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PROCEEDINGS

Bali International Seminar on Science and Technology

FACULTY OF INDUSTRIAL TECHNOLOGY - UPN "VETERAN" JATIM
CHEMISTRY DEPARTMENT, BIOMEDICINAL POSTGRADUATE PROGRAM

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A STUDY ON THE KINETICS PARAMETERS FOR A CONTINUOUS FLOW ACTIVATED SLUDGE PROCESS IN WASTEWATER OF TEXTILES

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Abstract

The textile industry is a major industry in Bandung. The use of the batch wastewater treatment process is not appropriate anymore. Besides, it reduces the land utility so that it needs more control from time to time. In this research the continuous flow system is developed. The important factor in the design process observed is the kinetics parameters. The research was started by the cultivation of mixed culture, followed by acclimatization into the real condition (textile wastewater media). The main experiment was conducted in a 3 L continuous reactor with different input flow rates of wastewater (3, 9, 15 ml / minute). The data of mixed liquor volatile suspended solid (MLSS), Dissolved Oxygen (DO), Biological and Chemical Oxygen Demand (BOD and COD) were observed daily until the steady state has been achieved. Subsequently the data were analyzed using the Lineweaver-Burk equation model to obtain the kinetic coefficients and the yield factor for this system. In future research, this parameter will be used for scaling up the reactor for the same wastewater.

Keywords : *textile wastewater, activated sludge, continuous reactor*

INTRODUCTION

Since the 1960s, the textile industry has been growing as the largest industry in West Java. Thousands of tons of textile products produced and became the leading export commodity. However, the factory wastes make the health problems to the communities around the industrial area.

Textile wastewater treatment techniques available today need large area to accommodate the process before being discharged into the rivers.

Continuous processing of liquid waste is expected to overcome the problem of textile wastewater treatment plant. By using a continuous reactor, it can minimize the use of land and also the recycle process can be done easily.

This research is a preliminary assessment of the continuous processing of textile waste using activated sludge. The purpose of this research is to study the performance of continuous systems in textile wastewater treatment and to obtained kinetic parameters that can be used to scale-up.

2 STRUCTURE OF WRITING

2.1. Continous reactor

The ideal continuous reactor can be identified as the plug flow reactor (PFR) and the continuous stirred tank reactor (CSTR). This type of reactor that will be used in the experiment is a type CSTR.

Parameters that affect in ideal reactor design are space-time (τ) and space velocity (s). Space time is the time required to process the input stream in accordance with the available reactor volume. In general, the input flow was measured at a certain pressure and temperature. Space velocity is the number of input feed stream that can be processed during a certain time.

$$s = \frac{1}{\tau} \text{ dan } \tau = \frac{V}{Q_0} \qquad (1)$$

Where V is a volume reactor and Q_0 is a volumetric rate.

In general, CSTR is used to liquid phase reaction. For liquid phase reaction, the density of the feed stream and the output of the reactor can be assumed unchanged. Form of continuous reactors are commonly used in wastewater treatment systems follow the principle of the Chemostat, a bioreactor with a constant flow of incoming (fresh medium) and outflow so that the working volume maintained constant. By adjusting the volume flow rate, the growth of microorganisms can be controlled properly. In the chemostat the culture environment changes continually. After a period of non-steady (acclimatization), bacteria and the substrate will reach a constant concentration.

In this reactor, mixing is done by the work of impeller and aeration so the composition of fluid in the reactor is not a function of position. In addition, the concentration of effluent is the same with the concentration in the reactors.

In steady state, the growth of microorganisms took place at a constant rate and other parameters remain constant, i.e the work volumes, levels of dissolved oxygen (DO), pH, and etc. The material balance in chemostat equation is:

Accumulation = in – out + generation

$$V_R \frac{dc_i}{dt} = Fc_{if} - Fc_i + V_R r_{fi} \qquad (2)$$

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Where:

V_R is reactor volume

F is volumetric flow rate

c_i is concentration of component i at the reactor output stream

c_{if} is concentration of component i at the reactor input stream (feed)

The weaknesses of the batch system which will be eliminated by using a continuous reactor are as follows:

- The system requires several reactors.
- The tanks can not be directly used for the next stage when the tank has finished a particular process.
- The daily flow rate is varied which may cause disruption in the system.

2.2. Activated Sludge

Activated sludge is a biomass of suspended microbe that is usally used in a biological wastewater treatment. Activated sludge process is an aerobic treatment that oxidizes organic material to CO_2 and H_2O, NH_4, and new cell biomass. The air is channeled through a blower pump (diffused) or through mechanical aeration. Microbial cells form a floc that will settle on the bottom of the tank. Activated sludge is a complex ecosystem composed of bacteria, protozoa, viruses, and other organisms.

Biological wastewater treatment can be divided into two types of processing i.e. anaerobic and aerobic treatment. Requirements for the selection system are the BOD content of the waste. If the value of BOD is less than 4,000 ppm, the aerobic treatment can be applied, while if BOD value greater than 4,000 ppm then anaerobic treatment should be chosen.

Both these waste processing requires certain conditions. Aerobic process can be used with the mass ratio of N: P = 100: 5 while for the anaerobic process: N: P = 400: 8. If the nutrient concentration is lower than the provisions, ammonium salt or phosphate salt may be added so that value comparisons can be achieved.

In the waste treatment system using continuous reactor general equation below can be used.

In – out+ generation = accumulation

$$QSo - QSe + r_s V = \frac{dSe}{dt} V = 0 \quad (3)$$

$$r_s = -\frac{Q(So - Se)}{V} = -\frac{So - Se}{\theta_d} \quad (4)$$

where :

Se is effluent concentration

So is influent concentration

To determine the parameters of activated sludge, it is needed Monod equation linearization. Monod equation is a simple equation that is used to connect the growth of bacteria with substrate concentration. Monod equation can be viewed as follows:

$$\mu = \mu_m \frac{S}{K_s + S} \quad (5)$$

There are several methods used to linearization Monod equation, among others: Linearization Hofstee, Hanes Linearization, and Lineweaver-Burk Linearization. For data derived from experiments using the bioreactor should be used equations based on Lineweaver-Burk method.

Lineweaver-Burk model has better accuracy, although the data obtained is not good. By using Lineweaver-Burk method will be obtained in the form of constants k and K are the parameters of activated sludge. Derivation of formula to get the parameters of activated sludge from the continuous reactor.

$$r_s = -\frac{k\, Xv\, Se}{K + Se} \quad (6)$$

$$r_s = -\frac{Q(So - Se)}{V} = -\frac{So - Se}{\theta_d} = -\rho \quad (7)$$

Both the above equation rearranged, and then we have:

$$\rho = \frac{k \quad Xv \quad S}{K \quad + \quad S} \quad (8)$$

$$\frac{Xv}{\rho} = \frac{Xv\, \theta_d}{(S_0 - S_e)} = \frac{K}{k}\frac{1}{S_e} + \frac{1}{k} \quad (9)$$

where:

k is maximum rate constant

K is half-reaction rate constant

θ_d is hydraulic retention time (HRT)

Xv is volatile suspended solid (VSS)

3 METHODOLOGY

This research was begun with the cultivation of activated sludge by adding glucose until the amount of microorganism (measured by MLSS –Mixed Liquor Suspended Solid) reachs 3,000 mg / L. It can be started also from the inoculation of microbes in the media glucose and nutrient browth, to accelerate the growth of microbes.

Before the main experiment was conducted, the acclimatization process was done. The aim of this process is to adapt the microorganism into a new environment (different substrate). Glucose and nutrient broth was replaced stepwise with textile waste every day started from 100 ml up to 1 liter.

Optimum aeration rate is determined by adjusting the aerator until dissolved oxygen in the reactor is in the range 7-8 mg / L.

Waste treatment was performed in a laboratory scale continuous reactor with a working volume of 3 L. Waste flow rate was varied at 3, 9, and 15 ml / min.

The experiment was conducted at pH 6-8, room temperature, the optimum aeration rate, MLSS of 3,000 mg / L, and the variation of influent flow rate of 3, 9, and 15 ml / min. During the experiment, the reduction of waste (in term of COD and MLSS) was observed. From the data collected, the kinetic parameters in this system can be calculated.

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The bioreactor set up can be seen in figure 1.

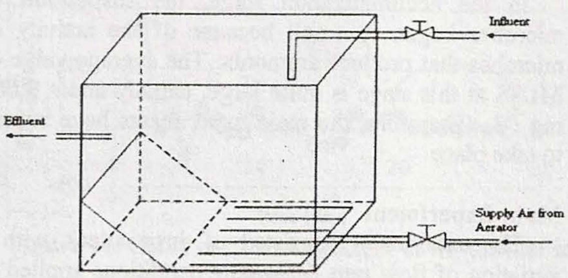

Fig. 1. Continuous Reactor Design Used in Experiment

The sample used was collected from textile waste sewage PT. Idaman Era Mandiri. This waste is combination of yarn dyeing wastewater. Once analyzed, the initial COD of the waste is equal to 457 mg / L and the initial BOD of 127.5 mg / L.

4 RESULTS AND DISCUSSION

4.1. Microbial Growth Curve

Microbial growth during adaptation, logarithmic, and stationary phase in batch systems with nutrient brooth (NB), glucose, and textile waste media is observed.

4.2. Microbial Growth Curve in NB Media

The turbidity change of NB medium indicates the microbial growth in it. Using the spectrophotometer the curve of microbes growth can be obtained. (fig. 2 and fig. 3)

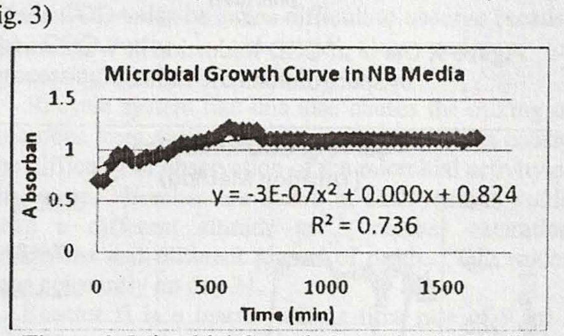

Figure 2. Microbial Growth Curve in NB Media

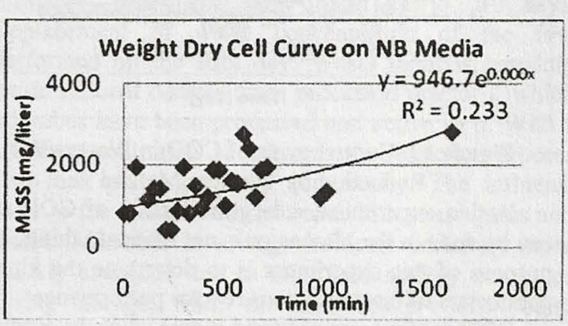

Figure 3. Curves Weight Dry Cell in NB Media

Stationary phase microbes on NB medium was reached after minutes to the 690 minutes.

From the observation of MLSS in NB medium it can be seen that although the amount of MLSS obtained tends to go up and down, the tendency of the MLSS was increased proportionaly to time.

4.3. Microbial Growth Curve in Glucose Media

The content of glucose will decrease over time because the microbes reproduce by taking glucose as a nutrient. Over time, the dry weight of cells will be growing due to the presence of glucose as a nutrient. Glucose content was measured using the Nelson method and reading with a spectrophotometer. **Figure 5.** shows that the MLSS weight tends to increase with time. Stationary phase of microbes in the medium glucose was achieved after 660 minutes.

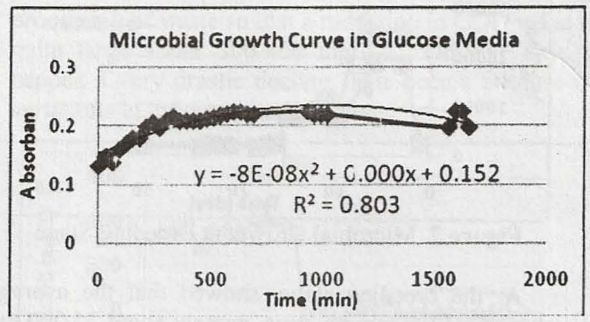

Figure 4. Microbial Growth Curve in Glucose Media

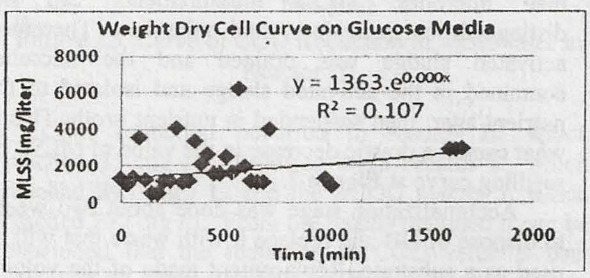

Figure 5. Curves Weight Dry Cell in Glucose Media

4.4. COD reduction curve on Media Waste

The microbes' growth in wastewater is observed through the reduction of COD. In this media the stationary phase is reached after 40 hours. (see fig.6)

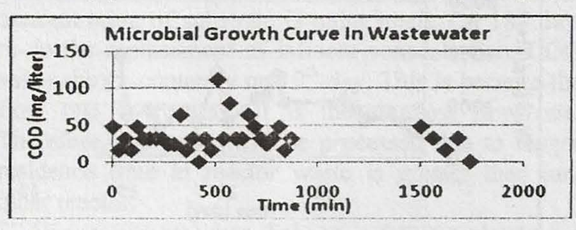

Figure 6. Microbial Growth Curve in Wastewater Substrate

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From these results we can conclude that, in this period was still in the stage of microbial adaptation. Microbes in the stationary phase required to obtain optimum results in waste degradation. Therefore to achieve optimum microbial growth done breeding and acclimatization stages to achieve the ideal amount of microbes to degrade textile waste.

4.5. Cultivation and Acclimatization Stage

Cultivation and acclimatization process aims to increase and adapt the activated sludge with the waste (substrate) as its media.

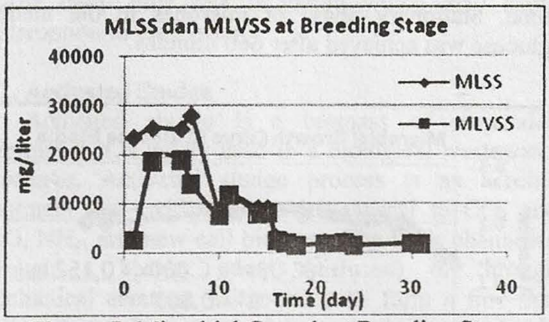

Figure 7. Microbial Growth at Breeding Stage

At the breeding stage, showed that the average value of MLSS is quite large, namely about 25,000 mg / L. Allegedly in activated sludge contains more inert than microbes. MLSS measurements can not distinguish between inert and microbes. Therefore, activated sludge was drained and the microbes contained in the activated sludge and isolated to the nutrient agar, then suspended in nutrient broth. This is what causes a drastic decrease in the value of MLSS on seedling curve at **Figure** 7.

Acclimatization stage was done about two weeks to dispose of NB and replace it with waste that will be used as a substrate. Replacement made of the volume of 100 ml to 1 liter. Observation of the MLSS was continued. Increase in value of MLSS can be shown that bacteria can still grow and adapt to a new substrate that is waste. Microbial growth curve during the acclimatization phase can be observed in **Figure 8.**

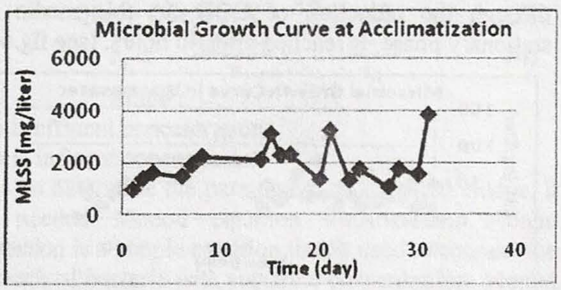

Figure 8. Microbial Growth at Acclimatization

In the acclimatization stage, the suspension of microbes began to smell because of the activity of microbes that produce ammonia. The average value of MLSS at this stage is quite large, namely about 3,000 mg / L. Therefore, the main experiments have started to take place.

Main Experiment

The experiment consisted of three attack with a variation of flow rate. Operating conditions applied to the main experiment were as follows:

- Volume of work: 3 liters
- Concentration of biomass: 3,000 mg / liter
- Aeration rate: 663 mL / min
- The rate of influent and effluent: 3, 9, 15 mL / min
- Cook time: 27 days

The experimental results can be observed in **Figure 9** and **Figure 10.**

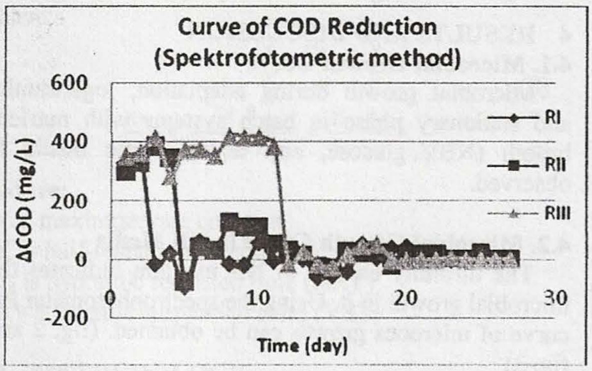

Figure 9. Curve of COD Reduction in Wastewater bySpectrofotometric Method

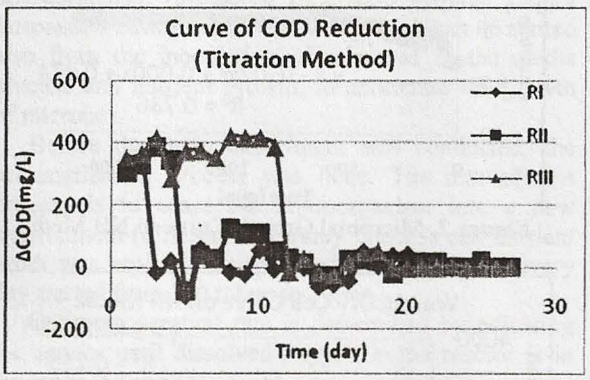

Figure 10. Curve Levels of COD in Wastewater Reduction by Titration Method

In this experiment, a large reduction of COD that can be done in the bioreactor is not the main thing. The purpose of this experiment is to determine the kinetic parameters of the continuous reactor performance.

COD values were obtained in two ways, by titration method and by spectrophotometric method. With plotting ΔCOD against time, the performance of the reactor with different flow rate can be seen. Both methods of analysis used showed a similar trend.

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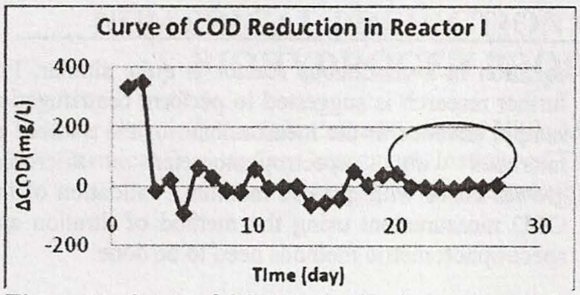

Figure 11. Curve of COD Reduction in wastewater in Reactor I

Reactor I is the reactor with a flow rate of 15 ml / min. With the rapid rate of operation, influent replacement must be done every day. On third day is the replacement of wastewater influents as fresh from the factory has been used up. New influent entering is a mixture of the processing of various reactors. In it was still there microbes carried in the effluent channel. Therefore, the new substrate concentration is entered into was very low due to microbial activity in this mixture. The process of changing influent was done almost everyday.

Based on the above curve, it appears that microbial activity is active in the third to the fifth day. In the following days, microbial activity does not occur significantly. Probably due to microbial activity are actively on the first day and second, because at that time still using fresh waste from the factory. But when there is change of influent, where waste products were used again into the reactor, the process of observation of the COD value becomes difficult to observe because the COD value is too small (less optimum for processing).

Recycle system like this also causes the mixing of microbes from various reactors every day. This causes the difficulty of observation of the microbial activity of the waste. Microbes are active in each reactor would have a different attitude as it reaches saturation conditions and different phases of death. COD values seen constantly on day 21.

Reactor II is a reactor with a flow rate of 9 ml / min. Flow rate is not too big cause the replacement of influents approximately once every 4 days. Replacement of waste concentration of the first performed on the fifth day. Waste input is certainly waste effluent derived from processed reactor I, which microbes have been processed and active in it. With a small concentration of influents the reduction process also took place gradually and slowly. The influents enter to the reactor with microbes in it cause gains and losses. Microbes in sewage influents definitely more quickly saturated due to microbial activity continues during storage, while the microbes are still young enough even wasted with the effluent stream. Even so, the COD still showed a decline that is not too drastic and constant gradually on day 20. COD reduction in reactor II can be observed in **Figure 12**.

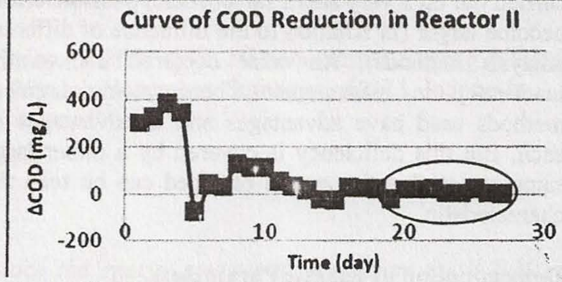

Figure 12. Curve Levels of COD in waste reduction in Reactor II

Reactor III shows the response of a more stable and constant from beginning to end. COD reduction took place with effective for 11 days. In this period, the microbes are already on the optimum stage in the processing of waste so that a reduction in COD value is quite large about 300-400 mg / L. On 11th day, it happen a very drastic decline. This occurs because of variations in influent concentration.

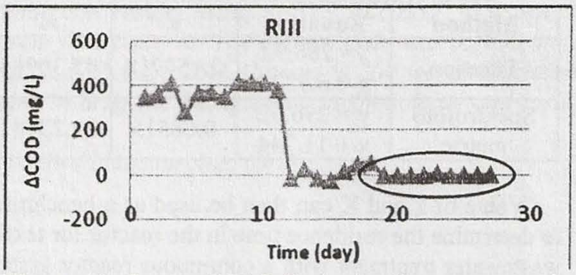

Figure 13. Curve of COD Reduction in wastewater in Reactor III

COD reduction occurred in reactor III which reached 350mg / L followed by a reactor II, which reached 295 mg / L, and the ΔCOD reactor I, which reached 277 mg / L. From the results obtained it can be concluded that the reduction in COD value is best achieved by reactor III because the reactor can reduce the waste better.

On 11th day, the substrate is a mixture of results that included the recycle of various reactors which still contain microbes carried by the channel of the reactor effluent. That's why influents contcentration is very small. With a little concentration entered this process does not show a significant reduction because of the concentration of substrate is quite small. On 18th day, re-do the replacement of influent concentration. COD value shown contantly on 19th day. This is because the flow rate in reactor III is the smallest flow rate. Therefore, the waste will be processed due to longer residence time in reactor waste is greater than any other reactor.

In experimental data there are a few samples of the difference of COD that has a negative value. This should not happen, but because the measurements

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carried out on a very small sample size, possible errors become larger (in addition to the influence of different analysis methods). An error occurred due to the inaccuracy in measurement, because measurement methods used have advantages and disadvantages of each. But this deficiency is covered by a rather large sampling so that the results obtained can be seen the characteristic.

Determination of Kinetic Parameters

Formula that has been derived to get the parameters of activated sludge from the continuous reactor is as follows:

$$\frac{Xv}{\rho} = \frac{Xv\,\theta_d}{(S_0 - S_e)} = \frac{K}{k}\frac{1}{S_e} + \frac{1}{k}$$

Where k is the maximum rate constant, K is the half-reaction rate constant, XV is the value of MLSS, and θd a residence time in reactor. From data plotting from reactor I, II, and III are obtained parameters k and K as follows:

Table 1. Equations and Kinetic Parameters

Method	Equation	k	K
Titration	y= 286.92 x + 6.3324	0.157918	45.30984
Spektrofotometric	y = 296.32 x + 11.744	0.08515	25.23161

Value of k and K can then be used as a benchmark to determine the residence time in the reactor for textile wastewater treatment with a continuous reactor system when a process scale-up reactor. The parameters obtained this will affect the process scale-up for those values obtained from the data processing volume of the reactor, influent and effluent flow rate, substrate concentration, and the MLSS. At this stage of scale-up, data that is usually known is the volume flow rate, concentration of microbes is used, the concentration of waste that want to be processed, and output the desired concentration of waste. And thus can be searched residence time in reactor waste (θ_d), which if known volume flow rate of waste that goes into the reactor, the continuous reactor volume needed to process the waste can be known.

By knowing the kinetic parameters of the continuous reactor and waste water quality standard, then this linear equation can be analyzed and adjusted for the variables that exist so as to produce the value of COD (substrate concentration output) is environmentally friendly.

5 Conclusion

In a continuous textile wastewater treatment, a minimal amount of initial microorganism is required to obtain an optimum performance. By using a continuous system in this experiment, the highest percent COD reduction of 82.86% is obtained when the influent flow rate of 3 ml / min. The value of k and K in the kinetic equation in a continuous reactor is quite similar. For further research is suggested to perform centrifugation sample advance in the measurement of the number of microbes with a spectrophotometer on microbial growth curve with glucose medium. Validation of the COD measurement using the method of titration and spectrophotometric methods need to be done.

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