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MODEL OF HYDRODYNAMICS FOR SETTLING FLOCS IN RECTANGULAR SEDIMENTATION BASIN

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ABSTRACT

The behavior of hydrodynamics for settling flocs was studied in rectangular sedimentation basin. A model and laboratory experiments were arranged to indentify flow pattern for various velocity flows. These experiments have been used for simulation on a model in addition to variation of basin length. The results revealed the flow pattern was caused by interaction of drag force, impelling force and buoyant force. The velocity rate 0.25 cm/s resulted in Reynold number (Re) of less than 2000 and Froude number (Fr) of more than 1.10^{-4} that could remove turbidity up to 87.5%. The velocity rate between 0.96 cm/s and 0.52 cm/s and the various type of coagulants and doses (dose alum 68 ppm, PAC 35 ppm and mixture between alum and PAC 70 ppm) in sedimentation basin resulted in turbidity removal, ranging from 37.5% to 87.5%.

Key words: hydrodynamics, rectangular sedimentation basin, settling velocity, flocs

1. INTRODUCTION

Generally, sedimentation tanks are characterized by hydrodynamic phenomena, such as density water, Eddy's currents, sensitive to temperature changing and wind effects. As it was well known, there were two main types of sedimentation tanks: primary settlers (such as individualized settlers used for grit removal) and secondary settlers (those in the activated-sludge process or chemical coagulation processes were also sedimentation tanks, where flocks were removed by hindered gravity); the latter ones have an important purge flow rate [3]. Many factors could be influenced the performance and efficiency of sedimentation tank such as velocity settling of flocks and geometry basin [6], concentration and suspended particles characteristic [8], effect of turbulence flow [4], inlet and outlet design [1], baffle used to flow control [2], detention time [10].

Direct evaluation to performance and efficiency of sedimentation tank require many expenses and time. Mathematical modeling was one of the alternative ways to determine of the flow field and hydrodynamics conditions in settling tanks. Many researchers have used mathematical modeling with same principles but in different methods [11-12]. One of the mathematical model was "Hydrodynamics Pollutant Dispersion In River (HP2S)". Model that was based on conservation law of mass and energy, mathematics solution of differential partial through leap frog explicit finite difference numerical method. This model visualized by using Matlab computer program [9]. Model of HP2S used to identify pollutant dispersion in river that was influenced by discharge of wastewater to river and could be expressed to correlate between hydrodynamics aspect (such as velocity, flow rate) and dispersion of concentration of pollutant in river. On the other hand, the model was neglected an external interferences such as wind, evaporation, Eddy current, tidal effect, river branch, rain, pH change of water and ground water flow.

This current research used HP2S Model to analyze the effect of hydrodynamic to the settling flocks, because transport mechanism in flocks dispersion before it settled was analogized to pollutant transport phenomenon in river.

2. MATERIALS AND METHODS

Jar test was the experimental to determine the optimum coagulant dose, which it used alum, PAC and mixture of alum and PAC. The experimental settling flocks consist of a coagulation tank and flocculation tank both with turbine mixer, a rectangular sedimentation tank (see Figure 1 illustrated its real appearance).

Fig. 1. Real appearance of the experimental device

Scaled physical models were based on a similarity theory, which used a series of dimensionless parameters that fully or at the least, partially characterize the physics. The choice of a scaling factor m (Lp/Lm), or length scale ratio, to be used in the experiments, was determined by the objectives of the research. According to the length of the tested section and laboratory constraints, the present laboratory model has been designed with horizontal and vertical scales of run n_L = 25. The selected flow rates were selected to take into account the tank dimensions according to Reynolds and Froude numbers. Runs were carried out with injection optimum coagulant dose for alum was 56 ppm, PAC 36 ppm and mixture alum and PAC 70 ppm. If failure flocks formed then must be selected flow rate again. Finally, running carried out with flow rates 5 m/h, 10 m/h and 15 m/h.

For identification of flow patterns, fluorescein was injected and the evolution of the color vein observed. This step was previous to the study [illegible] condition in sedimentation tanks, so that the observed phenomena (recirculation, preferential flow paths, etc.) could be used as a qualitative orientation in the comparison of [illegible] models. For identify of settling flocks pattern, Smart Spectrophotometer took samples at 10 different point of surface basin into equivalent turbidity.

The HP2S Model was prepared with visualization by Matlab program after changed axis y as width of river became axis z as depth of tank. Experimental data were used for simulation HP2S Model. Next simulation conducted with length sedimentation tank variation to observed hydrodynamics condition. Outputs of running model were visualization of horizontal velocity flow, settling flocks pattern, turbidity, and Reynolds and Froude numbers.

3. RESULTS AND DISCUSSION

Laboratory Experiments

After injecting the coloring with fluorescent, the veins in the tank may be observed. Figure 2 described schematically the observed paths with different flow rates. Every flow rates variation has the same flow pattern, but velocity was varying alongside basin. Flow at first (1st) point was tends to move faster than the others, a backward flow was observed at the second (2nd) point, and a stagnant flow was observed at the third (3rd) point. In the bottom section of the tank, the above is mentioned butterfly form. These currents touch the bottom, where a backwards flow was observed. In general, the upper plate [illegible] with this experimental device caused the formation of a main current at depth for low flow rates and in the upper regions for high ones. Several return currents were also noticed.

Three flow rates were used, which was taken into account the transversal section of the tank, representing mean pass-through rates ranging from 0.[illegible] cm/s – 0.[illegible] cm/s. In previous works, other authors used rates of up to 1.72×10⁻[illegible] m/s, but the usual values were below 1×10⁻[illegible] m/s [7]. Anyway, the Reynolds and Froude numbers were the key parameters and it was their orders that were to be maintained. Figure 3 showed the relation between flow velocity to Reynolds numbers, which it has linear correlation. But the relation to Froude numbers has nonlinear correlation like shown at Figure 4.

Since it was impossible to observe similarity according to both numbers at the same time, the Fr was the most often considered, as it related to the inertial forces with the gravity forces. Therefore minimum velocity rates was 0.25 cm/s so that Re values < 2000 and Fr values > 1×10⁻[illegible], which was design criteria for settling flocks in sedimentation basin [3].

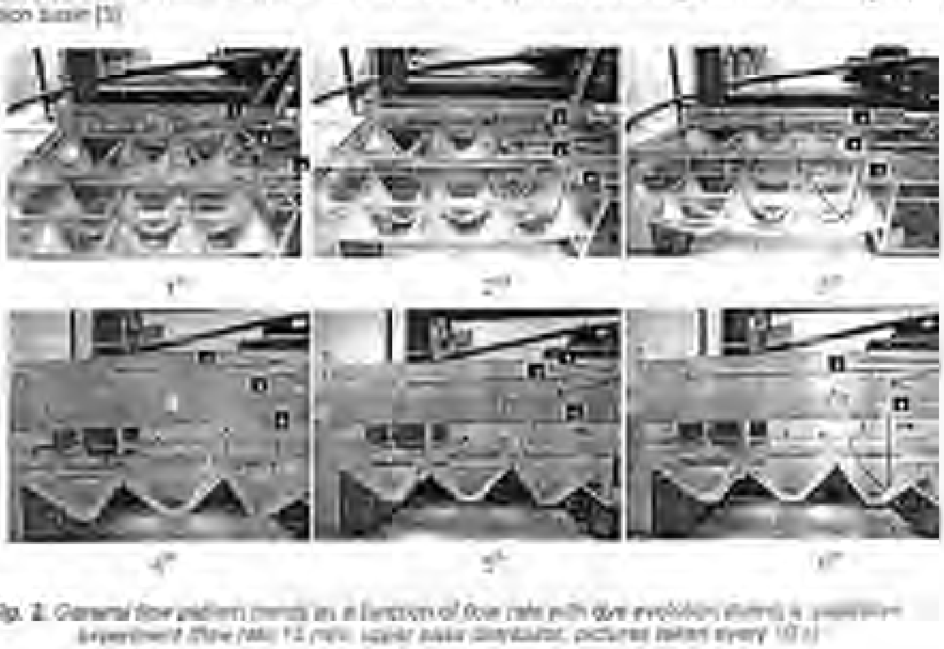

Fig. 2. General flow pattern (trends) as a function of flow rate with dye evolution during a [illegible] experiment (flow rate 15 m/h; upper plate [illegible]; pictures taken every 10 s)

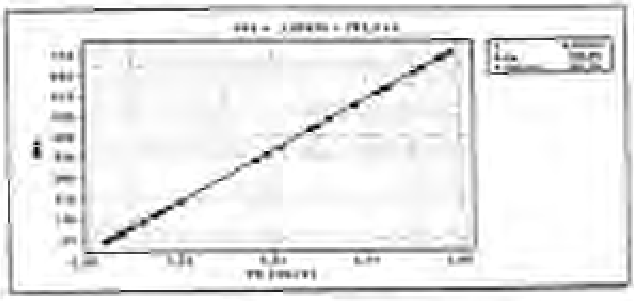

Fig. 3. Linear correlation of flow velocity to Reynolds numbers

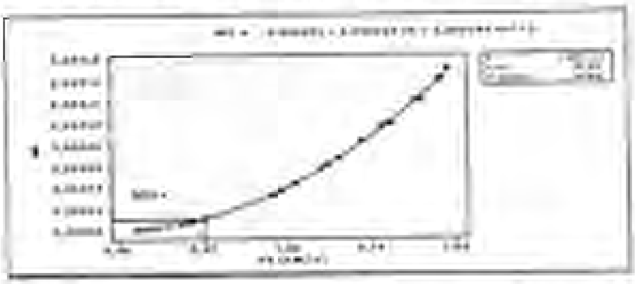

Fig. 4. Nonlinear correlation of flow velocity to Froude numbers

Turbidity, which indicates of settling flocks, was influenced by velocity flow and settling flocks velocity. Figure 5 showed that at various velocities have various turbidities. Coagulant influenced forming flocks quality and its characteristic [3]. Flow pattern without suspended particles would be run to outlet than with suspended particles has complicated pattern. It caused by interaction of drag force, impelling force and buoyant force [9]. Minimum velocity rates 0.25 cm/s so that Re values < 2000 and Fr values > 1.10^{-5} could removed turbidity until 87.5% as initial value removal.

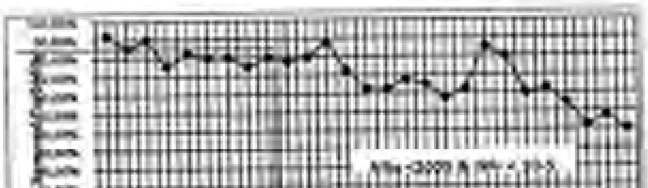

Fig. 5. Experimental results horizontal velocity flow with turbidity removal

Simulation Experiments

Simulation HP25 model in settling zone boundary used only on the certain of horizontal flow velocity, Reynolds number, Froude number and turbidity, detention times and depth of basin. It was happened because of influenced of a shear force, which fluid flow movement in each layer would be experience of mixing between layer in small scale and would be generated tension force then kinetic energy decreased [12]. While settling flocks velocity became increased in simulation. The particle settling velocity was decreased with increased of turbulence intensity, but this tendency diminished when diameter got smaller. That might be due to that the smaller particles settled down slowly for they were influenced more by turbulence than gravitation. When particle diameter was smaller enough, the particle was tends to suspended and hardly to settled, no matter how intense the turbulence was [4]. Figure 6 showed simulation of HP25 Model with length basin variation to ensure that hydrodynamic conditions has same pattern to length basin constant.

Behavior of hydrodynamic in rectangular settling basin was influenced by kinetic energy, which the biggest was on surface basin and dissipated along with length and depth of sedimentation basin. Therefore, velocity became decrease and particles were heavier than water were tend to sink to the bottom of the tank thereby dragging fluid along. The movement of fluid in turn affected to the settling of particles. It was mean that Reynolds number, Froude number, turbidity was decreased and settling velocity was increased. Based on simulation model experimental, minimum velocity rate was 0.52 cm/s so that Re values < 2000 and Fr values > $1{\cdot}10^{4}$ could removed turbidity 37,5% until 87,5% as initial value removal with various coagulants type.

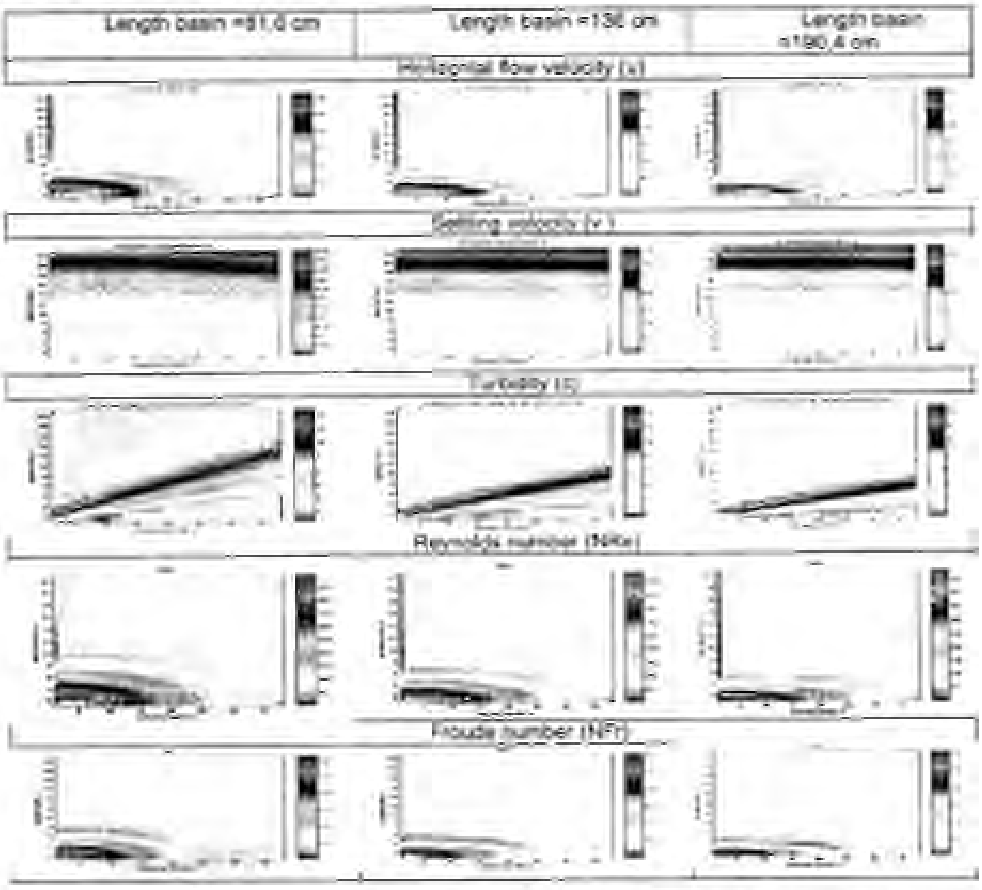

Fig.6. Hydrodynamic pattern in rectangular sedimentation basin with length variation

4. CONCLUSION

The behavior of hydrodynamic in rectangular settling basin was influenced by kinetic energy. The biggest energy is on surface basin and dissipated along with length and depth of sedimentation basin.

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