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MEASUREMENT OF FLOW VELOCITY IN DIFFERENT SECONDARY SETTLING TANKS FOR ANALYSIS OF THE FLOW

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Abstract: Settling tanks are essential parts of wastewater treatment process and their correct design is therefore crucial for its operation. Modeling of flow in these tanks is difficult, therefore it is necessary to find right tool to perform as precise work as possible. In this article flow velocity measurement in two different secondary settling tanks in Slovakia is presented. Rectangular settling tank in Dolný Kubín and radial settling tank with horizontal flow in Nižná nad Oravou were chosen for this purpose. Data gained from these measurement events will be used for building a model and followed by simulation. Additional data from operation of wastewater treatment plants are also used during the work.

Keywords: Secondary settling tank, Flow simulation, Wastewater treatment plants

1. Introduction

Nowadays, wastewater treatment process takes place in conventional Waste Water Treatment Plants (WWTP) based on the biological processes. In principle, they consist of mechanical stage, activation tank and Secondary Settling Tank (SST). To simplify, in activation tank purification process is carried out, in secondary settling tank residuals from this process is separated from the liquid [1]. Separation is forced by the basic physical principles like gravitation, in fact different specific weight of liquid and suspended solids. Important supposition for effective sludge removal is consistent design of the flow through the tank to avoid undesired flotation of the solids caused by the strong flow in the tank. Required flow in the tank can be achieved by the correct construction of the object [2].

Flow in the sedimentation tank is turbulent so it is very difficult to express it mathematically. The bio-kinetic processes consist of several soluble and particulate components [3]. It can be formulated by Navier-Stokes equations, which consist of continuity equation, momentum equations and energy equation. In Slovakia, usually radial sedimentation tanks with horizontal flow and rectangular settling tanks are constructed. In terms of flow, more effective is radial settling tank.
Settling velocity is also influenced by the weather changes [4], wet weather causes the increased hydraulic load to the WWTP and thus to the SST [5].

2. Settling tanks

Settling tanks are objects of the wastewater treatment plants where separation of solids from liquid takes place. Their main purpose is to separate suspended solids with residence time approximately 2 hours. Turbid water flows through the length of the tanks at low speed, giving enough time for suspended particles to settle [6]. Basic driving force of solid separation is gravitation; therefore, it is important to preserve flow in the tank that does not disturb the sedimentation process. In settling tanks, processes of sedimentation and flotation are used, while both phenomena use different specific weight of liquid and solids.

Flow in settling tanks is process very difficult to predict its behavior, as except of the sedimentation also turbulent flow of the mixture of wastewater and the sludge in the direction from the inlet to the tank goes on and turbulent currents develops [7]. These actions are very 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 [8]. 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:

$$\frac{\partial \boldsymbol{u}}{\partial t} + \boldsymbol{u} \cdot \nabla \boldsymbol{u} = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \boldsymbol{u} + \boldsymbol{f} , \tag{1}$$

where $\boldsymbol{u}$ is the flow velocity [m.s^{-1}], p is the pressure [Pa], t is the time [s], ρ is the specific weight [kg.m^{-3}], ν is the kinematic viscosity [m^{2}. s^{-1}], $\boldsymbol{f}$ is the summary of body forces [kg.m.s^{-2}].

They describe unstable turbulent flow, while software uses one of three methods to solve the equations, finite element method, finite volume method or finite difference method.

3. Field measurements

For building of simulation of flow, it is necessary to obtain data for calibration and verification of model. Measurements were carried out in two tanks, rectangular secondary settling tank of WWTP in Dolný Kubín (*Fig. 1*) and radial secondary settling tank with horizontal flow of WWTP in Nižná nad Oravou (*Fig. 2*).

Fig. 1. Rectangular tank in WWTP Dolný Kubín

Fig. 2. Radial settling tank Nižná nad Oravou

Model creation consists of several steps: geometry creation, calculation mesh creation of the object, model calibration, and model verification. As for calibration and verification of the model set of data is needed, measurement of the flow velocity in the tank will be supplemented by the data provided by the WWTP operator. For instance, flow rate at the tank inlet, concentration of suspended solids, data of sludge pumps work.

Measurements preparation

Actual flow velocity in a point of water in a tank was measured by the Flo-mate 2000 attached to 5 m long metal rod. 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 [9]. Water in the secondary settling tanks always differs; therefore it is necessary to calibrate the device before each measurement and water.

Device measures the velocity in one direction and recorded value is given in unit m/s. Value recorded by the device is total velocity v_{total}, including all components of the velocity. Velocity was measured in the direction of the flow for every point of measurement.

Rectangular secondary settling tank

Measurements were carried out in WWTP in Dolný Kubín (*Fig. 3*). Rectangular secondary settling tank with the width 11.34 m and length 43.5 m immediately follows nitrification tank, which significantly influences processes in secondary settling tank. In the distance of 2.5 m from the beginning of the tank, there is dividing wall, which serves for removal of floating foam which gets to the tank from the nitrification tank.

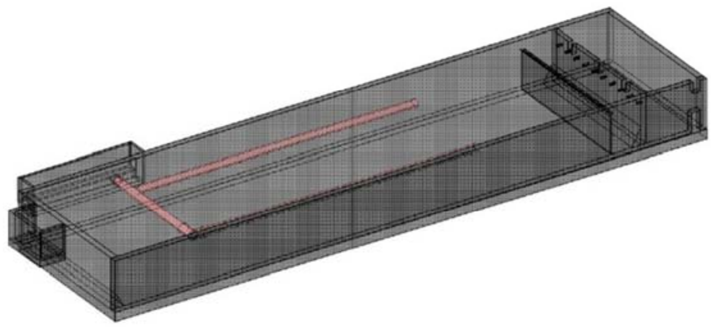

Fig. 3. Model of secondary settling tank created in CAD software

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 (*Fig. 4*).

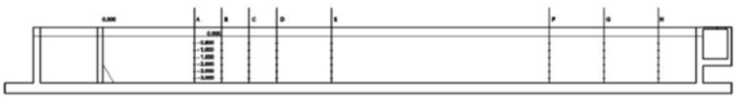

Fig. 4. Scheme of measurement profiles - longitudinal wall

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. 5*).

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. 6*).

All measurement points can be seen in the *Fig. 7*.

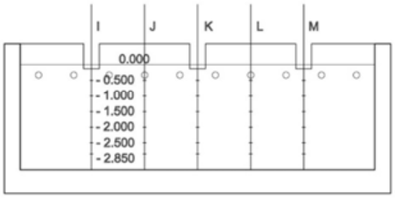

Fig. 5. Scheme of measurement profiles - north-western wall

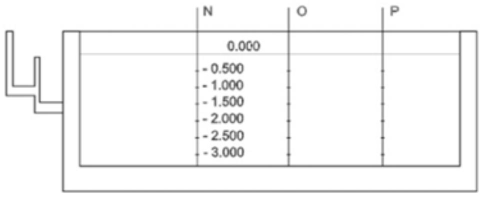

Fig. 6. Scheme of measurement profiles - south-eastern wall

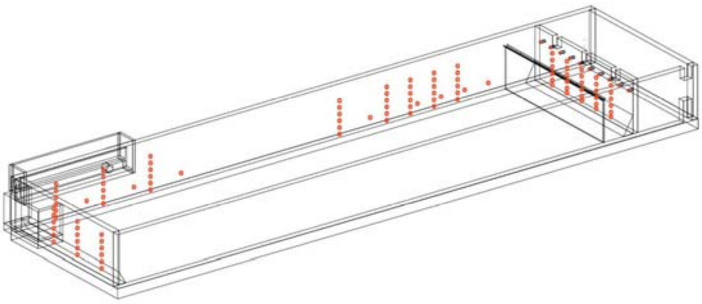

Fig. 7. Scheme of all measurement points in the rectangular tank

Radial tank

Measurements were provided in WWTP in Nižná nad Oravou (*Fig. 8*). Radial tank with horizontal flow has diameter 11.4 m and perimeter 71.6 m. Velocity measurements in radial settling tank were carried out 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 surface (*Fig. 9*) and (*Fig. 10*).

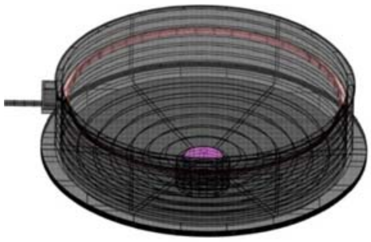

Fig. 8. Model of secondary settling tank created in CAD software

Fig. 9. Velocity measurements in radial settling tank

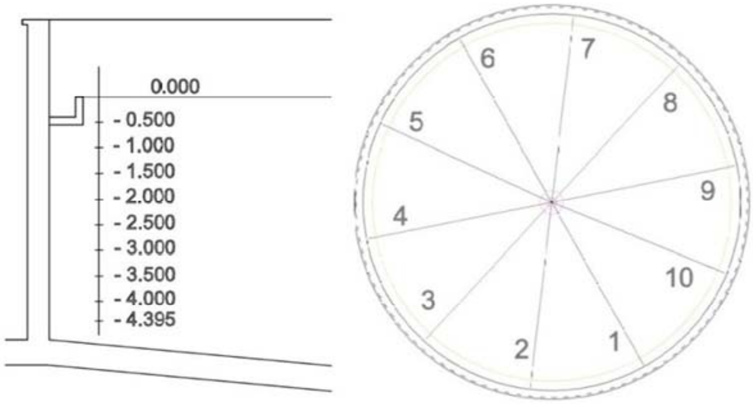

Fig. 10. Measurements profiles and plan of the radial settling tank

Measurements were carried out in several series which ensure statistically sufficient number of data. In case of rectangular tank, the actual velocities in 96 points were gained, in case of radial settling tank in 90 points. These data will be supplemented by data measured in the tanks by the operator and consequently used for calibration of the tank models and flow simulations will be run. Following, models will be used for operation optimization proposal of the tanks.

4. Discussion and results

Measuring of velocity was carried out in different objects during operation. Different geometrical configurations give the supposition for different flow behaviour in these objects. Measured data were recorded in prepared protocols. Before putting data into simulation software, data were sorted, analyzed and plotted in several graphs (*Fig. 11*).

The flow patterns are considerably influenced by the inlet design [7]. A uniform flow field is necessary to the efficient performance of a sedimentation tank [10]. The hydrodynamic processes in SST depend on the inner density currents as well [11]. In *Fig. 11* position of the inlet contributes to the flow pattern. Therefore, it is essential to simulate the flow in the tanks, so that measures leading to optimization of the flow can be designed.

The measurement should be carried out in stable weather conditions; especially important is to have approximately same conditions for all the measurements within one SST. Heavy rain may disturb the surface of the tank in such extent that it may influence the measured data just below the surface.

In the consequent work, working on simulations of flow in these objects is carried out that could lead to improvement of operation of secondary settle tanks in these WWTPs.

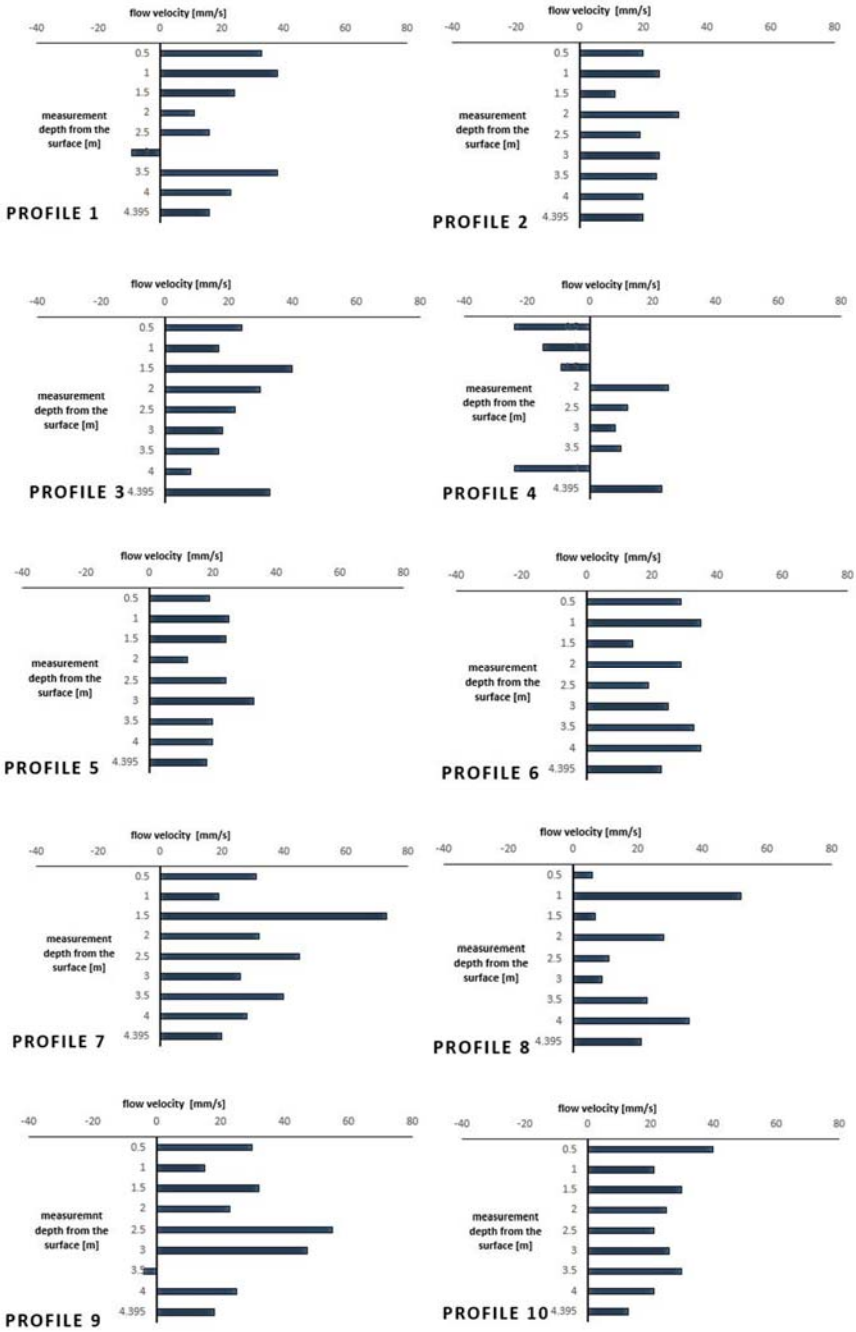

Fig. 11. Flow velocities in the measurement profiles in the radial secondary settling tank in Nizna nad Oravou

5. Conclusion

CFD modeling is a tool for flow simulation in objects in which turbulent flow occurs and that is impossible to describe by common means. After inserting real data, these models can serve for proposal of optimization solutions for the objects.

Acknowledgements

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