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THE 1ST YOUNG SCIENTIST INTERNATIONAL CONFERENCE OF WATER RESOURCES DEVELOPMENT AND ENVIRONMENTAL PROTECTION

MALANG - INDONESIA

5 - 7 June 2015

PROCEEDING

Environmental Engineering & Water Technology
Integrated Water Systems & Governance
Water Science & Engineering

WATER RESOURCES ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

icwrdep 2015

CERTIFICATE

This certificate is awarded to:

S. SYAFRUDIN

Diponegoro University (UNDIP)

as a:

PRESENTER

for paper titled:

"Kinetic Modeling Of Domestic Wastewater (Greywater Type) Using Uasb Reactor"

in

The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection

Malang, 5-7 June 2015

Rector
University of Brawijaya

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THE 1st YOUNG SCIENTIST INTERNATIONAL CONFERENCE OF WATER RESOURCES DEVELOPMENT AND ENVIRONMENTAL PROTECTION

May 15, 2015

LETTER OF ACCEPTANCE

International Conference of Water Resource Development and Enviromental Protection (ICWRDEP'15) will be held on June 5 - 7, 2015, in Faculty of Engineering Building (Dekanat) University of Brawijaya. This conference is a platform providing young scientists in water resources engineering a possibility to present and discuss their work in environmental engineering & water technology, integrated water systems & governance, and water science & engineering. Through this conference it hopes that the young scientist could bring their latest research and create the integrative understanding of water resources and the environment. It brings together young scientists in many fields related in water resources from physical, biological, chemical, social, and governance term to discuss solutions for better environment and water resources.

Herewith, the Committee is pleased to announce you that the paper;

ID : XV75U

Title : Kinetic Modeling Of Domestic Wastewater (Greywater Type) Using Uasb Reactor

Author(s) : S. Syafrudin

The paper has been reviewed and accepted for oral presentation at the conference and publication in proceeding.

We would like to invite the author(s) to present the research paper at the conference site in Malang, East Java, Indonesia.

Sincerely yours,

icwrdep 2015
THE 1st YOUNG SCIENTIST INTERNATIONAL CONFERENCE OF WATER RESOURCES DEVELOPMENT AND ENVIRONMENTAL PROTECTION

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FOREWORD

The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection 2015 (ICWRDEP 2015) Water Resources Engineering Department, Faculty of Engineering, University of Brawijaya was conducted on 5 - 7 June 2015. The Conference was organized by Faculty of Engineering and collaborated with International University of Malaya (UM), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM).

The participants of the Conference are about 60 participants come from more than 20 higher institutions, such as; Sepuluh Nopember Institute Of Technology, Surabaya (ITS), Bandung Institute of Technology (ITB), Bogor Agricultural University (IPB), The University of Lampung, Sriwijaya University, University of Muhammadiyah Malang (UMM), University of Brawijaya (UB), Padjajaran University, State University of Malang (UM), National Institute of Technology (ITENAS), Tidar university, State Polytechnic of Malang (Politeknik Negeri Malang), Mulawarman University, State Polytechnic of Padang (Politeknik Negeri Padang). Malang National Technology Institute (Institut Teknologi Nasional Malang), BBWS Mesuji Sekampung, Bengkulu University, Diponegoro University (UNDIP), Nusa Cendana University, Khairun University, Bantara University, University of Jember, State Polytechnic of Samarinda (Politeknik Negeri Samarinda), UM (University of Malaya), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM), and others, which reflect the importance water resources engineering development and environmental protection.

The topics of conference are Environmental Engineering & Water Technology, Integrated Water System & Governance and Water Science & Engineering. The conference provide platform for researchers, engineers and academician to meet and share ideas, achievement as well as experiences through the presentation of papers and discussion. These events are important to promote and encourage the application of new concept of water resources development and techniques to practitioners as well as enhancing the knowledge of environmental protection with the current requirements of analysis, design and construction of any engineering concept.

As Head of Water Resources Engineering Department, we would like to express our deepest gratitude to the Rector University of Brawijaya, Keynote Speakers (Prof Satoru Oishi & Prof Tsuyoshi Imai from Japan, Assoc. Prof Faridah Othman and Prof Amir Hamzah from Malaysia), International Advisory Board members, organizing committee and also to all participants.

We would like to express our deepest gratitude to the Faculty of Engineering conducted such conference. This is the first International conference for the Department and we expect that this is will become 2nd annual activity for our Department.

Malang, 5 June 2015

Ir. Mohammad Sholichin, MT., Ph.D
Head of Water Resources Engineering Department
Faculty of Engineering University of Brawijaya

Table of Content

THEME 2 Integrated Water Systems & Governance

THEME 3 Water Science & Engineering

Kinetic Modelling of Domestic Wastewater (Greywater Type) Treatment Using UASB Reactor

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ABSTRACT

This study mainly focuses on an alternative process to treat greywater namely Upflow Anaerobic Sludge Blanket (UASB), that works on the principle of distributing wastewater in the reactor with upward direction of flow through the sludge blanket with specific hydraulic retention time (HRT). A laboratory scale research using artificial greywater was conducted in 64 days with 5 units of transparent fiber column-shaped UASB reactors with 10.16 cm diameter and a height of 100 cm, and the outlet's height was 60 cm. Reactors were operated at variations concentrations of 155 -1400 mg/l; HRT of 4-12 hours; upflow (V_{up}) velocities of 0.05 m/hr-0,15m/hr, and Hydraulic Loading Rate (HLR) 0.05 to 0.15. $m^3/m^2/hr$. An optimum COD removal efficiency of 48.01 to 77.34% was obtained at 8 hours HRT with influent COD of 827-867 mg/l. Based on regression models, the largest BOD and COD removal efficiencies were respectively 72.35% and 74.43%, achieved at the respective load concentrations of 910 mg/l and 962.50 mg/l. The kinetic model of artificial wastewater (greywater type) treatment was influenced by influent concentration and removal rate. The higher influent concentration will result in higher degradation rate. BOD_5 elimination kinetics model resulted in the degradation rate constant (k) of 0.11/hr for loads from 473.76 to 643.10 mg/l and COD removal kinetics model resulted in the degradation rate constant (k) of 0.10/hr for loads of 960 to 1480 mg/l. COD and BOD removal efficiencies had significant relationship with hydraulic capacity (HRT, flowrate, V_{up}, HLR) and the influent concentration. Increase in the HRT decreased the flowrate, V_{up} and HLR, but increased the removal efficiency and vice versa. Reactor performed displayed better efficiency removal when real greywater was applied compared to the artificial greywater. Based on these results, UASB reactor can be used as one of the solutions to carry out the management and control of receiving water bodies. Further studies on UASB are needed to be implemented in order to obtain the height of the column for practical needs.

KEYWORDS

Greywater; UASB; HLR; upflow velocity and HRT

INTRODUCTION

Based on Ministry of Environmental Decree No. 112/2003, domestic wastewater originates from activities of human settlements (real estates), restaurants, offices, commerce, apartments, and dormitories. Domestic wastewater contributes to 60% - 70% of river pollution (Anonym, 1997). Semarang city, as the capital city of Central Java Province, consists of sub-districts with total area of 373.70 km^2. It has a settlement area of 12,355.96 ha inhabited by 1,544,358 residents and like many cities in Indonesia, suffers from domestic wastewater management issues. The management of domestic wastewater in Semarang is conducted by two methods depending upon the type of the wastewater: flowing into septic tanks for 90% blackwater into drainage for almost 94% of greywater; without any treatment.

Due to its large quantity, domestic wastewater should be properly managed. If released in the water bodies, the untreated water can potentially increase the COD and BOD levels, triggering reduction in

ISSN : 2460-0849

Dissolved Oxygen (DO) and increasing the risk of eutrophication (Eiger and Smith, 2002). Environmental Bureau of Semarang City (2013) states that some of the rivers near settlements in Semarang city have COD and BOD_5 exceeding the permitted limits based on Government Ordinance No. 082/2001 regarding water quality management and controlling; such as Banger Upstream River (COD 100 mg/l and BOD_5 26 mg/l), Banger Downstream River (COD 161.54 mg/l and BOD_5 39 mg/l); Kali Asin Upstream (COD 46.15 mg/l and BOD_5 18 mg/l); Kali Asin Downstream (83.46 mg/l and BOD_5 22 mg/l). The COD and BOD_5 contained within those rivers are supposed to be caused by residential activity. Therefore, the greywater generated from toilets, kitchens, and laundries of the residents in Semarang should be treated before being discharged into water bodies. Greywater characteristic of the unplanned settlement in Semarang which was represented by Gabahan village, Tengah sub-district with COD of 330.75 mg/l – 1400 mg/l, and BOD_5 of 125.60 mg/l – 673 mg/l. Meanwhile, Bukit Semarang Baru residential, Mijen sub-district, as the properly organised settlement had COD of 29.90 mg/l – 83.40 mg/l and BOD_5 of 11 mg/l – 41.88 mg/l. The aforementioned range of COD and BOD_5 have exceeded the permitted limits according to the regional regulation of Central Java Province No. 5/2012 regarding threshold value of wastewater. Therefore, if the waste water effluent enters water body, it can pollute the receiving water bodies.

Anaerobic treatment is a treatment method which only needs a low energy and low nutrition, stable effluent, low generated sludge, and producing biogas (Grady Jr., Daigger, & Henry, 1999; Lettinga, 1996). Generally used anaerobic treatments for domestic wastewater including greywater include septic tank, Imhoff tank, anaerobic lagoon (AL), anaerobic filter (AF), and upflow anaerobic sludge blanket (UASB). UASB treatment has some benefits such as: (1) capability of treating wastewater with high organic content; (2) tolerability to shock loading (Shanmugam & Akunna, 2008); (3) high efficiency; and (4) cost-effectiveness. Treatment performances of UASB reactors are highly affected by hydraulic capacity and loading capacity such as (1) hydraulic retention time (HRT); (2) hydraulic loading rate (HLR); (3) upflow velocity (V_{up}); (4) influent discharge; (5) organic waste concentration; (6) organic loading rate (OLR); and operational variables namely temperature and pH (Al-Shayah & Mahmoud, 2008; Aslan & Sekerdağ, 2007; Clark & Speece, 1970; Eckenfelder, Patoczka, & Pulliam, 1988; Ghangrekar, Asolekar, & Joshi, 2005; Lew, Tarre, Belavski, & Green, 2004; Nugrahini, Habibi, & Safitri, 2008; Van Haandel & Lettinga, 1994; Yasar & Tabinda, 2010).

Biological treatment performance is assessed through removal efficiency of BOD_5 and COD. Removal efficiency should ideally increase or at least remain stable. The decreasing efficiency of BOD_5 and COD removal is marked by decreasing pH value in the reactor. The decreasing pH shows that acidogenesis and acetogenesis have occurred, where the organics are transformed to volatile fatty acids so that the reactor pH becomes acid. If the volatile fatty acids accumulate in the reactor, they can prevent the methanogenesis and hence, the organic removal efficiency will decrease. The higher BOD_5 and COD concentration in the influent can be removed by the microorganisms in the UASB reactor. This is due to the entrance of substrate in microorganism cells through diffusion, where the molecules move from high concentration to low concentration. If the substrate concentration in the wastewater is high, the substrate entrance in the microorganism cells will be easier and will be translated into higher BOD_5 removal quantity. Therefore, it is necessary to build kinetic model of BOD_5 and COD removal of greywater using UASB.

According to Purwanto (2002), a wastewater treating reactor comprises of three types of reactor systems: batch reactor (BR), steady state flow reactor (STTR), and unsteady state flow reactor (USTR) or semi batch reactor. Batch reactor is usually modelled by stirred tank reactor. In the batch reactor, reactant is added into a well-mixed container and then left for a certain time period until the desired conversion level is reached and then the wastewater is discharged from the container as treated water. This process is called unsteady-state operation. There are two types of reactors based on the flow pattern: perfectly mixed flow reactors and plug flow reactors. In a plug flow reactor, fluid flows in the pipe parallel to the axis of pipe using the same velocity throughout the area of pipe cross-section. Assumption of such flow pattern specifies that there is no diffusion process through axial direction and back mixing. Conversely, the pipe flow reactor is usually used to process continuous flow without stirring.

ISSN : 2460-0849

Considering that the greywater treated in UASB reactor flows in the direction parallel to the axis of the pipe without mixing, the UASB reactor can be assumed as an example of plug flow reactor (PFR) system including bulk reactor. Perfect mixing reactor is divided into bulk reactor (batch) and continuous flow. Bulk reactor is among the perfect mixing type reactors, characterised by uniform concentration and temperature at any point in the reactor. The shape of the reactor in this category is a stirred tank reactor, and all forms of reactors for water and wastewater treatment that have characteristics such as stirred tank reactor.
Model equation in the bulk reactor is as follows:

$$Accumulation = input - output - transformation$$

$$\frac{d(VC)}{dt} = 0 - 0 - rV$$

$$-\frac{d(VC)}{dt} = rV \qquad \text{.......(1)}$$

In general, for a liquid system with constant volume, the equation is stated in the form of an integral equation:

$$t = -\int_{Co}^{C} \frac{dC}{r} \qquad \text{.......(2)}$$

It is the rate of transformation, marked by positive (+) in case of generation of compounds and negative (-) when there is a reduction or degradation into other materials.
When the processing reaction can be expressed in the order of "1", then the stirred tank reactor can be expressed with a constant volume so that the reaction rate r = kC can be expressed as:

$$r = -r_a + r_b \qquad \text{.......(3)}$$

The concentration "A" as a function of time, can be expressed as:

$$V\frac{dCA}{dt} = -rAV \qquad \text{.......(4)}$$

$$V\frac{dCA}{dt} = -kCA \qquad \text{.......(5)}$$

If equation (5) is integrated using limit value t = 0, $C_A = C_AO$ and t = t. $C_A = C_A$, so that C_A as time function can be obtained as:

$$C_A = C_{A0}e^{-kt} \qquad \text{.......(6)}$$

Then, concentration B can be calculated as:

$$C_B = C_{A0} - C_A \qquad \text{.......(7)}$$

$$C_B = C_{A0}(1 - e^{-kt}) \qquad \text{.......(8)}$$

Profile of concentration of reactant "A" and product "B" can be seen in Figure 1.

ISSN : 2460-0849

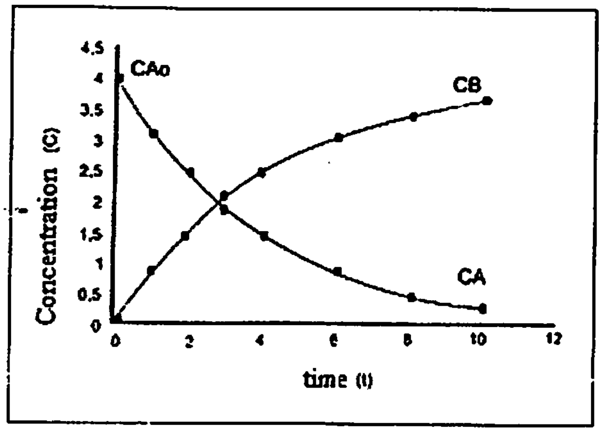


Figure 1. Concentration profile of reactant "A" and product "B"

Therefore, as for the equation application for domestic wastewater treatment which contains BOD_5, the degradation of BOD_5 in bulk system can be expressed as:

$$\frac{d[BOD]}{dt} = -k\,[BOD] \quad (9)$$

$$BODt = BOD_o e^{-kt} \quad (10)$$

As for COD, it can be expressed as:

$$CODt = COD_o e^{-kt} \quad (11)$$

METHOD AND MATERIAL

Scope

Treatment modelling was based on a laboratory scale quantitative research (experimental-laboratory) with UASB reactor column height of 100 cm and a diameter of 10.16 cm (4 inches) made of fiberglass using artificial waste greywater of Semarang in the laboratory of Departement of Environmental Engineering, Faculty of Engineering, University of Diponegoro, Semarang. The research was conducted by varying the hydraulic retention time, hydraulic loading rate, upflow velocity (V_{up}), discharge and concentration; which can affect the COD and BOD removal efficiencies as dependent variabies in a controlled situation on the temperature and the degree of acidity (pH). Hence they can be used for analysing the concentration and the efficiency of COD and BOD_5 removal as UASB reactor performance indicators. Experimental research was done by manipulating and controlling one or more independent variables and making observations to find the arising variations and causal relationship of these variations.

Variation of Concentration. Concentration variation was determined based on the characteristics test results of domestic wastewater (greywater type) in the residential area of Semarang city. From the results of the preliminary study, COD concentration range of 155 mg/l-1400 mg/l and BOD_5 of 107 mg/l-825 mg/l were obtained and were classified into 5 classes as high concentration (H), medium-high concentration (MH), medium concentration (M), low-medium concentration (LM), and low concentration (L) as described in

ISSN : 2460-0849

Table 1. Variation of influent concentration

No.	Parameter		Concentration Qualification
	BOD_5 (mg/l)	COD (mg/l)	
1.	107	155	Low
2.	350	560	Low Medium
3.	525	840	Medium
4.	700	1120	Medium High
5.	825	1400	High

BOD_5 test method was conducted in accordance to SNI 6989.72: 2009 and COD test according to ISO 6989.2: 2009.

Variation of HRT (Hydraulic Retention Time). This research was conducted with HRT of 4 hours, 6 hours, 8 hours, and 12 hours (Azimi & Zamanzadeh, 2004; Elmitwalli & Otterpohl, 2011; Lew et al., 2004; Yasar & Tabinda, 2010).

Variation of HLR (Hydraulic Loading Rate). UASB reactor had a diameter of 4 inches (10.16 cm), height of 100 cm and effluent-hole height of 60 cm. Therefore, the wet volume of reactor was 0.004862 m^3 or 4.862 litres. Hence the variation of discharge could be determined as Q_1 = 1.215 l/hour, Q_2 = 0.810 l/hr, Q_3 = 0.6075 l/hour, Q_4 = 0.4862 l/hour and Q_5 = 0.405 l/hour. Consequently, the variation of HLR could be determined as follows: HLR_1 = 0.15 m^3/m^2/hour; HLR_2 = 0.1 m^3/m^2 hour; HLR_3 = 0.075m^3/m^2/hour; HLR_4 = 0.06 m^3/m^2/hour; and HLR_5 = 0.05 m^3/m^2/hour.

Variation of Discharge. The variation of discharges had been determined to control reactor operation so that the discharge could be stable. The variations of discharges were Q_1 = 0.001215 m^3/hour; Q_2 = 0.00081 m^3/hour; Q_3 = 0.0006075 m^3/hour; Q_4 = 0.000486 m^3/hour and Q_5 = 0.000405 m^3/hour.

Materials and Equipment

(1) Material used in this study was artificial waste which replicated the domestic wastewater from Gabahan Village and Bukit Semarang Baru Residential. Chemical agents used for artificial waste were dextrose (Merck KGaA, 2012); seeding agent faecal sludge 1.7 litres or equivalent to 35% of UASB reactor's wet volume.

(2) The equipment used in this study was UASB reactor made of transparent tubular fiber with diameter 4 inches (10.16 cm), height 100 cm, and height of effluent holes 60 cm. As many as 5 units with 1 unit reactor consisting of 5 reactors; storage tank made of water drum as a place to accommodate artificial waste with a capacity of 200 l so as to provide influent for 2 days; tap infusion serving to regulate the discharge; 24×8×20 cm^3 glass aquarium as an equalisation basin to equalise the flow so that the entry velocity into the reactor could be managed; a twenty-five litres bucket as a treated water reservoir after leaving settling tank which was ready to be discarded and measured as a sample; and sludge container so that the sludge was recirculated and discarded.

The UASB reactor that had been utilised for the purpose of the laboratory experimental study conducted in this study has been illustrated in Figure 2 and Figure 3.

ISSN 2460-0849

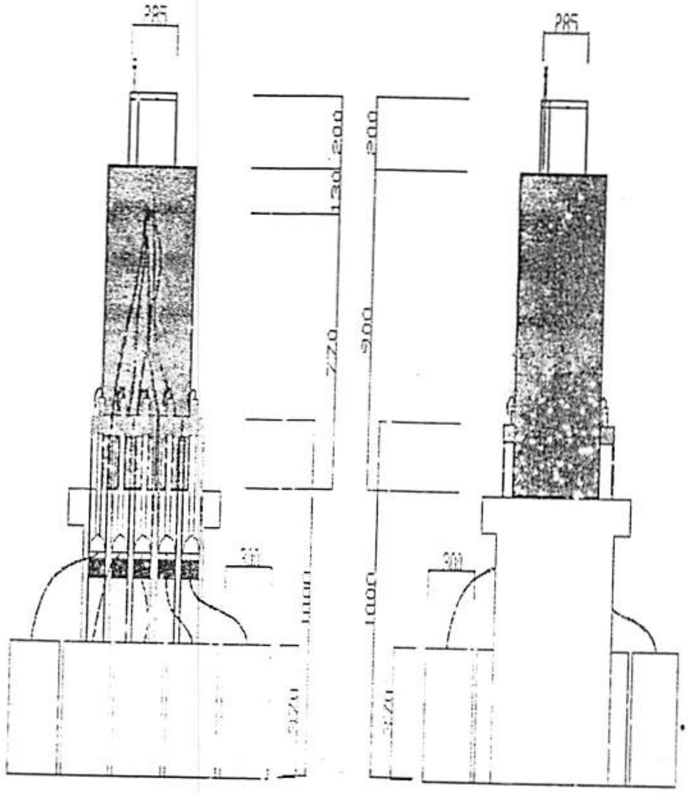
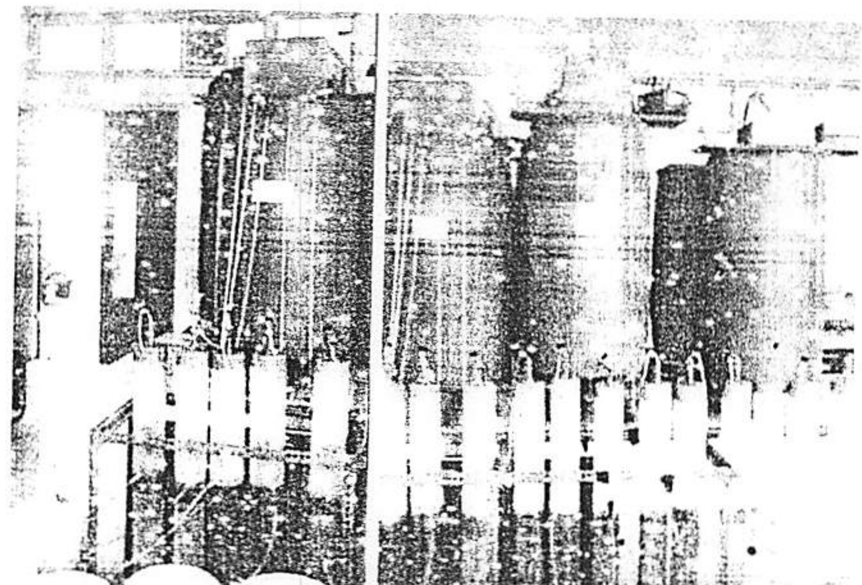


Figure 2 [illegible]



Research Phases

Artificial Waste Production. Artificial waste was made with aquadest mineral water and dextrose. For acclimatization process, five different artificial concentrations were made. Each concentration variation was made with 50% and 100% of the existing wastewater. Meanwhile, on the running

ISSN [illegible]849

process, only 100% concentration variation with concentration determination was done by calculation. As for determining glucose mass on dextrose, trial and error calibrated by curve was conducted. Furthermore, the same method was carried out to determine the other concentration of COD according to the range of variation concentration. Finally it was obtained that the glucose masses were 0.2901 gr, 1.0481 gr, 1.5721 gr, 2.0962 gr, and 2.6202 gr as can be seen in Table 2.

Table 2. Second phase of artificial waste test results (glucose mass calculation from curve determination of mass)

Range Concentration	Parameter (mg/l)		Glucose Mass used (g)	Dilution
	COD	BOD		
Low	155	107	0.2901	2
Low – Medium	560	350	1.0481	4
Medium	840	525	1.5721	4
Medium – High	1120	700	2.0962	6
High	1400	875	2.6202	6

Seeding and Acclimatization Phases. Seeding and acclimatization was done to multiply and adapt the anaerobic microorganisms with the wastewater. Seeding was conducted by providing sludge which incorporated to each reactor as much as 35% volume of UASB reactor. Moreover, the microorganisms also needed nutrients (carbon, nitrogen, and phosphorus) in ratios 300:5:1, consecutively. Materials used in the delivery of nutrients were dextrose as carbon (C), urea as nitrogen (N), and SP36 as phosphorous (P). The results of the calculations have been tabulated in Table 3.

Table 3. Nutrients of N and P requirement calculation

No.	COD Concentration	N Requirement	P Requirement	N Requirement in Urea	P Requirement in TSP
	(mg/l)	(mg/l.hour)	(mg/l.hour)	(mg/l.hour)	(mg/l.hour)
1.	155	1.87	0.37	4.08	1.25
2.	560	6.77	1.35	14.77	4.52
3.	840	10.15	2.03	22.07	6.77
4.	1120	13.54	2.71	29.42	9.02
5.	1400	16.92	3.38	36.78	11.28

Acclimatization phase is a phase for preparing the microorganisms to live and adapt to the wastewater. This is usually done by providing substrates gradually from low concentration of COD until the wastewater COD concentration is reached. This condition is necessary to prevent shock loading because the microorganisms are not accustomed to high load (Indriyani, 2003). In this study, 50% of concentration of artificial wastewater was initially provided until the microorganisms had adapted. Then 100% of concentration of artificial wastewater was finally given.

Data Collection Phase

Each variation was done for 20 days continuously. One cycle took 4 – 12 running. The sludge volume was designed as about 35% of total UASB reactor volume or 1.7 litres. After the running and sampling for one variation was done, another sampling for subsequent variation was performed.

Research phase was done at a laboratory scale study to obtain the primary data. Sampling was carried out starting from seeding, acclimatization and running for the COD parameter. Meanwhile, BOD_5 parameter was taken only in the running phase. Sampling was done at the inlet and at the outlet in order to identify the differences between initial condition before the treatment and condition at end of the treatment. The operational control of the reactor during the research was conducted with the control variables namely pH, temperature and discharge carried out during or when the wastewater

ISSN : 2460-0849

was leaving the reactor. Samples' analyses were conducted through analysis test according to the existing methods such as SNI 06-6989.2-2004 for COD and SNI 6989.72-2009 for BOD_5.

Data Analysis Phase

In this study, data analysis was conducted from acclimatization phase until running phase. Data analysis included analysing the variation of HRT, HLR/V_{up}, concentration, discharge against the concentration removal and the efficiency of artificial waste removal. Furthermore, analysing the determination of the optimum conditions of the reactor performance related to COD and BOD_5 concentration decrease using the kinetic model (the scatter plot mathematical model).

RESULTS AND DISCUSSION

Considering that the artificial waste treated in the UASB flows parallel to the axis of the pipe and without mixing, the UASB reactor can be assumed as a plug flow reactor (PFR) and so the results of this study can be modelled in the form of kinetic model. In accordance with the variation used in the operation, the results of this study can be modelled based on the influent concentration which entered the reactor after the 100% acclimatization, starting from the loading until running. Kinetics model employed for this study took into account the kinetics of the influent concentration relationship of influent and effluent for COD, based on the concentration variation (high, medium-high, medium, low-medium, low). Using the same method as for the COD model, BOD_5 removal had also been modelled based on the concentration variation.

The kinetics model of influent and effluent of UASB treatment can generally be stated as the following empirical relationship:

$COD = COD_o e^{-kt}$ and $BODt = BOD_o e^{-kt}$

Where:

COD_0	= influent COD concentration (mg/l)
COD	= effluent COD concentration (mg/l)
BOD_0	= influent BOD concentration (mg/l)
BOD_5	= effluent BOD concentration (mg/l)
k	= degradation rate (1/hour)
t	= retention time/HRT (hour)

Furthermore, based on the influent and effluent concentration, data from the concentration variation was obtained through a mathematical approach using scatter-plot employing the aforementioned formula. Based on the results and mathematical modelling, degradation rate constant for COD removal in high concentration (1160 mg/l-1480 mg/l) and medium-high concentration (960 mg/l-1180 mg/l) were 0.10 l/hour. Meanwhile, the medium concentration (827 mg/l-880 mg/l) and low-medium concentration (200 mg/l-467 mg/l) had the degradation rate constant of 0.09 l/hour. On the other hand, the kinetic model for low concentration (133 mg/l-160 mg/l) had degradation rate constant of 0.05 l/hour.

Overall, the COD removal kinetics model had significant value range in the form of regression coefficient R^2, from 0.974 to 0.996, the value range is approaching the number 1. This shows that the kinetic mathematical model significantly accounted for the COD removal pattern and that greater the concentration, higher the variation of degradation constant. Furthermore, higher the degradation constant, the greater the concentration removal, so the removal efficiency got better at a certain concentration variation.

According to the model, it can be concluded that greater the degradation constant, the longer will be the retention time (HRT) which will increase the performance of artificial wastewater treatment using UASB. This result is in accordance with Ali, Al-Sa'ed, and Mahmoud (2007) and Nugrahini et al.

ISSN : 2460-0849

(2008), who also mentioned that a long retention time in the reactor will give further time to the microorganisms for biomass degradation and will then enhance the effluent quality. Moreover, Al-Shayah and Mahmoud (2008) have also concluded that the reactor stability in COD removal will be reached over increasing time period. Similar to COD removal, BOD_5 removal was modelled with R^2 value in the range of 0.951-0.994. For the BOD_5 removal in high and low-medium concentrations the degradation rate constant was 0.09 l/hour. Meanwhile, for BOD_5 removal in medium and medium-high concentrations, the degradation rate constant was 0.11 l/hour. Whereas the degradation rate constant of the low concentration was 0.04 l/hour.

Referring to the results of the COD removal model, it can be presumed that the greater the concentration, the greater the variation of degradation constant. The greater the degradation constant, the greater would be the concentration removal and so the removal efficiency got better at certain concentration variation. According to the model, it can be concluded that with higher degradation constant and longer retention time (HRT), the performance of artificial waste treatment using UASB will be better. Generally, BOD_5 removal kinetic model was same as the COD removal kinetic model. However, in case of BOD_5 removal in high concentration, the degradation constant (k) was 0.09 which was smaller than 0.11 degradation constant of the medium-high concentration. It might be attributed to the anomalies in the current study such as the discharge fluctuated during 53rd day and thus resulted in flow turbulences. This condition caused the wastewater and the sludge contact to decrease, so that the removal efficiency also declined. This is in accordance with Farajzedehha *et al* (2012) study which also concluded that the flow turbulences will result in reduced wastewater and sludge contact time, thus the removal performance will also decrease.

The model is also in accordance with the studies conducted by Ali et al. (2007) and Nugrahini et al. (2008)which mentioned that the long retention time in the reactor would provide a longer time for the microorganisms to degrade the organic matter and thus the effluent would be better. Moreover, it was stated by Al-Shayah and Mahmoud (2008) that the reactor stability in COD removal would be attained over time. Overall, the kinetic model of BOD removal had regression coefficient R^2 in the range of 0.951 - 0.994, approaching the value of one. It means that the kinetic models were significantly accountable. The mathematical models have been summarised in Table 4.

Table 4. Kinetic model of artificial wastewater treatment using UASB

No.	Variation	Model (mg/l)	R^2 Model	Degradation Rate (l/hour)
A	COD Removal			
1.	High Concentration	$COD = 1422e^{-0.10.HRT}$	$R^2 = 0.991$	0.10
2	Medium – High Concentration	$COD = 1131e^{-0.10.HRT}$	$R^2 = 0.996$	0.10
3.	Medium Concentration	$COD = 788.0e^{-0.09.HRT}$	$R^2 = 0.974$	0.09
4.	Low – Medium Concentration	$COD = 552.1e^{-0.09.HRT}$	$R^2 = 0.994$	0.09
5.	Low Concentration	$COD = 154.6e^{-0.05.HRT}$	$R^2 = 0.981$	0.05
B	BOD_5 Removal			
1	High Concentration	$BOD_5 = 722.1e^{-0.09.HRT}$	$R^2 = 0.981$	0.09
2	Medium-High Concentration	$BOD_5 = 544.3e^{-0.11.HRT}$	$R^2 = 0.987$	0.11
3	Medium Concentration	$BOD_5 = 490.4e^{-0.11.HRT}$	$R^2 = 0.994$	0.11
4	Low-Medium Concentration	$BOD_5 = 337.1e^{-0.09.HRT}$	$R^2 = 0.951$	0.09
5	Low Concentration	$BOD_5 = 96.25e^{-0.04.HRT}$	$R^2 = 0.956$	0.04

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CONSCLUSIONS

It can be concluded that:

- The kinetic model of artificial wastewater (greywater type) treatment was influenced by influent concentration and removal rate. The higher the influent concentration, the higher the degradation rate.
- Kinetic model of treatment using UASB for low concentration in COD removal was $COD_x = 154.6e^{-0.05.HRT}$ with degradation rate of 0.05 litre/hour, whereas for low-medium concentration until medium concentration were referred to kinetic model $COD_x = 552.1e^{-0.09.HRT}$ and kinetic model $COD_x = 788.0e^{-0.09.HRT}$ with degradation rate of 0.09 litre/hour.
- Regarding the BOD_5 removal kinetic model for treatment using UASB for low concentration was $BOD_5 = 96.25e^{-0.04.HRT}$ with degradation rate as 0.04 litre/hour. While from medium concentration until medium-high concentration, the kinetic model was $BOD_5 = 490.4e^{-0.11.HRT}$ and kinetic model $BOD_5 = 644.3e^{-0.11.HRT}$ with degradation rate of 0.11 litre/hour. Especially for low-medium and high concentration had degradation rate of 0.09 litre/hour with kinetic model of $BOD_5 = 337.1e^{-0.09.HRT}$ and $BOD_5=722.1e^{-0.09.HRT}$, respectively.

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