enters the tank via the inlet sewer and leaves either via pumps to the waste water treatment plant (max. $Q = 1.600 \text{ l/s}$) or the side weir to receiving water.

2.3 Evaluation Methods for Discharge of Floating Solids

2.3.1 *Constructional Adaptation of the Downflow Baffle*

To evaluate the influence of the no-longer state-of-the-art-constructed downflow baffle from 1992 on the discharge of floating particles over the side weir, the downflow baffle is adopted to the current state of the art in a second geometric CFD model. This comes along with a reduced immersion depth of the baffle as well as an increased distance to the side weir.

2.3.2 *Analysis of Particle Trajectories*

To model floating particles within the fluid, Lagrangian discrete phase model (DPM) based on the Euler-Lagrange approach is applied. Fluid phase is treated as continuum by solving the Navier-Stokes equations, while dispersed phase is solved by tracking particles in the flow field. To keep numerical effort manageable, water surface in the simulation is treated as plane of symmetry, knowingly, that floating solids cannot completely be reproduced, here. It is taken into account, that this rather constitutes a critical scenario regarding the discharge of particles

but lets obtain a first impression. Two types of artificial floating particles are injected in the tank (Table 1). Diameter of floating solids is assumed with 1 mm to facilitate particle tracking, as larger particles must be modeled with macroscopic particle models coming along with higher numerical effort. Suspended solids are left out of consideration because downflow baffles generally only serve for the detention of floating solids (DWA, 2013a). Particle residence times as well as particle tracks and continuances are being interpreted.

Table 1: Characteristics of floating particles used in the numeric model

	Diameter [mm]	Density [kg/m ³]	Sedimentation velocity (Stokes, 1851) [m/h]	
Material 1 – Plastic	1	993	-10,49 ¹	¹ negative Sedimentation velocity correspond to floating velocity
Material 2 - Polystyrene	1	23	-1695,18 ¹	

3 SIMULATION RESULTS

3.1 Velocity Fields around the Downflow Baffle

Velocity vectors near the downflow baffle – comparing current state with optimized state – induce an acceleration of velocities in front of the baffle (acceleration downwards) as well as between baffle and side weir (acceleration upwards) in the current state (Figure 1, left side). Although water surface is represented as symmetry plane and behavior of floating particles is idealized, the comparison of velocity vectors lets resume that particles might be sucked down in front of the baffle and discharged towards the receiving water.

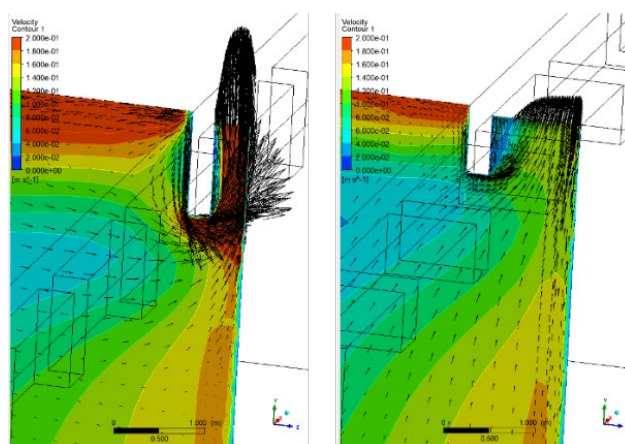


Figure 1: Velocity vectors near the downflow baffle - current state (left) and following the state of the art (right)

3.2 Trajectories of Floating Particles

Analysis of particle trajectories for plastic and polystyrene for current and an optimized state reveals

- a hydraulic short circuit for very light particles (polystyrene) directly behind the inlet. Solids with a density comparable to polystyrene do not have enough time to float onto the water surface and cannot be held back by the downflow baffle. They directly exit the tank over the side weir (Figure 2, below).
- that an optimization of the downflow baffle according to the state of the art does not affect the characteristic of floating particle tracks. Tracks for both investigated particles do not change significantly after having reconstructed the downflow baffle (Figure 2, right vs. left side)

In addition to qualitative evaluations, it is quantitatively evaluated how many particles exit the tank over the side weir or the installed pumps or stay in the tank – for current state as well as for the optimized baffle (Figure 3). It is confirmed that the reconstruction of the downflow baffle does not have a significant impact on the continuance of floating solids – discharge over the weir is only reduced by one and two percentage points for both particle types, respectively.

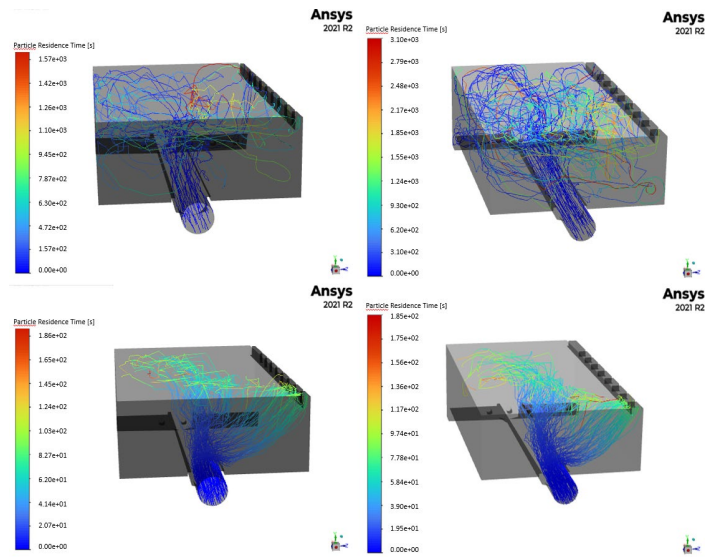


Figure 2: Particle trajectories of floating solids plastic (above) and polystyrene (below) in the current state (left) and with a downflow baffle according to the state of the art (right)

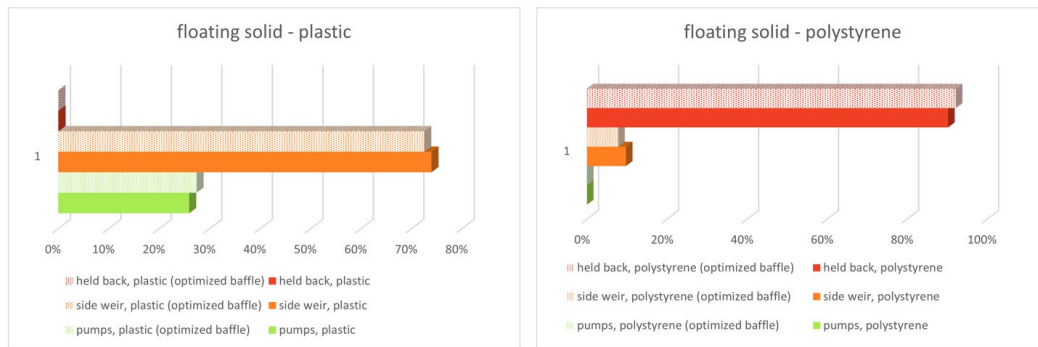


Figure 3: Continuances of plastic and polystyrene particles for the current as well as for the optimized state

4 SUMMARY

Main finding of this study is that a reconstruction of the downflow baffle according to the current state of the art will not significantly reduce the discharge of floating particles with densities similar to polystyrene and plastic, respectively. It is confirmed that side weirs generally bear the risk that particles exit the tanks independently of the construction of installed downflow baffles. The study demonstrates that innovative approaches like CFD can be helpful to improve efficiency of structures in waster water management by analyzing and understanding flow characteristics and thereupon realize reasonable and knowledge-based optimizations. In this study, a renewal of an existing screen in the discharge sewer downstream the side weir is recommended.

LIST OF REFERENCES

- DWA (2013a). *Arbeitsblatt DWA-A 166. Bauwerke der zentralen Regenwasserbehandlung und -rückhaltung – Konstruktive Gestaltung und Ausrüstung*. Arbeitsblatt der Deutschen Vereinigung für Wasser, Abwasser und Abfall e.V. (DWA), Hennef.
- DWA (2013b). *Merkblatt DWA-M 176. Hinweise zur konstruktiven Gestaltung und Ausrüstung von Bauwerken der zentralen Regenwasserbehandlung und -rückhaltung*. Arbeitsblatt der Deutschen Vereinigung für Wasser, Abwasser und Abfall e.V. (DWA), Hennef.
- Fricke K. I., Hoppe H., Hellmig M. und Muschalla M. (2016). *10 years spectrometry based P-RTC in Wuppertal - experiences and enhancements*. 9th International Conference NOVATECH 2013 in Lyon, 23.-27.6.2013.
- Stokes, G. G. (1851). *On The effect of internal friction of fluids on the motion of pendulums*. Transactions of the Cambridge Philosophical Society. 9, part ii : 8-106.
- Vosswinkel, N., Lipeme Kouyi, G., Ebbert, S., Schnieders, A., Maus, C., Lailly, A.-G., Mohn, R., Uhl, M. (2012). *Influence of Transient Behaviour on the Settling of Solids in Storm Water Tanks*. 9th International Conference on Urban Drainage Modelling. Belgrade 2012.
- Yan, H. (2013). *Experiments and 3D modelling of hydrodynamics, sediment transport, settling and resuspension under unsteady conditions in an urban stormwater detention basin*. Other. INSA de Lyon, 2013. English. NNT : 2013ISAL0034.