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Improving Performance of Water Treatment on Oxidation Ditch Using Modification of Reactor Hydrodynamic

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Graphical abstract

Abstract

Urban wastewater treatment in Indonesia is limited, due to its high investment cost. To date, there are only 11 big cities that have centralized domestic wastewater treatment plant, such as in Jakarta, Tangerang, Bandung, Medan, Yogyakarta and Surakarta. There is also city sludge faecal treatment plant, like in Surabaya, Jakarta, Yogyakarta and Semarang. All the treatment process in these treatment plants is based on biological process, which are oxidation ditch (Tangerang and Surabaya), stabilization pond (Bandung) and extended aeration (Jakarta and Yogyakarta). Mostly, the biological treatment on the plants are malfunctioning, some of them because of operational capacity which cannot fulfill the design capacity. Yet, the effort of optimization only focuses on biological process aspect, while the hydraulic and physical aspects have a great influence to treatment performance. Research on modification of hydraulic aspect, both experimentally and by using computer simulation to improve treatment performance is needed.

Keywords: Hydraulic aspect; computer simulation; wastewater treatment plant

1.0 INTRODUCTION

Untreated waste water is potent to pollute land and water, whether ground and surface water. One of objectives on Millennium Development Goal is Goal 7 which is to ensure environmental sustainability. As a country that embraces this Goal, Indonesia is committed to ensure that 50% of its people will have water and sanitation access in 2015. That is why the government put a long term vision to reach the goal. Waste water management system in Indonesia is usually on-site system using individual septic tank in household. But unfortunately, many of them have permeable construction, so its overflow and effluent have potential to pollute the environment. There are also off-site systems in some cities, which are usually based on biological treatment of activated sludge. The kinds of activated sludge system are oxidation ditch, oxidation pond, aerated lagoon and stabilization pond. Through wastewater treatment plant, access of proper sanitation could improve.

Oxidation ditch is a modification of activated sludge which was firstly constructed in 1940 [1] and since then, it has been replicated in many countries, including Indonesia. In comparing with conventional activated sludge, oxidation ditch have longer time detention and enhancement possibility to remove nitrate, nitrite and phosphate [2]. Optimization could be done by improving biochemical process performance and design modification by field observatory, laboratory experiment and computation. Through computational simulation, design modification with hydrodynamics simulation in reactor could be done with many variations of construction to obtain optimal design.

Factors that influence the treatment performance consist of main factors and supporting factors. The main factors are organic loading (waste water influent), solid accumulation, dissolved oxygen level, while the supporting factors are mixing, biological characteristic, equipment enhancement (inlet, outlet, and aeration equipment).

Biological treatment process is an option in domestic wastewater treatment [3], mainly because of wastewater characteristic, beside the financial factor and operational simplicity. Unfortunately, because of this easiness, optimization is rarely done. If any, it only focuses on biological and biochemical aspects inside microorganisms [4]. On the other side, hydraulic and physical aspects in treatment unit have greatly improved the performance. Besides, design of wastewater treatment plant is usually based on design criteria resulted from four-season country, which has different climate characteristic than two-season country as in Indonesia.

Research on hydraulic and physic aspects in laboratory scale and field observatory could be done using tracer studies [5, 6]. However, there is another method that is common in optimizing treatment performance which is modeling the hydrodynamic and chemical removal using computer simulation, i.e. *Computational Fluid Dynamics (CFD)*. The wastewater treatment unit is considers as a reactor. CFD application in many fields shows many advantages in easiness, accuracy, applicable to follow nature phenomena in chemical-physic process, as in medical, aviation, ocean movement, land movement and industrial processes, while the example of application on environmental engineering is ground water pollution [7], surface water [8], water treatment [9], and waste water treatment [10].

To get the optimal design of wastewater treatment, the hydraulic and physic aspect of a research is needed. The research adopted the oxidation ditch as a reactor with CFD application. Initially, a mathematical model of the hydrodynamics and kinetics in wastewater treatment reactor is needed. Subsequently, computer simulation with reactor modification focuses on inlet-outlet and aerator arrangement.

2.0 REVIEW ON OXIDATION DITCH UNIT

Oxidation ditch was first build by Pasveer in Texel in 1940 and in Vorschoten, Netherland in 1954 [1]. The application is then widely expanded to other parts of the world, especially where excess land is available. Some of the strengths of this unit include easiness to operate and maintain, high removal efficiency, tolerable to shock loading variation without influencing effluent quality, sludge production relatively small, control easiness by change rotor rotation, efficient in energy, nitrification and denitrification process can easily occur with *biological oxygen demand* (BOD) removal efficiency up to 85-90%. Oxidation ditch can be categorized as advanced aeration activated sludge that could remove organic parameter and even nitrogen-phosphor [2]. Typical form of oxidation ditch unit that was firstly introduced as shown in Figure 1 [1].

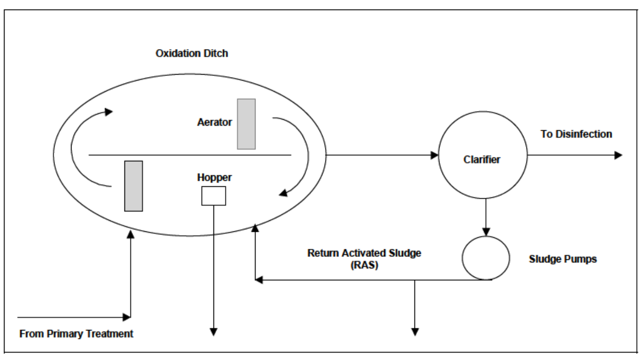

Figure 1 Typical oxidation ditch system [1]

There are two kinds of oxidation system [11, 12], which are carrousel system (Figure 2) and orbal system (Figure 3). Wastewater treatment plant (WWTP) in Indonesia that adopts the oxidation ditch system can be found at the Tanah Tinggi WWTP in Tangerang. Table 1 shows laboratory analysis result of influent and effluent of the WWTP [12]. The table indicates the lack of WWTP performance, comparing with effluent standard of Government Decree No. 82/2001 with regards to Water Environmental Quality Management and Water Pollution Control.

Table 1 Laboratory analysis of water influent and effluent quality on oxidation ditch WWTP Tanah Tinggi Feb 18th 2011 [12]

Parameter	Unit	Effluent Standard*	Influent	Effluent
pH	-	5 – 9	7,3	7,4
TSS	mg/L	20	98	30
BOD	mg/L	12	156	28
COD	mg/L	100	117	45

*Based on Government Decree No. 82/2001 with regards to Water Environmental Quality Management and Water Pollution Control

Figure 2 Oxidation ditch unit in WWTP Jababeka [11]

Figure 3 Oxidation ditch unit in WWTP Tanah Tinggi [12]

3.0 REVIEW ON REACTOR HYDRODYNAMIC

The most common hydrodynamic study is tracer study, as conducted buy Mendez-Romero in 2011 [13]. The tracer study usually gives good result, but there is a constraint in scaling-up and scaling-down implementation because of some parameter values that are outside the experimental parameter values. However, this constraint can be overcome by using computer simulation.

The correlation between hydrodynamic aspect and microorganism activities can be shown in the mathematical modeling of the dispersive flow [14]. The mathematical model can be developed using computational methods to observe the increment of oxygen supply in oxidation ditch reactor. A model can be built based on various types of oxygen supply: diffuser [15], up aerator spray [16], bottom aerator spray (along reactor) [17], and surface aerator [18].

4.0 REVIEW ON COMPUTATIONAL FLUID DYNAMIC

Computational Fluid Dynamic (CFD) Model has been applied in many fields, including environmental engineering. Specifically, CFD is use to model process kinetics, transfer oxygen, modification on treatment unit and hydrodynamic in various water treatment [19-22]. Computer simulated CFD can be applied in channeling activated sludge reactor [15-17] and expanded granular sludge bed reactor [10]. According to Huang *et al.*, combination of CFD model and kinetics of reaction was more accurate and make sense than kinetic model in biological system modeling [20]. Therefore the research focus on hydrodynamic aspects and kinetic reaction in oxidation ditch reactor is needed to get the optimal design of oxidation ditch water treatment unit.

5.0 EXPERIMENTAL

5.1 Reactor Design

Based on a review of past studies and from field observation, we built reactor design to conduct a tracer study (Figure 4).

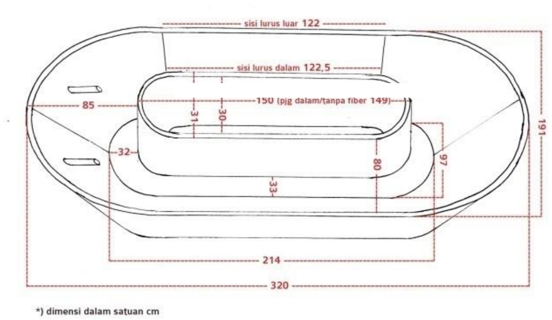

Figure 4 Oxidation ditch reactor in laboratory scale

The dimensions of the reactor were based on the following design criteria: wall slope of 45º and the inlet velocity is 1 m/sec. The equations used for computer simulation are continuity equation and momentum Equation [10]:

$$\frac{\partial Ui}{\partial Xi} = 0;$$

$$\frac{\partial}{\partial Xj}(UiUj) = -\frac{1}{\rho}\frac{\partial P}{\partial Xi} + \frac{\partial}{\partial Xj}\left[\gamma t\left(\frac{\partial Ui}{\partial Xj} + \frac{\partial Uj}{\partial Xi}\right)\right]$$

Where :

U = velocity in x-direction (m/sec)
P = pressure force
X = distance (m)

Media in the simulation is liquid (water).

6.0 RESULTS AND DISCUSSION

The 2D simulation on reactor surface shows the results as illustrated in Figures 5-7.

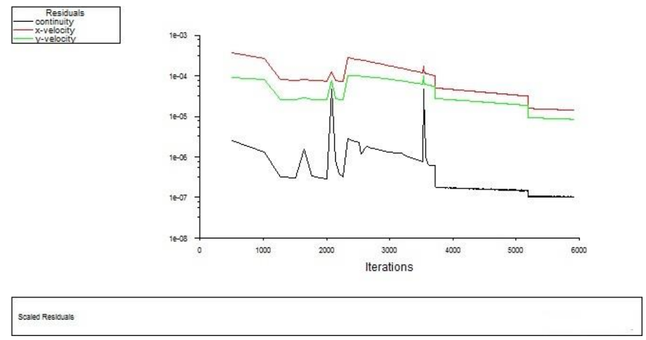

Figure 5 Residual statistic of 2D simulation

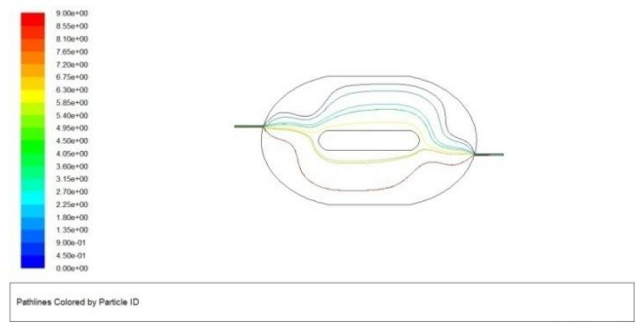

Figure 6 Pathline of 2D simulation

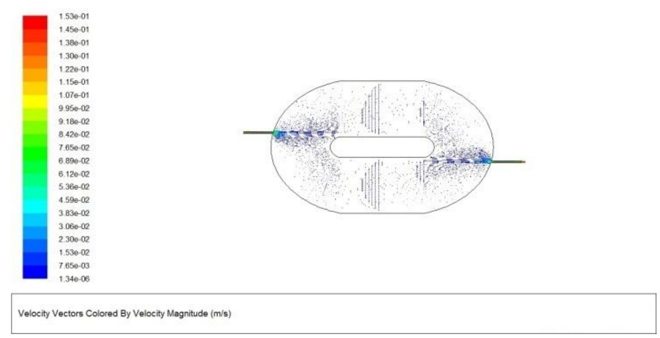

Figure 7 Vector velocity of 2D simulation

Figure 5 shows that the simulation converges after 5000 iterations. In Figures 6 and 7, it is known that there is some dead zone in part of the reactor. Figure 6 shows that the dead zone especially occurred in reactor outer bank, while figure 7 shows that the fastest flows occurred around the inlet and outlet. The existence of the dead zone, i.e., when the water appears to be “stuck” and must be avoided since it influences the biochemical process in the reactor. This will decrease the treatment performance in the reactor. To reduce the dead zone, methods recommended include the modification of inlet and outlet configuration as well as installment of an aerator [18]. The aerator main role is to supply the oxygen into thus reactor thus increasing the water flow and making faster flow velocity.

7.0 CONCLUSIONS AND RECOMMENDATIONS

From the computer simulation, there is dead zone in the reactor that could affect the reactor treatment performance. To increase the performance, the modification of inlet and outlet configuration as well as aerator installation could be considered. Yet this computer simulation must be compared with the results of the experiment in laboratory scale using a tracer study. The computer simulation itself must be run in multi-phase media, which are fluid-solid-air simulation.

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