

OBTAINING COMPLETE MIXING USING HYDRODYNAMIC ANALYSIS ON BATCH REACTOR

*Rositayanti Hadisoebroto¹, Suprihanto Notodarmojo², Idris Maxdoni Kamil², Yazid Bindar³, Rangga Santosa²

¹Environmental Engineering Department, Faculty of Landscape Architecture and Environmental Engineering, Trisakti University, Indonesia; ²Environmental Engineering Program, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia; ³Chemical Engineering Program, Faculty of Industrial Technology, Institut Teknologi Bandung, Indonesia

*Corresponding Author, Received: 26 Sept. 2016, Revised: 26 Sept. 2016, Accepted: 30 Nov. 2016

ABSTRACT : This research aims to find the best possible mixing conditions in a multi-phase reactor consist of wastewater, activated sludge and aeration. This has been done by analyzing flow profiles in the system using experimental and computational work. Hydrodynamic characteristics, such as influent flow rate, aerator configuration, baffle installment, play important role for wastewater treatment process. Determination of influent flow rate and the reactor configuration have done by analyzing flow profile in laboratory scale single-phase reactor with the dimension of 16 L. Velocity profile was developed from tracer study. There were 2 influent flow rate variations of 0,0095 L/s and 0,02 L/s, in 3 variations of reactor configuration. The first variation was without modification (control), the second was baffled reactor and the third was porous reactor. From the experimental work, it was obtained that the influent flow rate of 0,0095 L/s gave longer Residence Time Detention (RTD) and longer time to reach the outlet than flow rate of 0,02 L/s. The baffled configuration gave longer RTD and longer time to reach the outlet as well than other configuration. This two results was reasonable since the first influent flow rate and the baffled reactor have higher effective volume than other variations. In multi-phase system, experimental work was done in batch system to observe the contact between air-bubble and sludge in reactor, which then calibrated using CFD (Computational Fluid Dynamic) model. The result showed that the model of mixture in $k-\varepsilon$ equation was considerable to use in future simulation work. The using of diffuser could increase mixing condition inside the reactor due to its higher effective volume.

Keywords: Hydrodynamic, CFD Model, Multi-phase System, Batch Reactor

1. INTRODUCTION

Chemical reactor is an important part of wastewater and water treatment. Inside the reactor, chemical process occur to change the substance of various chemical compounds. Reactor effectiveness is an integral part on every wastewater and water treatment industry. This affects materials used in processing, energy required, to reliability of the process.

Chemical reactor is divided into two types, the stirred tank reactor and a plug flow reactor. When viewed from the kinetic parameters and chemical reactions under isothermal conditions, a plug flow reactor is more efficient than stirred tank reactor. In a plug flow reactor, a factor that make ineffective process is the flow nature. When the flow in the reactor is non ideal flow, reactants and reaction products flow at a different speed across the cross section of the pipe. It can be caused by the hydraulic factors of the reactor that being overlooked or disregarded.

Based on above, hydraulic simulation on a laboratory-sized plug flow reactor will be conducted with discharge variation to analyze its effect to flow

patterns. Moreover, effects from it to residence time distribution (RTD) will be analyzed with tracer test. Tracer test technique is an effective method to identify efficiency of a purification process that occurs in a wastewater treatment, both in design optimization and process performance [1]. Thus, this study was conducted to obtain the most optimum pollutant removal efficiency in a plug flow reactor with physical modification such as discharge variation.

The use of tracer and dye are very helpful to determine the ideal conditions to make the reactor design. Determination of the ideal conditions can be done by finding the resident time distribution curve (RTD) to determine the hydraulic character of a reactor. To find the RTD curve, tracer test must be conducted.

Beside doing the experimental works, research focus as well to the hydrodynamics simulation in computational works using Computational Fluid Dynamics software. Reference [2] indicates that CFD simulation shows the good work on analyzing Residence Time Distribution (RTD) and flow field. Numerical simulation is based on governing equation of flow, which are continuity and

momentum equation. Multiphase flow that involve 2 or more media could be modeled using Eulerian model with realizable $k-\varepsilon$ turbulence [3]

2. MATERIALS AND METHODS

The research was started from preparation of batch reactor, preparation of tracer substance and media, reactor trial, building and meshing geometry on computational works. The next steps are tracer study in reactor and the flow simulation in computer. Then data sampling from experimental works and computational works are analyzed.

2.1 Batch Reactor

In this study, a batch reactor is used to perform tracer study. The reactor is made of block-shaped acrylic with open surface. For control experiment is batch reactor without any configuration. Dimensions of the reactor can be seen in Table 1, while the scheme and the view can be seen in Fig. 1 .

Table 1.Dimension of Batch Reactor

Dimension	Magnitude (cm)
Length	40
Width	20
Height	20
Ø inlet	0.7

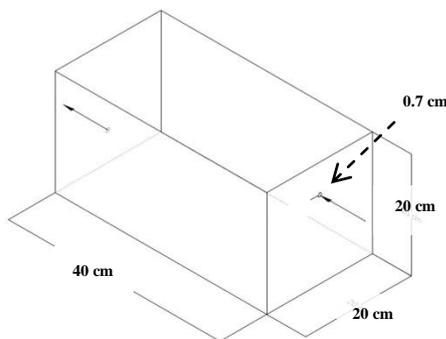


Fig. 1 Batch Reactor sketch



Fig. 2 Batch Reactor Photo

Reactor configuration variations are baffled and porous reactor. Baffled reactor is made by installing

baffle in middle of reactor, hanging in height of 5 cm. Porous reactor is made by filling reactor with 2 mm round-rock. These two configuration variations are shown in Fig. 3 and Fig. 4 below.

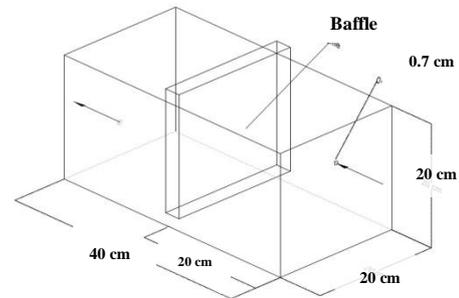


Fig. 3 Configuration of Baffled Reactor

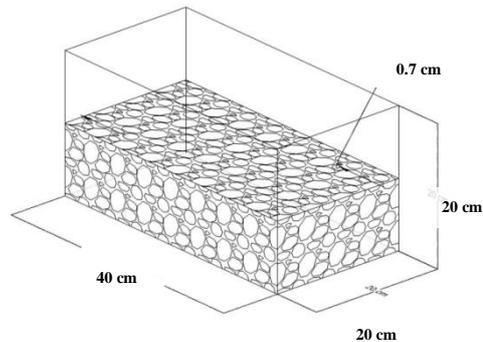


Fig. 4 Configuration of Porous Reactor

2.2 Experimental Works on Batch Reactor

The independent variable in the study is the discharge of water at the inlet and the concentration of the tracer fluid at minute 0 operation. The dependent variable is the concentration of tracer fluid in the water at any time of the test. While the control variable is the water in the reactor and test time. This research was conducted by using the independent variables mentioned above, the flow of water into the reactor. Thus, it can be seen spread the concentration of tracer in each discharge.

Water flows into the reactor through the inlet reactor until the flow is steady, then tracer substance is injected into the reactor using pulse technique. After that, tracer substance concentration is measured from the outgoing water flow based on time to discover water movement inside the reactor.

2.3 Geometry and Mesh Building of Batch Reactor

Building geometry and meshing is done using Gambit Processor. Geometry is based on batch

reactor dimension, while meshing is made using Tet/Hybrid elements in map and sub-map scheme type.

2.4 Computational Works of Hydrodynamic Simulation

The computational works starts from define the model and parameter. In this study, simulation is done based on unsteady, turbulent, eulerian model mixture in $k-\varepsilon$ equation. The model is run in 3 dimensional in multi-phase system.

3. RESULTS AND DISCUSSIONS

Two discharge variations is being used on this preliminary study. The first discharge variation is 0.0095 L/sec while the second is 0.02 L/sec. To standardize the measure result for tracer concentration at the outlet versus time curve with pulse injection method, tracer substance in the outlet usually normalized first. Normalized curve is called RTD Curve (residence time distribution curve). RTD curve function can be calculated using equation (1) :

$$E(t) = \frac{C(t)}{\int_0^\infty C(t)dt} \quad (1)$$

Using Equation (1), RTD curve function calculated and transformed into graph as shown in Fig. 5 and Fig. 6.

Based on the image below, time required for the 50% tracer substance reaches the reactor outlet is obtained. In discharge variation 1, approximately 50% of the tracer substance takes between 0 to 200 seconds to get to the outlet. Otherwise in the discharge variation 2, the time required approximately 50% tracer substance to come out through the outlet is 0 to 100 seconds. The effective volume in discharge variation 1 is 63.07%, while in discharge variation 2 is 34.41%.

From the RTD calculation of both discharge variations, it can be seen that discharge variation 1 has higher effective volume and longer time for tracer substances to reach outlet. It means that discharge variation 1 has better condition for mixing.

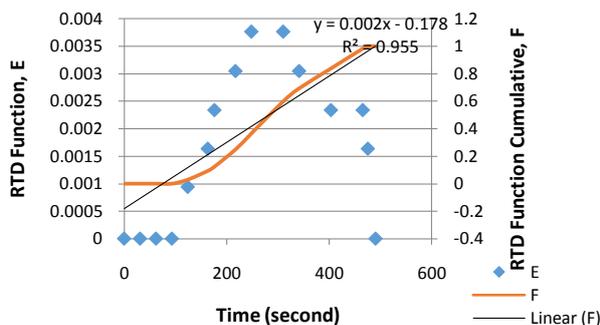


Fig. 5 RTD curve in Discharge Variation 1

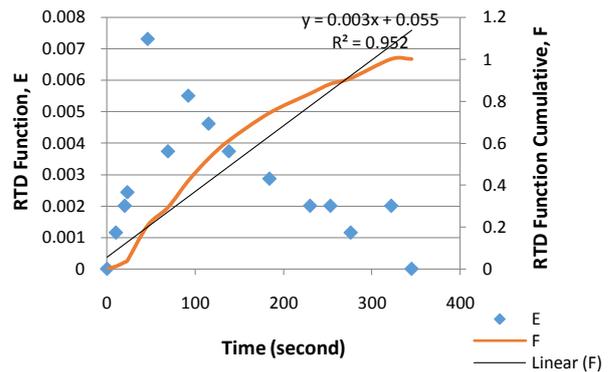


Fig. 6 RTD curve in Discharge Variation 2

Based on the results obtained, the average detention time is calculated using equation (2) [4] :

$$\bar{t}_c = \frac{\int_0^\infty tC(t)dt}{\int_0^\infty C(t)dt} \quad (2)$$

Where \bar{t}_c is detention time, t is the time (s) and $C(t)$ is the concentration of tracer at time t (ML^{-3}). From equation (2) calculation, detention time for Variation 1 is 82.789 seconds and 90.593 seconds for Variation 2. After that, the theoretical detention time is calculated using discharge data and water height in the reactor. Therefore, theoretical detention time for variation 1 is 350 seconds and 288 seconds for Variation 2.

There is a significant difference detention time in the both variation. In addition, there may be a short flow in the reactor, which can cause a dead zone. In this zone, the flow is stagnant so fluid does not mix well. If the inlet and outlet are not placed properly, fluids will be flows straight from the inlet to the outlet, without being mixed well within reactor [5].

From detention time calculation and time required for the tracer to reach out the outlet, the second discharge variation, 0.0095 L/sec found has more effective volume area for the treatment than 0.02 L/sec inlet discharge. So, for the next research of reactor modification, the discharge is maintained in 0.0095 L/sec. The first modification is baffled reactor, while the second is porous reactor. In this study, the RTD calculation for those reactor modification are shown in Fig. 7 and Fig. 8.

Calculation of RTD in various reactor modification shows that baffled reactor gives higher effective volume, since it's need 310 seconds for the 50% tracer to reach out the outlet in baffled reactor, while it's only take 160 seconds in porous reactor. It means that in porous reactor, the dead zone is higher and there is a short circuiting. The effective volume of baffled reactor is 64.7% higher than control (without configuration). In other side, the porous reactor has lower effective volume than control, which is 47.65%. It could be concluded that baffled reactor only gives a little influence to increase the effective volume in reactor, while porous reactor decreases mixing condition inside reactor.

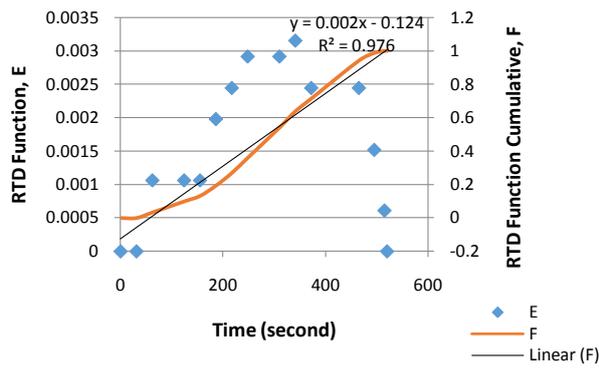


Fig. 7 RTD Curve in Baffled Reactor

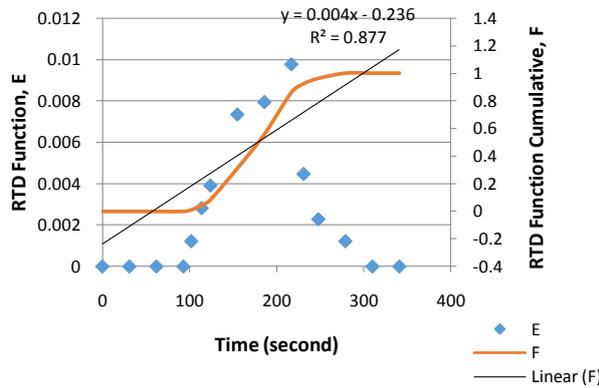


Fig. 8 RTD Curve in Porous Reactor

To calculate effective volume in reactor, velocity measuring is a good approach. Velocity measuring experimentally could be get from computational simulation. Other ways to increase effective volume is using mixing properties like aerator. In aerobic wastewater treatment reactor, aeration is used to maintain dissolved oxygen concentration along the reactor as well. One of aeration type is diffuser. The diffuser not only keep the aerobic condition but gives well-mixed condition as well. The experiment of mixing condition in real wastewater treatment, when wastewater, activated sludge and aeration are presence, is great to be computationally simulated as multi-phase system.

The aeration is run in two diffuser flow rate variations, 0.1 cm/s and 0.25 cm/s. The simulation result shows that the mixing condition is from bottom upward along the reactor height, indicated by air velocity released from diffuser. Air flow inside reactor with diffuser flow rate variation 1 in X axis and Y axis, are shown in Fig. 9 and Fig. 10 respectively. In Fig. 11 and Fig. 12 show air flow with diffuser flow rate variation 2 in X axis and Y axis, respectively.

As can be seen in Fig. 9 and Fig. 10, in below part of reactor is air within liquid phase (water and sludge) while upper part is air within gas phase. Velocity value is represented by length of vector. In batch reactor, mixing is occurred because presence

of air flow from the submerged-diffuser located 10 cm from edge with air flow rate is 0.1 cm/s. The effective volume reach 76.18%.

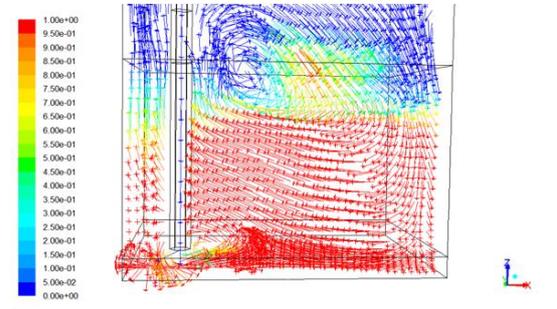


Fig. 9. Air Flow Velocity Vector in X-axis with Air Flow Rate of 0.1 cm/s

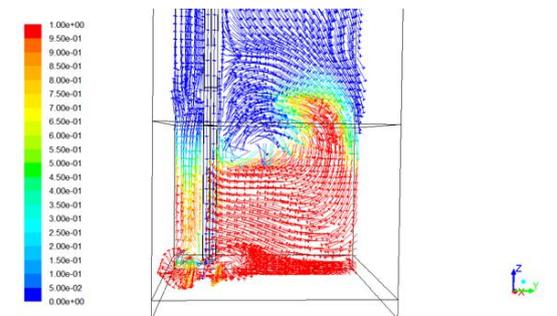


Fig. 10. Air Flow Velocity Vector in Y-axis with Air Flow Rate of 0.1 cm/s

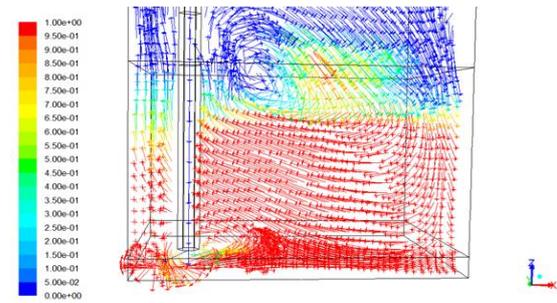


Fig. 11. Air Flow Velocity Vector in X-axis with Air Flow Rate of 0.25 cm/s

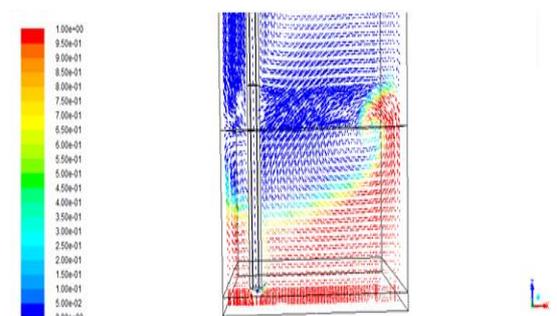


Fig. 12. Air Flow Velocity Vector in Y-axis with Air Flow Rate of 0.25 cm/s

Other air flow rate variation of 0.25 L/min show the same phenomenon although occurs in different time and distance from diffuser. It can be seen in Fig. 11 and Fig. 12 that the higher air flow rate make a force to push water movement. Higher air flow rate also give higher effective volume which is reach 83.94%.

It could be concluded that using diffuser aeration, mixing condition becomes better due to its higher effective volume, indicated by the existence of non zero velocity along the reactor as well. Still it needs other variations of aeration such aerator and running in continuous flow in future works.

4. CONCLUSION

Preliminary study of experimental works shows second variation discharge, 0.0095 L/sec has more effective volume for the treatment than first variation, 0.02 L/sec inlet discharge due to its detention time and time required for the tracer to reach out the outlet. In experimental works of reactor modification, the discharge is maintain in 0.0095 L/sec. In reactor modification experiments with 0.0095 L/sec discharge, it could be concluded that baffled reactor gives higher effective volume than porous reactor.

The simulation result shows that the eulerian multiphase system could relied to get the great picture of water flow pattern inside the reactor. It is concluded that the mixing condition with diffuser aeration give best mixing condition due to its effective area reaching 83%. Otherwise, yet still need more aerator variations and running in continuous flow in future works.

5. ACKNOWLEDGEMENT

The author would like to thank Directorate of Intellectual Property Management, Directorate General of Research and Development

Strengthening, Ministry of Research, Technology and Higher Education, Program of Decentralization 2015 for funding part of this research through Doctoral Dissertation Scheme.

The author grateful is deliver for supervisor team : Prof. Suprihanto Notodarmojo, Ph.D; Prof. Yazid Bindar, Ph.D; and deceased Dr. Idris Maxdoni Kamil.

6. REFERENCES

- [1] International Atomic Energy Agency (IAEA). 2011. Radiotracer Applications in Wastewater Treatment Plants. Vienna
- [2] Le Moulec, Yann, Potier, Olivier, Gentric, Caroline, Leclerc, Jean Pierre (2008) : Flow Field And Residence Time Distribution Simulation Of A Cross-Flow Gas-Liquid Wastewater Treatment Reactor Using CFD, Chemical Engineering Science 63, pp 2436 – 2449
- [3] Okan Topcu (2011) CFD-DP Modelling of Multiphase Flow in Dense Medium Cyclone, CFD Letters Vol. 4(1) 2012, 33-42
- [4] Metcalf & Eddy (2003) Wastewater Engineering Treatment and Reuse. 4th ed. McGraw-Hill Inc.
- [5] Hayes, R., & Mmbaga, J. (2012) Introduction to chemical reactor analysis (2nd ed.). CRC Press.

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.
