IN-SITU MEASURED VELOCITY IN THE SECODARY SETTLING TANK AND ITS APPLICATION FOR THE FLOW SIMULATION

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ABSTRACT

Wastewater treatment process consists of several steps. Separation of sludge from water is one of the essential. Correct design of the settling tanks is therefore crucial for its operation. In case that these objects don't work properly, they cause problems in the whole ecosystem as they lead to the increased load to the recipients. In this paper proper data collecting method is investigated and data collection is described. Actual point velocity of flow in the secondary settling tank was measured in several points throughout the tank. Measurement was carried out in WWTP Dolný Kubín and WWTP Nižná nad Oravou in Slovakia and these data are used for model calibration and verification. Consequently, simulation of the flow in the tank will be provided. Modelling of the flow in this type of conditions is difficult therefore it is necessary to find right tool to perform precise work. Data that were obtained by measurement have been supplemented by the data provided by the operation of the WWTP.

Key words: *flow simulation, WWTP, flow velocity*

1 INTRODUCTION

Wastewater treatment is process that is essential for modern nowadays societies. Conventional wastewater treatment plants (WWTP) are based on the biological processes. They usually consist of mechanical stage and biological stage including activation tank and secondary settling tank (SST). In secondary settling tank, residuals from the purification process performed in the activation tank are separated from the liquid (Patzinger 2012, pp 2416). Separation is run by the basic physical principles like gravitation, to be more specific by the difference between the specific weight of the liquid and the specific weight of the suspended solids. What is important for the correct performance of the separation process in the SST is the consistent design of the flow through the tank so that the undesired flotation of the solids resulting from the strong flow of the liquid in the tank doesn't occur. Required flow in the tank can be achieved by the correct construction of the object (Stanko 2017, pp 588).

Normally, flow in the sedimentation tank has turbulent character so it is very difficult to express it mathematically. The bio-kinetic processes in the tank can be expressed by several soluble and particulate components (Molnár, 2011). Navier-Stokes equations consisting of continuity equation, momentum equation and energy equation, can be used to formulate these processes.

In Slovak conditions, usually radial sedimentation tanks with horizontal flow or rectangular settling tanks are constructed. In the terms of flow, radial settling tanks are more effective.

Settling velocity is influenced also by the weather changes (Ramin 2014, pp 447), wet weather causes the increased hydraulic load to the WWTP and thus to the SST (Rostami 2011, pp 3017)

2 SETTLING TANKS

Settling tanks are the objects of the wastewater treatment plants in which suspended solids are separated from the liquid. Residence time in the SST is usually approximately 2 hours when the suspended solids divide from the liquid. Turbid water flows through the tanks at low speed, so that suspended particles have enough time to settle. Gravitation is the basic driving force for the separation, therefore it is essential to have the undisturbed flow in the tank.

Flow in the sedimentation tanks is very difficult process to predict because not only sedimentation carries out, but also turbulent flow of the mixture of wastewater and the sludge from the inlet can occur and cause turbulent currents (Ghavi 2008, pp 62). These actions are difficult to predict. Computational Fluid Dynamics (CFD) is tool, which allows it. CFD is science discipline dealing with scientific knowledge from physics, fluid mechanics, thermo-mechanics, mathematics, which connects and together with the software simulate physical phenomena of various complexities. It is used in fluid dynamics, which can be compounds from three parts:

- theoretical fluid mechanics and thermo-mechanics;
- experimental fluid mechanics;
- CFD supported by computers and numeric mathematics.

Important base of the fluid mechanics are basic principles of flow: mass conservation, momentum conservation and energy conservation. In praxis, they are described by the continuity equation, momentum equations and energy equations. These are formed into the system of partial differential equations, Navier-Stokes equations.

3 FIELD MEASUREMENTS

Data from the actual tank in operation are needed to perform the flow simulation. These data sets are used for calibration and verification of the model. In our case, we obtained data from two SST located in two different WWTP. Measurements were carried out in rectangular secondary settling tank of WWTP in Dolný Kubín (Fig. 1) and radial secondary settling tank with horizontal flow in Nižná nad Oravou (Fig. 2).

Fig. 1. Rectangular tank in WWTP Dolný Kubín

Fig. 2. Radial settling tank Nižná nad Oravou

Creation of the model includes several steps: geometry creation, calculation mesh creation of the object, model calibration and model verification. Because sets of data for calibration and verification are necessary, measurements of the flow velocity in the tank will be supplemented by the data obtained from the WWTP operator. For example, flow rate at the tank inlet, concentration of the suspended solids or data of sludge pumps work.

3.1 Measurement preparation

Flo-mate 2000 attached to 5 m long metal rod was used to measure actual flow velocity in a point of water in a tank. Probe of the device was mounted 0.5 m from the end of the rod. Device works on the principle of electromagnetic induction. There is electromagnetic coil built-in, which produces magnetic field. When water flows through this field, the coil produces voltage. The magnitude of this voltage is directly proportional to the velocity of water flow (Flow-Mate Model 2000 1990). Water in the secondary settling tanks always differs; therefore, it is necessary to calibrate the device before each measurement and water.

3.2 SST in Dolný Kubín

Measurements in the rectangular settling tank were carried out in WWTP in Dolný Kubín. Dimensions of the tank are 11.34 m for the width and 43.5 m for the length and tank immediately follows nitrification tank. This disposition causes significant influence on the flow in the SST. Tank is equipped with the dividing wall in the distance 2.5 m from the beginning of the tank, which serves for removal of floating foam which gets to the tank from the nitrification tank.

Measurements were carried out in several measuring profiles along the walls of the tank and in the distance of 3.75 m in the depth 0.5 m as the tank construction, operating bridge and measuring device limited the possibilities of measurements in different spots of tank. Along the wall the measurements in vertical profiles A - H were caries out. Velocities were measured in depths 0.5 m; 1.0 m; 1.5 m; 2.0 m; 2.5 m; 3.0 m under surface.

Along the short side of the tank the measurements in profiles I - M were carried out. In every vertical velocity measurement in depths 0.5 m; 1.0 m; 1.5 m; 2.0 m; 2.5 m; 2.85 m under surface were performed (Fig. 3).

On the other side of the tank the measurements in profiles N - P were carried out. In every vertical velocity measurement in depths 0.5 m; 1.0 m; 1.5 m; 2.0 m; 2.5 m; 3.0 m under surface were performed (Fig. 4).

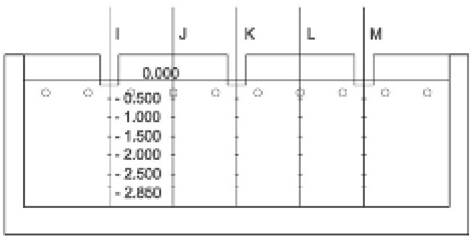

Fig. 3. Scheme of measurement profiles - north-western wall

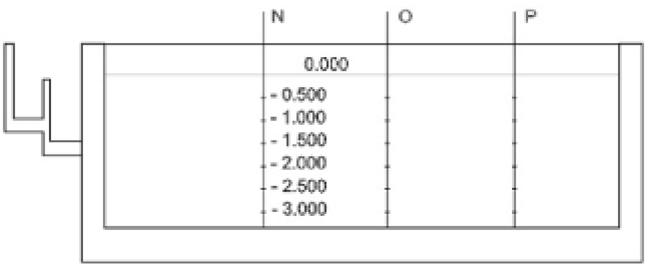

Fig. 4. Scheme of measurement profiles - south-eastern wall

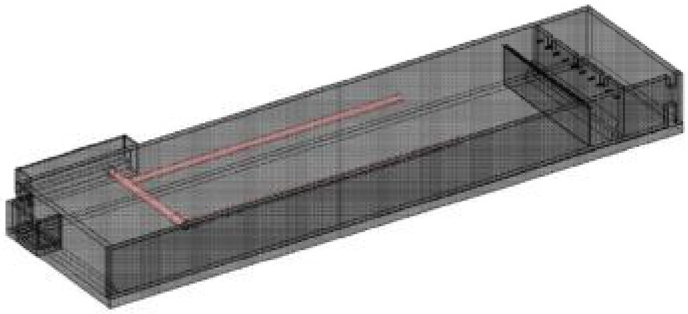

Fig. 5: Model of the tank in CAD software

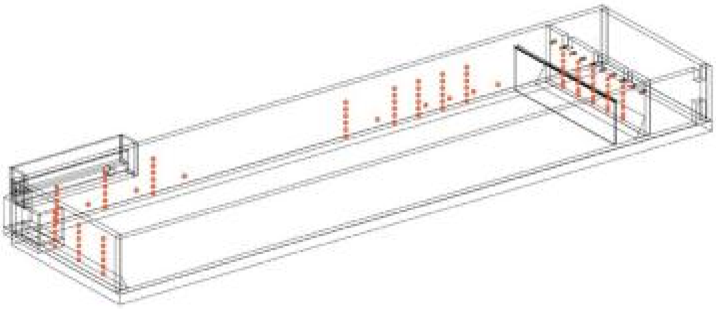

Fig. 6: Scheme of all measuring points in the rectangular tank

3.3 SST in Nižná nad Oravou

Measurements in the radial tank with horizontal flow were carried out in WWTP Nižná nad Oravou. Diameter of the tank is 11.4 m, perimeter 71.6 m. Measurement points were located along the perimeter of the tank in front of the effluent weir in ten verticals 1 – 10 spaced 7.16 m from each other in depths 0.5 m; 1.0 m; 1.5 m; 2.0 m; 2.5 m; 3.0 m; 3.5 m; 4.0 m and 4.395 m under the surface (Fig. 5).

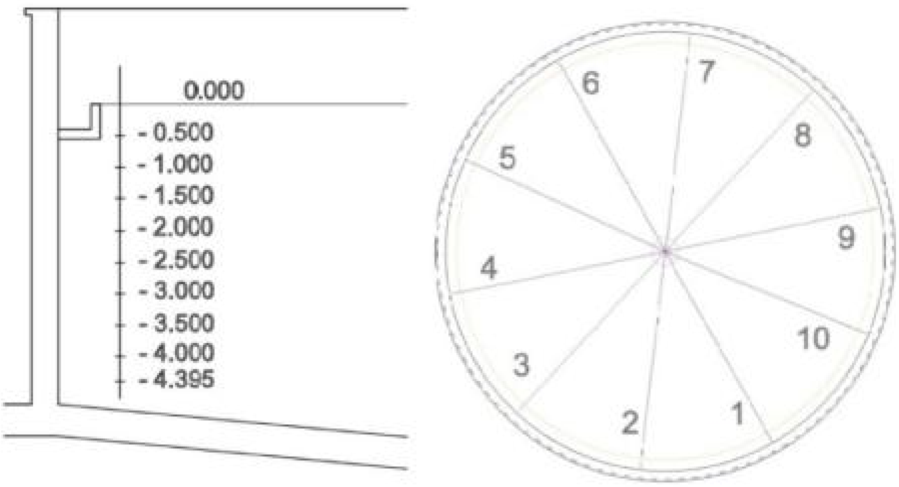

Fig. 7. Measurements profiles and plan of the radial settling tank

Measurements were done in more series to ensure statistically sufficient number of data. In rectangular tank, velocities were taken from 96 points in the tank, in case of radial settling tank in 90 points. These data will be supplemented by data provided by the operator and consequently used for calibration of the tank models and flow simulation will be run. Afterwards, models will be used for optimization proposal of the tank operation.

4 RESULTS AND DISCUSSION

Actual flow velocity measurements were carried out during the operation of the objects of the WWTPs. Different geometrical configurations are supposition for the different flow behaviour in these objects. Measured data were recorded in the prepared protocols. Before using these data for the simulations, they were sorted, analysed and presented in several charts.

Flow velocity in the tanks is considerably influenced by the inflow to the tank. Therefore, it is essential to simulate influence of these parts of the tank to the overall flow in the object.

Velocity flow measurements in the tank should be carried out during stable weather conditions, especially important is to perform all the measurements in one object in more less the identical conditions. Intensive rainfall can disturb the surface in the tank to such an extension that values measured close to the surface can be influenced.

Next step in this work will be simulation of the flow in these objects and consequent evaluation of the possibilities for the flow optimisation in the tanks after potential small construction modifications.

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