Feasibility Study on the Monitoring of Internal Flow and Transport Processes in Combined Sewer Overflow and Waste Water Treatment Structures

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Presently, the implementation of measures to comply with the requirements of the EU Water Framework Directive is of primary concern to the water sector in Europe. For this reason, the construction and update of facilities in urban waste water systems is being realised. Further efforts include the assessment of impacts of waste water systems on receiving waters using modelling approaches to enable a sustainable water resources management. Currently, neither dimensioning nor modelling of emissions of treatment structures incorporates a detailed assessment of the flow regime and transport processes in the structures. Especially dynamic loadings have significant effects on internal processes and consequently on the treatment efficiency of structures. Additional information on flow conditions within structures would allow for detailed modelling, followed by an optimisation of their performance. Therefore the evaluation of flow velocity profile (FVP) measurements in large scale structures will be a valuable tool in improving the treatment performance of such structures. The study presented here focused on FVP test measurements in large scale tank structures at the waste water treatment plant Pétange (Luxembourg). The application of two monitoring systems led to promising results.

Keywords: Flow measurement, flow velocity profile, sedimentation tanks, combined sewer overflow tanks, primary clarifiers

1 INTRODUCTION

Emissions of urban waste water systems (drainage networks and waste water treatment plants) have a significant impact on the quality of surface waters. For this reason, the assessment of performance and emissions of separate and combined sewer overflow structures is of increasing importance to achieve a sustainable management of surface waters.

However, neither the dimensioning and update of treatment structures nor the modelling of their emissions incorporate a detailed assessment of the flow regime and transport processes in the structures built to date. Especially the dynamic hydraulic and pollutant loadings have a significant effect on internal processes and consequently on the treatment efficiency of these structures. More detailed modelling and a subsequent optimisation of overflow structures would be possible if information on flow conditions were available. Therefore, a technique that allows for the evaluation of flow velocity profile (FVP) measurements in large scale structures will be a valuable tool in improving the treatment performance of such structures and inherently assist in complying with EU requirements.

So far, monitoring devices for the observation of FVP have been used in open channels and large pipes under laboratory conditions [1] and in surface waters [2] as well as in a lab scale vortex separator [3]. Further studies focus on using the Doppler principle to measure velocity profiles in large scale clarifiers [4] or to monitor total suspended solid concentrations and settling velocities in lab scale clarifiers [5].

In the framework of a feasibility study test measurements of FVP in a large scale tank structure for combined sewer overflow treatment and in the primary clarifier of the waste water treatment plant Pétange in Luxembourg were carried out. The application of two monitoring systems by NIVUS and UBERTONE indicates that flow velocity measurements are feasible in large scale structures.

2 METHODOLOGY

The test measurements have been carried out with two different FVP monitoring devices. The monitoring system OCM Pro LR by NIVUS (Germany) is based on the cross correlation method [6] whereas the UB-Flow F156 by Ubertone (France) applies the Doppler method.

Beside the observation of flow velocity profiles the UB-Flow F156 provides turbidity profiles. Based on the turbidity profiles the monitoring system can provide further information on Total Suspended Solids (TSS) profiles if calibrated using reliable

TSS samples for calibration.

Both monitoring systems were mounted on floats to measure profiles from the water surface to the base of the structures under investigation (s. Figure 1). Therefore disturbances by deposits were avoided and both monitoring devices could be moved without problems to do measurements at different locations in the tanks. The time resolution of the measurements was 1 minute.

Figure 1: Installation of the two tested monitoring devices OCM Pro LR (on the left) and UB-Flow F156 below floats

2.1 FVP measurement in a combined sewer overflow tank

The first test of FVP measurement was done in a two lane offline sedimentation tank upstream of a combined sewer overflow (CSO) in Pétange (Luxembourg). The rectangular tank (length: 46 m, width: 22 m average depth: 3,4m) has a total volume of about 3,400m³ and is the last CSO structure upstream of the waste water treatment plant Pétange. The measurement was carried out in lane 1 of the structure during a 2 day overflow event. For the measurements the float with the sensor was mounted to the scraper bridge moving along the structure (s. Figure 2, 3 and 4).

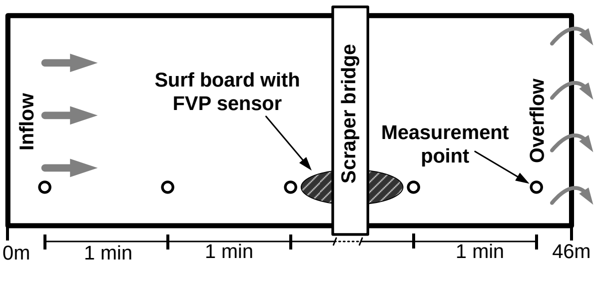

Figure 2: Set up of the monitoring and measurement locations in the CSO tank

Due to this, several velocity profiles could be measured along the flow direction towards the CSO weir down to a depth of up to 4.0 m. The time period between FVP measurements at specific location was about 1 h linked to the periodic movement of the scraper bridge. In parallel reference measurements by using a hydrometric vane at a depth of 0.5 m were carried out [7].

Figure 3: Float with FVP sensor below the scraper bridge in a CSO tank in Pétange (Luxembourg)

Figure 4: Float with FVP sensor below the scraper bridge in a primary clarifier in Pétange (Luxembourg)

2.2 FVP measurement in a primary clarifier

Further tests were implemented in lane 1 of the primary clarifier of the waste water treatment plant of Pétange using the monitoring device UB-Flow F156. The tank under investigation has a total volume of 552 m³ and an average depth of 2 m. The float with the sensor was mounted below a scraper bridge like in the CSO tank (s. Figure 3). Further measurement campaigns including reference measurements with a hydrometric vane and reference analysis of TSS concentrations in different depth of the tank are not done yet but planned to verify FVP monitoring results.

3 RESULTS AND DISCUSSION

3.1 FVP measurement in a combined sewer overflow tank

The FVP measurements in the CSO tank have been carried out successfully. The reference measurements with the hydrometric vane confirm the FVP measurement [7].

The profile measurements close to the tank inflow show the dynamic of the flow velocities over the depth in this region (s. Figure 5, top). Local velocity peaks in depths of up to 1.5 m correlate with the design of the tank inflow structure, a rectangular orifice.

The profile curves close to the overflow weir illustrate the quite obvious behavior of the flow velocities in this region. The velocity peaks in depths up to 1 m can be correlated with a baffle in front of the weir crest (s. Figure 5, bottom).

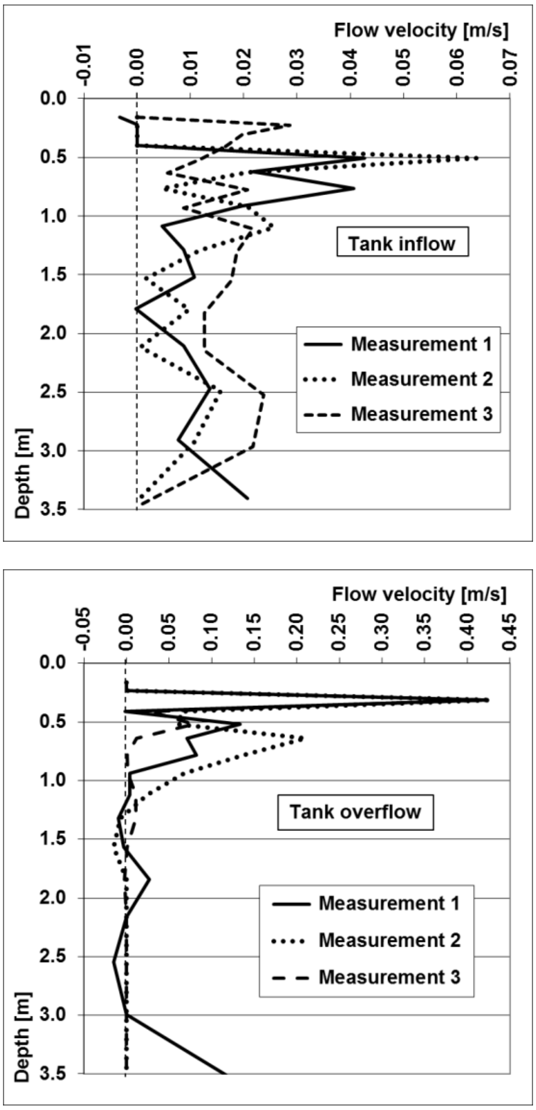

Figure 5: Flow velocity profiles at the inflow of the CSO tank (top) and close to the overflow of the CSO tank (bottom)

3.2 FVP and turbidity profile measurement in a primary clarifier

The measurement profiles illustrated in Figure 6 show velocity and turbidity profiles along a line from the inflow to the outflow of the primary clarifier. The FVP measurements show an increase of the flow velocities with increasing depth (s. Figure 6, on top). This possibly indicates that the inflowing volume flows are sinking down to the base because of their lower temperature.

The observed turbidity profiles expectedly indicate higher TSS concentrations in depths lower than 1 m. The signals in depth of about 0.4 m and 1.5 m are caused by components of the scraper bridge. Additional measurements along different cross sections of the tank could provide further valuable information.

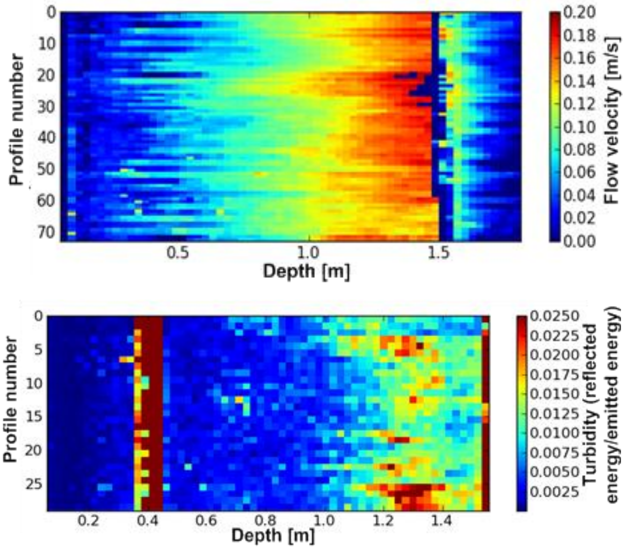

Figure 6: Flow velocity profiles (on top) and turbidity profiles in primary clarifier of WWTP Pétange (Evaluation Ubertone, Strasbourg, F)

Before the monitoring system can be applied for an explicit evaluation of flow and transport processes in tank structures further efforts should be spent to verify and calibrate velocity and turbidity profiles by reference velocity and turbidity measurements as well as TSS samples. In this context Ubertone strongly recommends the calibration of turbidity profile by standard turbidity measurements devices.

4 CONCLUSIONS

The test measurements show that the measurement of flow velocity profiles in CSO tanks is possible and delivers plausible results. Measurements in primary clarifiers seem to be possible but should be verified with reference measurements.

It is planned to further evaluate the application of flow velocity and turbidity profile measurements in detail in a follow up project. In this context it is planned to use several monitoring devices in parallel to get information on multiple profiles per flow cross section along the length of a tank. It is expected that this will provide valuable information on internal flow and transport processes in the tank structures under investigation.

If further studies confirm the reliability of the profile measurements the monitoring results could be applied to a wide range of applications:

- Observation and optimisation of flow conditions in tank structures (e.g. prevention of short cut flows and/or dead zones, ensure complete mixing in treatment systems)
- Calibration and validation of CFD models (computational fluid dynamics)
- Support of the development of simplified modelling approaches that take into account important transport and treatment processes (e.g. detailed balancing of emissions of CSO structures)
- Take into account internal processes in a detailed evaluation of the treatment performance of treatment systems

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