Environment and Ecology Research 11(6): 973-978, 2023 http://www.hrpub.org
DOI: 10.13189/eer.2023.110608

Utilisation of Ruminant Waste Microorganisms in a Simple Co-Composting Method in Bioremediation of Used Oil Contaminated Soil

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Received August 21, 2023; Revised October 27, 2023; Accepted November 20, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Ivone Wulandari Budiharto, Surya Kusuma Wijaya, Dwi Budiono, Citra Buana Sari , "Utilisation of Ruminant Waste Microorganisms in a Simple Co-Composting Method in Bioremediation of Used Oil Contaminated Soil," Environment and Ecology Research, Vol. 11, No. 6, pp. 973 - 978, 2023. DOI: 10.13189/eer.2023.110608.*

(b): *Ivone Wulandari Budiharto, Surya Kusuma Wijaya, Dwi Budiono, Citra Buana Sari (2023). Utilisation of Ruminant Waste Microorganisms in a Simple Co-Composting Method in Bioremediation of Used Oil Contaminated Soil. Environment and Ecology Research, 11(6), 973 - 978. DOI: 10.13189/eer.2023.110608.*

Abstract The increase in vehicle ownership is directly proportional to the increase of lubricant oil usage (used oil) which has an impact on the environment. The purpose of the study was to determine the ability of the co-composting method to reduce the content of pollutants in soil contaminated with used oil by adding organic waste with ruminant livestock waste which contains many microorganisms. The used method for co-composting is a laboratory-scale rotary aerobic composter for 10 days of treatment with treatment components of 500ml used oil lubricant polluted soil, 1kg leaf litter, 2kg ruminant waste and 150ml agricultural EM4. The measured parameters were temperature, colour, texture, pH, humidity, Total Petroleum Hydrocarbon (TPH) and red spinach plants. The results showed that there were changes in the test parameters during the 10 days of treatment. The results of the T test data analysis showed that the application of compost fertilizer from the remediation results had a very significant effect on temperature, pH, humidity and a significant effect on the number of leaves due to the content of nitrogen (N) in compost that stimulates the formation of stems, roots and leaves. Isolated and identified microorganisms that consist of 14 bacterial isolates derived from ruminant livestock manure Application of microorganisms and EM4 bioactivator influenced the degradation of pollutants. The longer the composting process, the higher the percentage of TPH degradation.

Keywords Composting, Contaminated Soil, Parameters

1. Introduction

Currently, the automotive industry is growing very rapidly, characterised by the large number of motor vehicles. Increase in vehicle ownership is directly proportional to the increase in lubricant oil usage (used oil) (Azharuddin et al, 2020). The continuous utilisation of oil results in a massive amount of used oil waste (Buana et al, 2021).

Most components of petroleum waste contain total petroleum hydrocarbons (TPH) which are reactive, mutagenic and toxic, and are included in dangerous waste (B3 waste). TPH is a hydrophobic compound with low water solubility, making it easy to bind with toxic solid organic particles. These toxic substances accumulate in the environment, requiring human intervention and existing technology to resolve this pollution (Dewi et al, 2023).

The basic concept of bioremediation is to recover all organic matter using the biological activity of microorganisms, nutrients, electron donors and acceptors, which contribute to the hydrocarbon degradation (Latif et al, 2022). One of the bioremediation techniques used to remediate the used lubricant oil contaminated soil is combined composting. Combined composting is an application of more than one raw material to control aerobic degradation of organic matter. Hydrocarbon microbial activity is stimulated by mixing contaminated soil with biodegradable organic matter as nutrients (Setianingsih and Titah, 2020).

Microorganisms from livestock manure can help the composting process. Livestock manure contains nutrients such as nitrogen, potassium and phosphorus that provide nutrients for bacteria to break down terrestrial hydrocarbons that are contaminated with oil waste, and can accelerate the composting process and eliminate existing odours (Ratriyanto et al, 2019). The results of Setianingsih and Titah (2020) research in 2014 showed that co-composting of polluted soil and organic materials successfully reduced total petroleum hydrocarbons (TPH) down to 77.3%.

Therefore, this study will apply the composting method of mixed fermentation of ruminant waste liquid and leaf litter with the addition of microorganisms using a rotary aerobic composter to remediate used oil contaminated soil. The research objective is to see the success of the co-composting method in remediating used oil contaminated soil.

2. Materials and Methods

2.1. Ruminant Waste Fermentation

The first step of the research was to ferment ruminant waste for 7 days. Ruminant waste comes from 2.5 kg of cow manure, 2.5 kg of sheep manure and given water up to 30 liters. The fermented liquid is used as research material to assist in the composting process of leaf organic waste (Figure 1).

Figure 1. Rotary Aerob Composter

2.2. Research Design

2.2.1. Manufacture of Rotary Aerob Composter

The components of making a rotary aerobic composter are a supporting iron frame with dimensions of 90 x 50 x 60 cm. A composter barrel that has been designed with a composter door with a size 30x15 cm, a crusher with a size of 40 cm, and 8 holes for air circulation (aerobic). The barrel that has been installed on the supporting frame is added with a lever for compost stirrer and installed on the right side of the barrel (Figure 1).

2.2.2. Rotary Aerob Composter Testing in Composting

The research stages of the co-composting method were carried out by mixing 1.95 kg soil, 500 mL used oil waste, 1 kg leaf waste, 30 liters of ruminant waste fermented liquid and 150 ml agricultural EM4 bioactivator in a rotary aerobic composter barrel for 10 days. The barrel was rotated twice a day for 10 minutes as a stirring process for composting. After 10 days, compost characteristics were tested, namely temperature using a soil thermometer, color and texture as well as chemical parameters of pH and moisture using a soil moisture meter.

2.2.3. Application of Compost on Red Spinach Plants

The remediated compost was measured for physical parameters, including temperature, humidity, colour and texture, and chemical parameters, namely pH, according to the quality characteristics of compost based on SNI-19-7030-2004. Compost that has been matched with compost quality characteristics is applied as a planting medium for red spinach seeds. Observation of red spinach plant growth was carried out for 4 times within 7 days with parameters observed including temperature, humidity, pH, number of plants growing and maximum number of leaves.

2.3. Bacterial Isolation and Identification Test

The composted soil was subjected to bacterial isolation and identification. Tests were carried out by observing macroscopic characteristics, biochemical tests and gram staining of bacteria. Identification of bacteria uses the Cowan and Steel method, 1974 with Bergey's Manual of Systematic Bacteriology (Fierdaus, 2015).

2.4. Research Parameter Test

Observations of pH, temperature, and moisture parameters were conducted every 3 days and TPH parameters were observed at the beginning and at the end of the co-composting process. Measurement of temperature parameters uses a soil thermometer, pH and moisture chemical parameters use a soil moisture meter.

2.5. Contaminated Soil Characteristic Test

Characteristic tests of contaminated soil with used oil waste were conducted at the beginning before treatment. Parameters used for the characteristic test are pH, temperature, and TPH.

Table 1. Early characteristics of contaminated soil with used oil

Parameter	Unit	Contaminated soil
pH	-	6,8
Temperature	^{0}C	30
TPH	%	6.05

2.6. Total Petroleum Hydrocarbon (TPH) Content Test

The gravimetric method (Yahya, 2019) was used to measure the elimination rate of TPH levels in contaminated soil. Samples of contaminated soil from the treatment were weighed as a 5 gram mixture with 10 mL of n-Hexan and then shaken at high speed. After that, it was filtered using filter paper. The residue was discarded while the filtrate was collected. The filtrate was added with 2.5 grams of NaSo4 hydrate then stirred for 10 minutes then filtered and discarded the residue, while the resulting filtrate was put into a porcelain cup that had been weighed early. The next step, the filtrate was heated in an oven at 105 ^{0}C for 1 hour and put into a desiccator. The residue in the cup was weighed and recorded. Heating was done again until a constant weight was obtained. Calculation and data analysis of the calculation of the percentage of TPH use the equation formula

$$\boldsymbol{TPH}(\%) = \frac{Residu\ \ weight\ \ (gram)}{Sample\ \ weight\ \ (gram)} \times 100\%$$

2.7. Data Analysis

Data analysis was carried out using software Statistical Products and Solution Services (SPSS) to test independent T-tests (Uji-T) to see the Effect of Compost Application of Used Oil Polluted Soil Remediation Results on the Growth of Red Spinach Plants (*Amaranthus Tricolor* L.).

3. Result and Discussion

Co-composting is one of the alternative solutions in the utilisation of automotive waste. Co-composting from used oil contaminated soil with biodegradable organic waste as nutrient can stimulate the growth of indigenous bacteria to degrade the pollutant compounds.

3.1. Bacterial Identification Result

Based on the results of isolation and identification of bacteria using the Cowan and Steel method with Bergey's Manual of Systematic Bacteriology on used oil polluted soil in used oil polluted soil, results of composting after 10 days showed the presence of as many as 14 isolates namely *Bacillus* sp., *Lactobacillus* sp., *Escherichia* sp., *Nitrococcus* sp., *Pseudomonas* sp., *Leuconostoc* sp., *Nitrosomonas* sp. *Staphylococcus* sp. *Proteus* sp., *Streptococcus* sp. *Clostridium* sp. *Staphylococcus* sp. *Shigella* sp., *Citrobacter* sp., *Enterococcus* sp.

Microbes consumed hydrocarbons as a carbon source to produce the energy that they need to survive and release metabolites into the medium, which can be CO_2 gas, H_2O, biomass. The released CO_2 gas would react with H_2O and produce acid (H+), which decreased the pH. Increased bacterial activity to degrade hydrocarbons also increases the production of organic acids. This causes the pH to drop. The application of different bacterial strains will affect different in pH values. This is because each type of bacteria produces a different type of organic acid. (Kadarwati et al., 2008).

3.2. Temperature Parameter

During the co-composting process, the supporting factors were measured and analysed periodically for 10 days of observation (Figure 2).

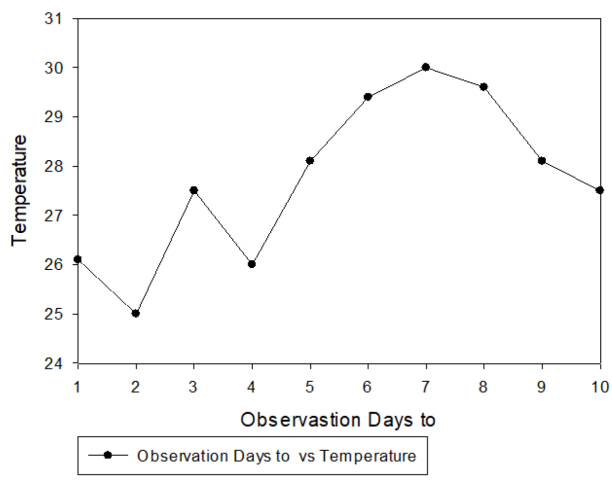

Figure 2. Temperature changes during co-composting

The temperature during the co-composting process (Figure 2) was between 25-30℃ with an average temperature at 27.73℃. This temperature range is categorized as mesophilic conditions (20-45℃) and has fulfilled the characteristics of compost quality (Siagian et al, 2021). The increase in temperature on observation days 3, 5, 6 and 7 indicates that the toxicity degradation process of pollutant compounds is running optimally, while the decrease in temperature on observation days 2,3,8 and 10 is caused by the decrease in biodegradation activity by microorganisms due to the shrinkage of organic matter that decomposed in the compost (Larasati and Puspikawati, 2019).

Humidity during co-composting ranged from 40-55%, with an average humidity at 49.6% (Figure 3). During the co-composting process, the moisture content decreased due to evaporation so that microbial activity in the degradation process decreased. Compost moisture has fulfilled the quality characteristics of compost with a moisture content of 41%.

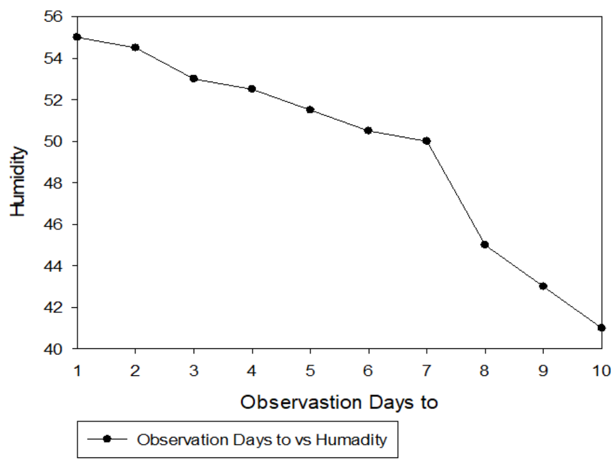

Figure 3. Humidity changes during co-composting

3.3. pH Parameter

During the co-composting process, the pH in the composter ranged from 7-8 with an average pH of 7.3 (Figure 4.) Microbial activity is optimum with at pH of 5.5 - 8. The results of the study during the co-composting process showed fluctuations in pH value. Increasing pH value indicated an increase in microorganism activity and NH_3 production (Siagian S, 2021), while decreasing pH value was caused by nitrate formation as a result of H+ release during microbial nitrification. The pH value of the remediated compost has fulfilled the quality characteristics of compost with a pH range between 6.8-7.49 (Figure 4).

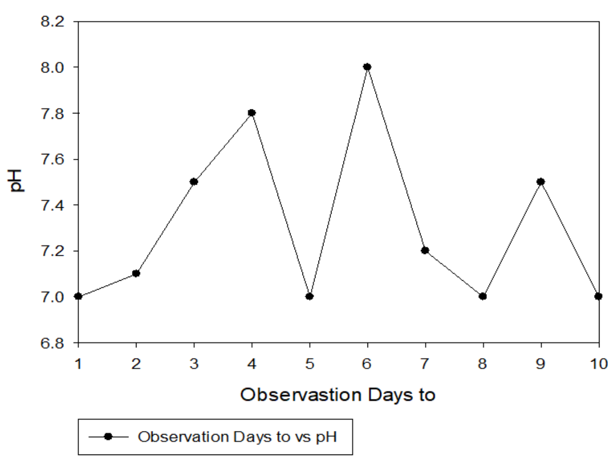

Figure 4. pH changes during co-composting

3.4. Colour, Texture and Odour Parameters

Colour, texture and odour parameters of the compost were observed based on the research results. Colour of the remediated compost changed from blackish brown to black. Changes in compost color at the end of the observation indicate the maturity level of the compost. Changes in compost color are caused by microorganisms that can decompose organic matter well. The soil texture of the compost has changed to become loose.

Loose soil will increase soil pores which will cause plant roots to grow and develop easily. The content of organic matter will make the soil become loose so that the development of plant roots is more optimal (Widodo and Kusuma, 2018). The odour of the remediated compost changes from the dominant odour of soil, oil, and EM-4 to the dominant odor of soil. Colour, odour and texture parameters in the remediated compost have fulfilled the quality characteristics of compost based on SNI 19-7030-2004 with blackish colour, loose soil texture, and dominant soil odour.

The results of Remediation of Used Oil Contaminated Soil with a dose of 850 gr affect the growth of Red Spinach Plants in terms of the number of plants and the average number of leaves that grow.

3.5. Compost Application Effect of Used Oil Contaminated Soil Remediation Results toward Red Spinach Plants (*Amaranthus Tricolor* L.) Growth

Red spinach productivity can increase if it is planted on land conditions that contain organic matter and high availability of nitrogen nutrients. Research results of Fatmawati et al. (2021), explained the optimum temperature, humidity and pH requirements for the growth of red spinach plants, specifically having an average temperature of 29.96 ^{0}C, humidity of 83.64% and pH ranging from 6-7. Based on the results of the research with the treatment, the average pH value was 6.975, temperature 28.95 ^{0}C and humidity 81.25%.

This represents that the application of compost has temperature, pH and humidity characteristics that are suitable to support the productivity of red spinach plant growth. The physical and chemical variables observed in the planting media towards red spinach plant growth are presented in Table 2. Compost from soil remediation with 850 grams of application rate contains nutrients that are suitable for red spinach growth. The results of the T test data analysis showed that the application of compost fertilizer from the remediation results had a very significant effect on temperature, pH, humidity and a significant effect on the number of leaves due to the content of nitrogen (N) in compost that stimulates the formation of stems, roots and leaves (Rangkuti *et al.* 2017).

Table 2. T Test Analysis Result

Parameter	With Treatment	Without Treatment
Temperature (^{0}C)	29,7±0,2	30±0,2
P-Value		0,001**
pH	6,9±0,5	7,7±0,08
P-Value		0,001**
Humidity (%)	81,8±0,6	62,5±3,6
P-Value		0,001**
Number of Plant	63,6±2,5	53,6±3,5
P-Value		0,16
Number of leaf	4,3±0,5	2±0,001
P-Value		0,02*

*the mark indicates that the treatment of EM4 has a significant effect compared to the control (p-value <0.05), **the mark indicates that the treatment of EM4 has a very significant effect compared to the control (p-value <0.01).

3.6. Total Petroleum Hydrocarbon (TPH) Level

The TPH levels produced during the co-composting process differed daily. TPH levels on the 1st day were the highest while TPH levels on the 10th day were the lowest. This showed that the removal of TPH levels by hydrocarbonoclastic microorganisms in co-composting began on day 4 (Figure 5). Decrease in TPH levels occurred due to the decomposition process that occurred during the composting process by microorganisms. Isolated and identified microorganisms consist of 14 bacterial isolates derived from ruminant livestock manure and the combination of agricultural EM4 bioactivator began to degrade TPH into simpler organic acids and organic waste acted as additional nutrients to help accelerate the activity of microorganisms in decomposing organic matter including degrading TPH (Yahya, 2019).

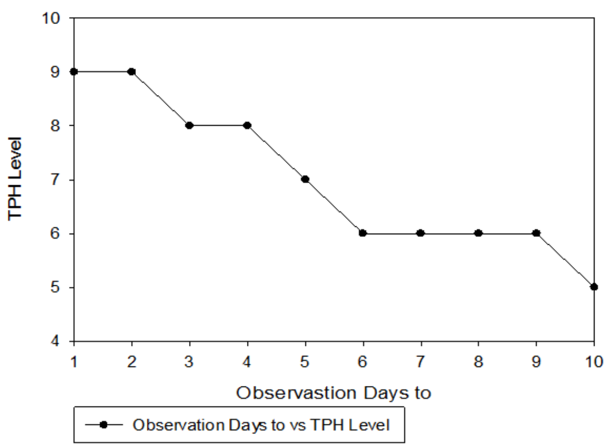

Figure 5. TPH level changes during co-composting

4. Conclusions

Co-composting process in used oil contaminated soil remediation has fulfilled the quality characteristics of compost according to SNI 19-7030-2004 in terms of the parameters of average temperature 27.73 ℃, pH 7.31, humidity 49.6%, blackish colour, loamy texture (loose) and dominant odour of soil and Total Petroleum Hydrocarbon (TPH). Used oil contaminated soil remediation with the composition of litter compost and ruminant livestock manure uses a rotary aerobic composter that has good organic material characteristics in degrading toxicity of oil contaminated soil pollutant compounds and application of compost.

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