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Biochemical Process of Low Level Radioactive Liquid Simulation Waste Containing Detergent

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Abstract. Research of biochemical process of low level radioactive liquid waste containing detergent has been done. Thse organic liquid wastes are generated in nuclear facilities such as from laundry. The wastes that are cetegorized as hazard and poison materials are also radioactive. It must be treated properly by detoxification of the hazard and decontamination of the radionuclides to ensure that the disposal of the waste meets the requirement of standard quality of water. This research was intended to determine decontamination factor and separation efficiencies, its kinetics law, and to produce a supernatant that ensured the environmental quality standard. The radioactive element in the waste was thorium with activity of 5.10^{-5} Ci/m^3. The radioactive liquid waste which were generated in simulation plant contains detergents that was further processed by aerobic biochemical process using SGB 103 bacteria in a batch reactor equipped with aerators. Two different concentration of samples were processed and analyzed for 212 hours and 183 hours respectively at a room temperature. The product of this process is a liquid phase called as supernatant and solid phase material called sludge. The chemical oxygen demand (COD), biological oxygen demand (BOD), suspended solid (SS), and its alpha activity were analyzed. The results show that the decontamination factor and the separation efficiency of the lower concentration samples are higher compared to the samples with high concentration. Regarding the decontamination factor, the result for 212 hours processing of waste with detergent concentration of 1.496 g/L was 3.496 times, whereas at the detergent concentration of 0.748 g/L was 15.305 times for 183 hours processing. In case of the separation efficiency, the results for both samples were 71.396% and 93.465% respectively. The Bacterial growth kinetics equation follow Monod's model and the decreasing of COD and BOD were first order with the rate constant of 0.01 $hour^{-1}$.

Key words: biochemical process, bacterial growth kinetics, low level radioactive waste, waste containing detergents, SGB 103 bacteria

INTRODUCTION

Radioactive wastewater treatment is a complex problem due to the variety of chemicals added at different stages of processing. Major problems in radioactive wastes are its radioactive substances content. Many processes were carried out to treat radioactive wastes such as evaporation, oxidation process, and chemical process [1]. Among these, physical and chemical methods are considered very expensive in terms of energy and reagents consumption. Nuclear power plant (NPP) operation, maintenance, and decommissioning, spent fuel reprocessing, and different applications of radioactive isotopes in research, medicine, and industry generate radioactive waste, some of which contain organic subtances e.g. solvent for extraction, complexing agents used in most of decontamination procedures, and detergent. There are a number of processes used currently for destruction organic complexes such as ozonization, chemical destruction, photocatalytic destruction, biochemical destruction, or UV-destruction and removal of radionuclide from solution such as co-precipitation, coagulation, sorption on ion-exchange materials, ultrafiltration, and evaporation. There are no adequately developed technological schemes and instalations for treatment of liquid radioactive waste [1].

Biological methods are employed for secondary treatment of a large number of industrial wastewaters. Knowledge of the microbial kinetics and determination of the kinetic coefficients for a particular wastewater are, therefore imperative for the rational design of treatment facilities [2].

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One of many type of wastes generated in handling the work and operation of nuclear facilities, especially in the area of radiation is residual waste washing clothes radiation workers. The waste contains detergents and radioactive substance. The radioactive substance contained in the supernatant depends on the job site workers in nuclear facilities. One of them is thorium in the form of Th-232 which has a half-life of 14.05 billion years. Detergents used in washing the worker clothes are usually yield low foam and an aryl alkyl sulfonate compound with the formula of $CH_3(CH_2)_{10}$-CH_2-OSO_3Na or R-SO_3-Na^+ [3-4].

The method commonly used in the processing of low activity radioactive waste liquid is evaporation. Evaporation causes foaming of detergent waste, so that to prevent contamination of radioactive elements is needed to distillate anti-foam material [5]. Therefore, evaporation is costly because of requiring anti-foaming material and nitric acid busting crust, also requires heating the water vapor generated from oil combustion in the boiler. One method of waste treatment which can be used as an alternative to replace the evaporation is a biochemical process using microorganisms (bacteria). Microorganisms can accumulate heavy metals and radioactive elements from the external environment [6].

In biochemical methods, there are two basic phenomena as follows: due to oxygen consumption by bacteria, the bacteria break down organic matter in the waste, and a mass of new cells are finally formed. The oxygen needs are met through aeration, ie air bubbles into the solution. The biochemical oxidation reaction are described by equations (1) and (2) [7,8].

Bacteria (cel) + Organic substance + a' O_2 + N + P
$\rightarrow$ a new cel + CO_2 + H_2O + Residual dust resistant cell (1)

cel + b' O_2 $\rightarrow$ b CO_2 + H_2O + N + P + Residual dust resistant cell (2)

Biochemical process is an effective way of treatment for toxic and hazard wastes detoxification through decomposition of organic compounds by bacteria aerated and given nutrients into CO_2, water and biomass as well as residual dust resistant cell. The bacteria use organic substances contained in waste as food or substrate [7]. Through biological treatment is expected to be the conversion of organic matter into a solution of suspended organic matter, which is then reformed into a mass of cells that flocculate and deposited by gravity, which is commonly referred as the biological floc. Simultaneously there is also the decontamination of radioactive substances from the solution by biosorption of radioactive elements by bacteria. The result is a biological radioactive sludge whitch had higher levels of COD, BOD, and SS, and supernatant with low radioactive elements and has met the quality standard [9].

Performance of waste treatment process can be studied through its biochemiclly reactions kinetics, one of them is the kinetics of bacterial growth. The number of bacteria contained in the waste can be evaluated based on the value of BOD. The existence of BOD in the environment is largely determined by organic waste, both derived from household and industrial waste. The BOD is a measure of water pollution by organic substances that can be oxidized naturally through microbiological processes, and the resulting reduction in dissolved oxygen in the water [8]. The BOD value in the supernatant is reduced along with the reduced concentration of organic matter contained in waste water. By knowing the value of BOD in waste during the sewage treatment process biochemically, it will note the success rate of waste decomposition [10].

Microbial growth in batch reactors will go through the following stages: (1) lag phase, (2) logarithmic/ exponential phase, (3) stationary phase, and (4) death phase. In the exponential phase, the rate of bacteria growth follows the first order differential equation in equation (3) [11].

$$\frac{dX}{dt} = \mu X \tag{3}$$

Where: X = biomass concentration (g/L); t = time (hour(s)); μ = rate of specific growth.

Integration of the equation (3) yields the equation (4).

$$\ln X = \mu\, t + \ln Xo \tag{4}$$

Equation (4) is a linear equation y = mx + b, with ln X as abscissa and t as ordinate. When the value of bacterial biomass concentration (X) at each time the process is known, then by making a graph of ln X to t, the rate of specific growth of bacteria, (μ), can be seen as the slope of the equation.

The kinetics of bacteria growth is described using the Monod equation. This model expresses that the specific growth rate of microbes will increase if the substrate concentration increases. However, the specific growth rate would drop when the substrate concentration is too high. Monod equation describes the specific growth rate is a function of the limiting substrate concentration (S) [12-13].

$$\mu = \mu_{\max}\left[\frac{S}{Ks+S}\right] \tag{5}$$

To determine the value of μm and Ks, equation (5) can be arranged as follow

$$\frac{1}{\mu} = \frac{Ks}{\mu_{\max}}\left[\frac{1}{S}\right] + \frac{1}{\mu_{\max}} \quad \mu \tag{6}$$

Based on equation (6) with 1/μ as abscissa and 1/S as ordinate, then 1/μm is intercept and Ks/μm is the slope. The combination of the equation (3) and (5) has the following form.

$$\frac{dX}{dt} = \mu_{\max}\left[\frac{S}{Ks+S}\right]X \tag{7}$$

The kinetics of microbial growth on biochemical oxidation by SGB bacteria is represented using a relationship between the rate of growth which are characterized by two kinetic parameters such as maximum specific growth rate (μm) and maximum biomass concentration (Xmax). By using least square method [12], the relationship of both parameters can be represented by a non-linear regression [12].

The form of the model equations are:

$$\frac{dX}{dt} = \mu_{\max}\left[1-\frac{X}{X_{\max}}\right]X \tag{8}$$

Integration of equation (8) yields the following equation:

$$Xt = \frac{XoX_{\max}\exp(\mu_{\max}t)}{X_{\max} - Xo + Xo\exp(\mu_{\max}t)} \tag{9}$$

Equation (9) can be expressed as

$$\frac{1}{Xt} = \frac{1}{X_{\max}}\left(1-\frac{1}{\exp(\mu_{\max}t)}\right) + \frac{1}{Xo\exp(\mu_{\max}t)} \tag{10}$$

Based on equation (10), the Xmax can be calculated.

MATERIALS AND METHODS

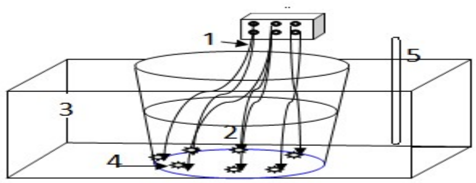
Materials

Liquid radioactive simulated waste was prepared by dissolving 7.7392 g of thorium nitrate crystals in 500 mL of water to obtain a solution of Th-232 with activity of 7.10^{-4} Ci/m^3. The solution is used as a mother liquor solution for preparation of liquid radioactive activity of 5.10^{-5} Ci/m^3 through dilution. Detergent persil as much as 10.472 g weighed dissolved in 7 L solution of 5.10^{-5} Ci/m^3 to obtain a solution with detergent concentration of 1.496 g/L and activity of 5.10^{-5} Ci/m^3. The value of COD and BOD area 744 and 417 ppm, respectively. The same proedure was done for the preparation of the solution with detergent concentration of 0.748 g/L. The bacteria used are Super Bacteria Growth Bacteria (SGB) 103 produced by PT Nusantara Water Center, Jakarta, consist of species mixture of bacteria i.e. bacillus sp., pseudomonas sp., aeromonas sp., and arthrobacter sp., with contain about 10 million/mL. Another materials used are urea as a nutritional source of Nitrogen and super phosphate (SP) as a nutritional source of phosphorus[14-16].

Experiment Procedure

Equipment

The experiment was conducted using the equipment presented in FIGURE 1.



1. Aerator
2. Aerator bath
3. Supernatant Bath
4. Sludge accumulator
5. Termometer

FIGURE 1. The research equipment

The first procedure was to determine the operating paramaters. In this study, used aerator has 6 (six) outlet to discharge air of 14 L/min in order to avoid the formation of sludge-type filaments. A number of bacteria is added and adjusted based on the BOD and oxygen concentration in the supernatant. Based on the calculations, the amount of bacteria that should be added is about 100 mL. In order to live well, the bacteria must also be given sufficient food supply in the form of the nutrients nitrogen and phosphorus. For a good nutrition, other macronutrient and micronutrient do not need to be added anymore because they are considered to have been sufficiently available in the water used.

The nutrients containing nitrogen and phosphorus were added also to adjust the BOD in the solution, ie BOD:N:P = 100:5:1 [10]. Not all organic nitrogen compounds can be added to supply the nutrients to the bacteria. Nitrogen compounds must first be converted to the form of ammonia before using in experiment. Nitrogen was used in this study in the form of urea with N content by 46%, while phosphorus added was SP (Super Phosphate) with a P content of 27%.

In addition to give the nutrients, other parameters need to be considered in the processing of waste using bacteria are temperature and pH of the solution.. The bacteria can live with a mesophilic temperature range of 4 to 39 °C. Therefore, this process can be carried out at room temperature that must be kept in the range of 27 to 31 ºC. If the temperature is too low, it will cause an increase of the amount of suspended solids in the solution. Meanwhile, when the temperature is too high, there will be a reduction in the biological floc.

Acidity, pH, of the solution should also be maintained because the bacteria can die in too acidic or too alkaline conditions. The effective pH in biochemically wastewater treatment is 5-9 with the optimum value from 6.5 to 8.5. Many detergent solutions contain -OH groups so that the feed solution is alkaline. However, this waste solution will be diluted when it has been aerated and neutralized by the CO_2 produced in the oxidation by bacteria to form bicarbonate (HCO_3-) which is an effective buffer for pH 8.

Preliminary experiments

Preliminary experiment was aimed to determine the characteristics of the interaction of SGB 103 bacteria in the simulated waste. Based on this preliminary study it will be known phases of life (period of adaptation and growth) SGB bacteria in the waste so that it can be used as a reference in the waste treatment process. There is no radioactive material Th-232 in the preliminary study. Simulated waste was prepared by dissolving detergent as much as 10.472 g into 7 L then put it into the aeration basin. After that, nutrients is added to the bacteria urea and SP as much as 0.2627 g and 0.0895 g respectively. Aerator that have 6 spouts, each output pasted on the walls of the tub and cultivated arrangement evenly, then add as much as 100 mL SGB bacteria. Aerator run continuously to supply oxygen for the bacteria. Afterwards, samples were taken every 1 hour to analyze the levels of COD, BOD, and SS in the sample. The thorium has not been added yet in the waste, so that it was not necessary to analyze alpha at this stage.

This preliminary study was aimed to determine the phase of bacteria live, especially to determine the time needed by the bacteria to adapt to the environment of the waste. To determine the phase of bacterial life, then the sample was analyzed as many as possible along the experiment until there is no increasing number of bacteria observed.

Biochemical Radioactive Liquid Waste Treatment

A total of 7 L simulated wastewater with activities of 5.10^{-5} Ci/m^3 and detergent content of 1.496 g/L was poured into the tub, then the nutrients are added such as urea and SP with a ratio of BOD: N: P = 100:5:1, ie urea 0.2627 g and 0.0895 g SP [9]. Aerator w has 6 pieces outlet was executed. Each output was pasted on the walls of the tub and arranged evenly, pH was measured using a pH meter. The SGB bacteria 103 of 100 mL was inserted into the tub then the Aerator run continuously to supply oxygen for the bacteria. Waste solution temperature during the process is maintained in the temperature range of 27-31 ºC. Afterwards, samples were taken every 12 hours to determine the COD, BOD, SS, and alpha activity in the solution.

RESULTS AND DISCUSSION

FIGURE 2 presents the results of the COD value during the process. The adaptation period is marked by a reduction in COD value quite drastically. This indicates that the rate of bacterial growth has begun. Samples were analyzed its COD value to estimate the rate of growth of bacteria in this biochemically sewage treatment process. When the bacteria are added to the waste, they would adapt to their environment until their feeling are quite able to grow and thrive.

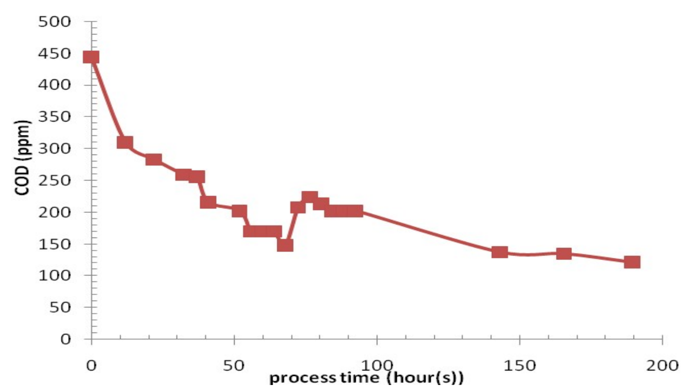


FIGURE 2. The COD value during the process time

The longer the time process, the COD value in the solution decreases. This is because the bacteria added in the solution have grown and developed so that the COD decrease. In the process, the impairment is the most significant COD during the process of 0-12 hours. The range of the adaptation period was still too long time. To know the exact of the adaptation time, it repeated at narrower intervals sampling, ie every hour.

FIGURE 3 presents the results of COD values with the time interval of 1 hour. Based on these data, a drastic reduction in COD value occurs in the range of 0.5-1 hours of the processing time. Thus, the actual bacterial adaptation period is for 0.5 hours. The results of this is quite short. This indicates that bacteria have adapted since they first put into the waste.

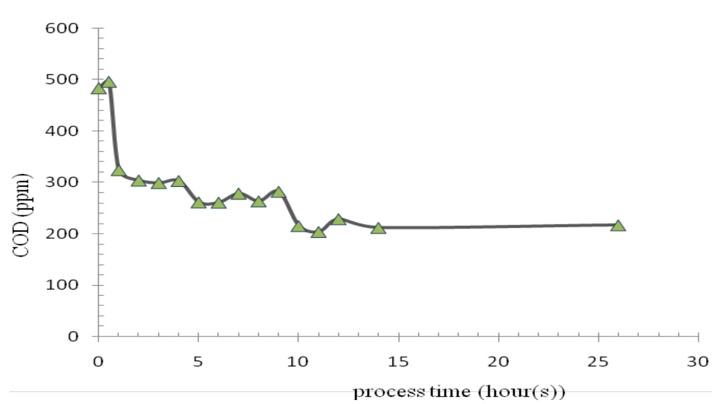


FIGURE 3 The relationship between the COD value of the process time

The time needed by the bacteria for the adaptation is quite short because the bacteria living media and wastes used were liquid phase so that it does not require a long time for the adaptation.

Relationship between COD and time

The relationship between the COD value of the process time is shown in FIGURE 4. which shows the value of COD as a function of processing time for the detergent concentration of 1.496 g/L. FIGURE 4 shows that the longer the time process, the COD value decreases. This is due to the decomposition by bacteria into CO_2 and new cell.

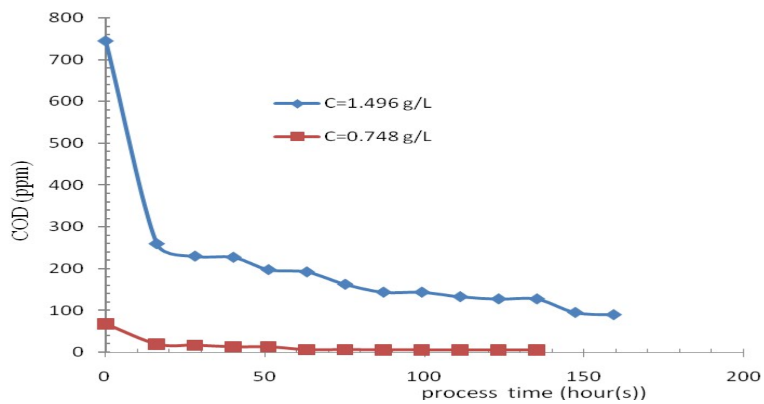


FIGURE 4 The relationship between the COD value

At the beginning of the process, the COD fell drastically which is followed by a longer form a hyperbole, and eventually, the COD reaches a constant value. The COD tends to have a constant value after 135 hours processing times. It is caused by bacterial growth rate which has reached equilibrium state because the growth rate and death rate of bacteria are in balance. That means, the number of bacteria in the waste is always the same. When the food supply in the wastes have been exhausted, then the death rate of bacteria will be greater than the rate of growth, until eventually all the bacteria in the sewage die.

The supernatant for the waste with initial detergent concentration of 0.748 g/L resulting shape of the curve is quite similar to the shape of the curve at wastewater treatment with a concentration of 1.496 g/L.

The COD value in the biochemical wastewater treatment containing detergent using SGB 103 bacteria follows the equation of COD = $472.4e^{-0.01t}$ when the detergent concentration is 1.496 g/L. Other result shows that the COD values are represented as the following model such as COD= $33.68e^{-0.01t}$ in a concentration of 0.748 g/L where COD is value of COD in the supernatant and t is the process time. The equation is a mathematical model of impairment COD in biochemical waste containing detergent which is processed using SGB 103 bacteria. Based on the equation, the rate law is is $-r_A$= 0.01COD ppm/hour and the value of the reaction rate constant, k, is 0.01hour^{-1}.

During the process, the amount of bacteria and nutrients added to both samples is the same. However, when compared to the waste with initial detergent concentration of 1.496 g/L, the result of the waste with initial detergent concentration of 0.748 g/L COD value is smaller. This is caused by the differences in the amount of COD that must be broken down by bacteria in the supernatant. If the detergent concentration in the supernatant 1.496 g/L, the COD to be processed is certainly higher than the detergent concentration 0.748 g/L. If the amount of bacteria is the same, the time needed by bacteria to decompose COD in the supernatant which has a smaller concentration of detergent will be shorter. Based on these facts, it can be concluded that the SGB 103 bacteria are more adaptable at lower concentrations waste eventhough without aeration.

Based on the Ministry of the Environment Rule No. Kep-51/MENLH/ 10/1995 on Liquid Waste Quality Standard for Industrial Activities, the requirement of the COD in the supernatant is less than 100 ppm. For wastewater treatment detergent biochemically by SGB 103 bacteria, this value is reached after processing for 147 hours at the initial concentration of detergent of 1.496 g/L and since the starting point of the process with time delay (storage) for 15 hours at a concentration of 0.748 g/L.

The Influence of Process Time to the BOD Value

The BOD values in the supernatant can be determined using the Winkler titration analysis of samples that should be kept in an incubator for 5 days. The analysis process requires considerable time. At the same sewage conditions, obtaining the value of BOD will be proportional to the BOD. Therefore, to determine the BOD value the correlation between the COD and the BOD was used.

The use of BOD value calculation by means of the correlation is a simplification analysis, because the analysis of COD only takes approximately 3 hours, whereas for a minimum of a 5-day BOD. In addition to the BOD tests are substances that are toxic to microorganisms that cause interference analysis.

Proportionality between COD and BOD values in solution has been shown in FIGURE 5 with the R^2 value of the graph is 0.999. Thus, the comparison between the BOD and COD can be used in determining the BOD values. Based on the average ratio values, a correlation of BOD = 0.47675 COD was obained. This correlation number is used as the reference value in calculation of the BOD on the characteristics of the processed waste.

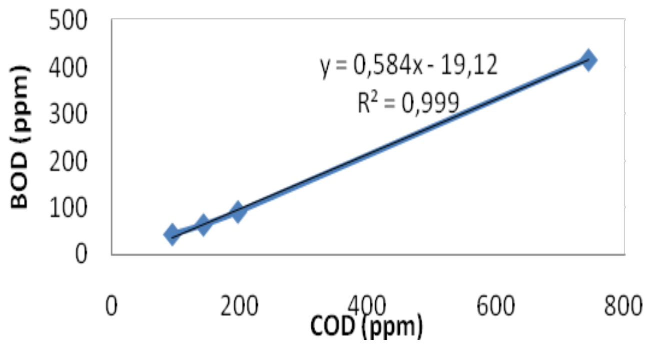


FIGURE 5. Relationship between the values of BOD and COD

FIGURE 6 shows the dependency of the BOD values on the processing time for the detergent concentration of 1.496 g/L. The graphs are the same as the shape of the curve on the graph COD value of the processing time in FIGURE 6. This is caused by the BOD value is obtained from the method of correlation between COD and BOD.

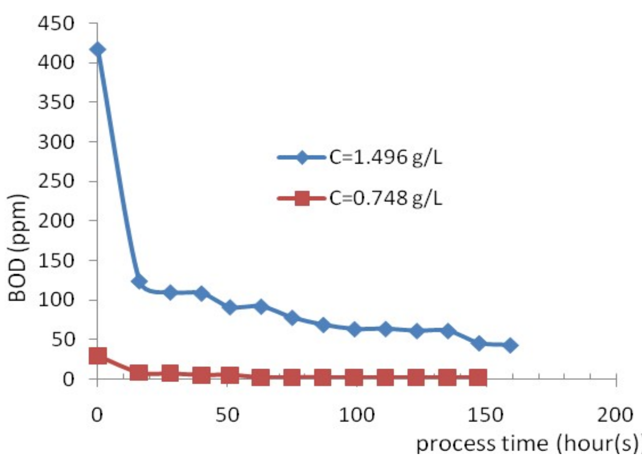


FIGURE 6. Dependency of BOD values on the processing time

The BOD values in the waste diminished exponentially with time due to the process of decomposition by the bacteria. A similar trend is obtained on the value of the BOD in wastewater treatment with the the detergent concentration of 0.748 g/L. The BOD values in the biochemical treatment of the liquid containing detergent of radioactive waste using SGB 103 bacteria are measured for two different detergent concentration such as 1.496 g/L for the fist sample and 0.748 g/L the other sample. Based on the curve fitting, BOD values for first sample with the detergent concentration of 1.496 g/L follows the exponential equation of BOD = $244{,}7e^{-0{,}01t}$ whereas the other sample with a concentration of 0.748 g/L can be represented as BOD = $14{,}44e^{-0{,}01t}$. where t in both equation is processing time. So that the value of the reaction rate constant k, is 0.01 $hour^{-1}$ and equation kinetic is -rA = 0.01BOD ppm/hour.

Based on the Liquid Waste Quality Standard for Industrial Activities from Ministry of the Environment No. Kep-51/MENLH/10/1995, the required maximum BOD value is 50 ppm. Under these requlation, the biochemical wastewater treatment proposed in this study that produced supernatant, should ensure that the waste to be disposed meet the quality standards required by government. Using the proposed biochemical treatment, liquid waste with the detergent concentration of 1.496 g / L a solution with 45.287 ppm BOD value was reached at 147 hours processing time.

Influence of Process Time to Suspended Solid (SS)

FIGURE 7 shows the relationship of the suspended solid in the liquid phase against the process time. The longer the process time, then the suspended solid contained in the solution decreases.

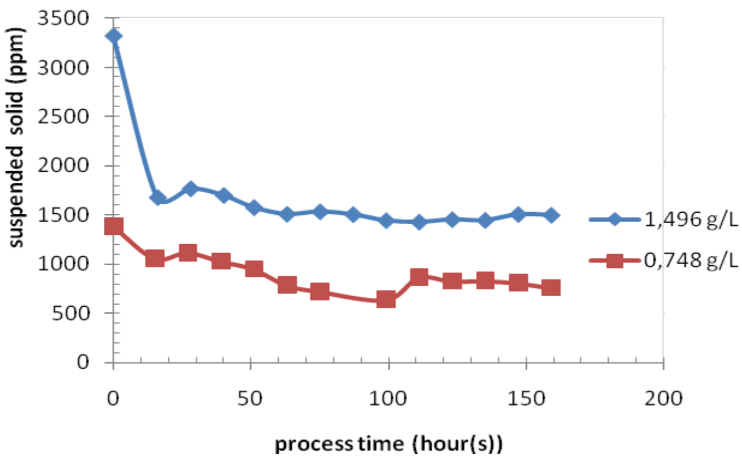


FIGURE 7. Relationship between suspended solid against the process time

The longer the time of decomposition of detergents in the waste increases, then more of biomass are formed. This resulted in amount of solid material contained in the waste either in the form of suspended solids or dissolved solids attracted by biological flocs formed from decomposition process by bacteria, forming larger flocs. The Flocs are then deposited by gravity and form sludge at the bottom of the tub. The more solids are deposited, so that total solid content in the waste decreases.

Influence of processing time on the alpha radioactivity in waste

Thorium is an alpha-emitting radioactive element that is a source of internal radiation that is extremely dangerous for the human when this radioactive element enters the human body. Therefore, the presence of thorium in the waste influences the process. Through a biochemical method using 103 SGB bacteria, the process occurs to decontaminate the thorium through biosorption mechanism. By measuring the alpha count of the solution, then results is presented in FIGURE 8.

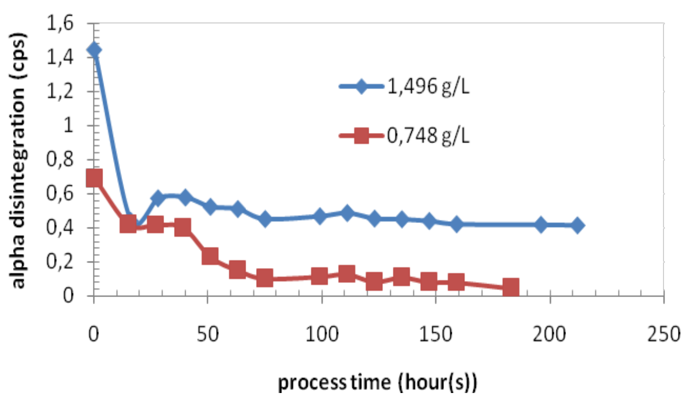


FIGURE 8. The relationship between alpha disintegration and the process time

In this study, the alpha activity is measured as disintegration or count per second (cps). FIGURE 8 shows that the longer the time of decomposition process is applied, the lower alpha activity in the solution was observed. This is caused by thorium in the waste solution has undergone adsorption by biological flocs generated during the waste decomposition by bacteria through biosorption mechanism.

Based on FIGURE 8, it can be concluded that when the alpha activity in the solution decreases, then the decontamination factor (DF) and separation efficiency (EP) increases significantly. The result of decontamination factors for biochemical process of the detergent with initial concentration of 0.748 g/L for 212 hours processing time using SGB 103 bacteria was 3.496 times, while for the initial concentration detergent of 0.748 g/L was 15.305 times for the process time for 183 hours. The results of separation efficiencies (SE) are 71.396% and 93.465%, respectively.

The results show that in the detergent concentration of 0.748 g/L the decontamination factor, DF and SE at a concentration greater than 1.496 g/L. This is caused by the bacteria will be more adaptable in the media that have a lower concentration of detergent.

Parameter in Bacterial Growth Kinetics

To determine the kinetics model that occured, the relationship between the substrate concentration (S) and the specific growth rate of the bacteria (μ) need to be investigated as is shown in FIGURE 9. The graph was made based on the analysis of the data on the waste treatment process with the initial detergent concentration of 1.496 g/L and 0.748 g/L. The relationship as shown in FIGURE 9, is in accordance with the Monod model's for bacterial growth. In this model, the specific growth rate of bacteria (μ) will be increased if the concentration of the substrate (S) increases. However, the specific growth rate would drop for the substrate concentration is too high to reach the maximum value (μm).

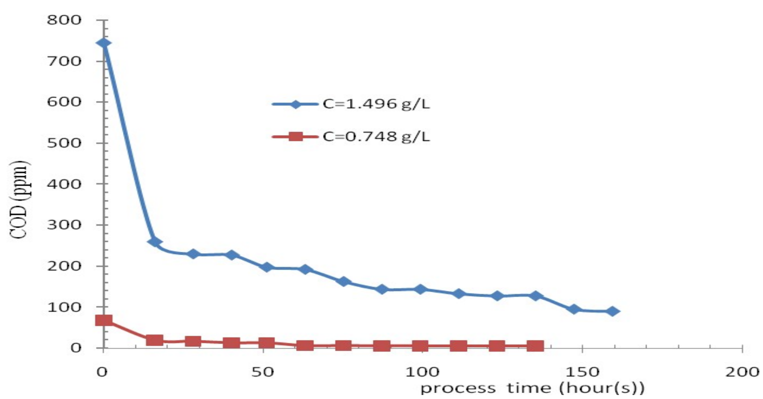


FIGURE 9. The relationship between the specific growth rate of bacteria to the substrate concentration

Monod equation describes the specific growth rate as a function of substrate concentration (S) according to equation (3). In the exponential phase, the rate of bacterial growth following the first order as differential equation in Equation (1). By integrating equation (1), the bacterial growth rate equation is obtained by plotting the relationship between ln X and t. The specific growth rate of bacteria (μ) is the intercept, which is -0.009/hour. The same calculation was done for the data obtained in the preliminary study and the detergent concentration of 0.748 g/L. The maximum biomass concentration (Xm) is determined by plotting the relationship between the 1- $(1/(e^{(\mu m t)}))$ to 1/X, the slope is the Xm. The specific growth rate (μ) and Xm value for liquid radioactive simulated waste treatment process containing detergent are presented in Table 1.

Table 1. Kinetics parameters of the bacterial growth

No.	Activity	Initial Detergent Concentration, g/L	μ (hour^{-1})	Xm (g/L)
1.	Preliminary experiments (no thorium)	1.496	-0.050	0.38
2.	activity of 5.10^{-5} Ci/m^3	1.496	-0.009	0.1562
3.	activity of 5.10^{-5} Ci/m^3	0.748	-0.014	4.42.10^{-3}

As it was shown in Table 1, the specific of bacterial growth rate (μ) is negative. The negative values indicate that the rate of decomposition of BOD by bacteria is more dominant than the growth rate of the bacteria. This was caused by the calculation of the number of bacteria (X) was not analyzed directly but rather is based on the results of measurements in the supernatant BOD value. The BOD values in waste diminished exponentially with processing time, so that as if the bacteria contained in the waste continues to decrease so that the growth rate is negative.

The maximum biomass concentration (Xm) is the maximum amount of biomass that can be grown in the waste media. The Xm value at the waste with initial detergent concentration of 0.748 g/L is less than at concentration of 1.496 g/L. This is caused by the availability of more substrate (food supply) in the supernatant with a detergent concentration of 1.496 g/L.

Other kinetics parameters that must be determined are the maximum specific growth rate of bacteria (µm) and saturation constant (Ks). Table 2 shows that in the same detergent concentration, specific growth rate of bacteria in waste no thorium was greater than in waste containing thorium. That is, the presence of radioactive elements in the waste can cause the SGB 103 bacterial growth rate become slower. This is possible because the alpha radiation emitted by thorium also affect the growth of bacteria. Alpha radiation is a strong ionizing radiation.. If the radionuclide ingested and gotten into the living body, alpha radiation will ionize tissue and cells, even cause cell death.

Table 2. The results of the bacterial growth kinetics

No	Activity	Initial detergent concentration, g/L	μ_{max} (/jam)	Ks (g/L)	Rate of bacteria growth
1.	Preliminary experiments (no thorium)	1.496	0.2	0.436	$\mu = 0.2\left(\frac{S}{0.436 + S}\right)$
2.	activity of 5.10^{-5} Ci/m^3	1.496	0.1579	0.5103	$\mu = 0.1579\left(\frac{S}{0.5103 + S}\right)$
3.	activity of 5.10^{-5} Ci/m^3	0.748	0.0418	0.0615	$\mu = 0.0418\left(\frac{S}{3.42 \times 10^{-3} + S}\right)$

At the lower concentrations of the detergent, specific growth rate is lower than the bacteria at higher detergents concentrations due to the amount of substrate that can be used as its food. In the same amount, the rate of bacterial growth will be faster when they present in a live media that provides more substrate. The Ks is the saturation constant at the substrate concentration at, µ of ½ µm.

CONCLUSIONS

Based on the research, it could be concluded as follows:

1) liquid radioactive waste containing detergents and thorium can be processed biochemically using SGB 103 bacteria.
2) Through a biochemical treatment processes by bacteria SGB 103, COD, BOD, and SS generated in the supernatant decrease to ensure the quality standard.
3) The kinetics of bacterial growth follow Monod's law.
4) The decreasing of COD and BOD were first order with the rate constant of 0.01 hour^{-1}.

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