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ASSESSMENT OF WASTE CHARACTERISTICS AND POTENTIAL RESOURCE RECOVERY AT THE PIYUNGAN: A STUDY BASED ON LANDFILL AGE

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ABSTRACT: Landfills play a crucial role in waste management, but the age of a landfill can have a substantial effect on the composition and characteristics of the waste contained within it. This study seeks to examine the waste characteristics, including microbes, at the Piyungan landfill in Yogyakarta, Indonesia, using the landfill's age as a determinant. The research methodology is exhaustive, incorporating both qualitative and quantitative analyses. A representative sampling method is used to collect waste samples from various sections of the landfill, taking into account the varying ages of the waste. 0–6 months, 1–2 years, 3–4 years, and >5 years are used to determine location points based on the age variation of the garbage pile. Using techniques such as physical separation, chemical analysis, and microbe characterization, the collected samples are then classified and analyzed. Based on the age of the landfill, the analysis reveals dynamic variations in waste characteristics. Mixed methods in landfill operations affected the characteristics of waste. The results highlight the importance of proper waste management strategies that evolve with the changing composition of waste and microbe characteristics over time. Effective waste segregation, recycling, and resource recovery initiatives can be implemented to minimize the environmental impact of landfills and maximize resource utilization. In conclusion, this study emphasizes the significance of considering the age of a landfill when assessing waste characteristics. By understanding how waste evolves over time within landfills, sustainable waste management practices can be implemented, leading to reduced environmental impact and improved resource efficiency.

Keywords: Landfill, Resource, Waste Age, Waste Characteristics

1. INTRODUCTION

Landfills are critical waste management facilities that have become an integral part of modern society's waste disposal practices. However, conventional landfilling methods have led to significant environmental and social concerns, prompting the exploration of alternative approaches that focus on resource recovery from waste.

Then, waste characterization entails assessing the physical, chemical, and biological attributes of waste, which is crucial for comprehending its makeup and identifying the most efficient techniques for recovering resources. Previous studies examined important technologies such as the analysis of physical and chemical properties of foundry wastes, geophysical approaches, and trenching techniques employed in the recovery of resources from landfills [1]. Other study emphasized the importance of source separation and mechanical-biological treatment in waste recovery methods. These techniques are used to separate biodegradable recovery fractions from the reject fraction, which is then sent to landfills [2].

Resource recovery strategies involve methods such as recycling materials, generating energy from waste, and producing products with added value. Previous studies showcased the utilization of integrated biological techniques and innovative technology to extract resources and energy from food waste in landfills [3]. Past studies examined various techniques employed in the reduction and extraction of landfill gas, including revegetation technologies, methane oxidation, and anaerobic digestion [4].

This paper presents an assessment of waste characteristics and potential resource recovery at the Piyungan Landfill in Yogyakarta, utilizing the landfill's age as a key parameter in the study.

Waste management practices in the Piyungan Landfill have a direct impact on the surrounding environment and public health. The efficient utilization of waste resources is crucial to minimize the environmental burden and maximize the economic benefits associated with waste disposal. To address these challenges, this study examines the composition and properties of the waste stream at the Piyungan Landfill and investigates how these characteristics evolve with the landfill's age.

To provide a comprehensive analysis, this study draws on the knowledge and insights gained from previous research in the field. The previous research have shed light on waste characterization techniques, resource recovery methods, and landfill aging processes [5–7]. These contributions form the foundation of our study and help us understand the context and relevance of our assessment at the Piyungan Landfill.

Waste characterization involves evaluating the physical, chemical, and biological properties of the waste stream. The analysis provides valuable insights into waste composition, moisture content, organic content, and other relevant parameters. By collecting samples from different zones within the landfill, representing varying ages of waste deposition, we can track the changes in waste characteristics over time.

Furthermore, this assessment aims to identify potential resource recovery opportunities at the Piyungan Landfill. Resource recovery techniques encompass a wide range of practices, including material recycling, energy generation from waste, and the production of value-added products. The findings of this study will contribute to the development of sustainable waste management strategies that prioritize resource recovery and minimize the environmental impact of waste disposal.

In conclusion, this paper presents an assessment of waste characteristics and potential resource recovery at the Piyungan Landfill in Yogyakarta. By considering the landfill's age as a critical parameter, this study aims to provide insights into waste evolution, decomposition rates, and opportunities for sustainable waste management. The research builds upon the foundations laid by previous works, and the findings will contribute to the development of effective waste management strategies at the Piyungan Landfill and serve as a valuable reference for similar landfill sites in other regions.

2. RESEARCH SIGNIFICANCE

The significance of this research lies in its contribution to sustainable waste management practices and resource recovery at the site. By assessing waste characteristics and potential resource recovery opportunities based on landfill age, this study addresses several important aspects:

1. Environmental Impact: Understanding the composition and properties of the waste stream enables the identification of potential environmental risks associated with landfilling.
2. Resource Recovery Potential: The assessment of resource recovery opportunities is crucial for maximizing the value obtained from waste.
3. Policy and Planning: The results of this study can guide the development of waste management policies and planning strategies in Yogyakarta and similar regions.

3. MATERIALS AND METHODS

3.1 Location

Waste sampling was carried out in the Piyungan landfill area with coordinates 7° 52' 10.475" S 110° 25' 47.856" E. The analysis of particle size distribution testing was carried out at the Environmental Quality Laboratory, Environmental Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia. Sampling takes place in the morning until noon when the weather is hot. The samples analyzed were piles of waste at the Piyungan landfill with 4 points of collection. Determination of this sampling point is based on consideration of the desired age of the waste pile. The age of the waste is obtained from tracking the time records of waste placement and information from the manager. In addition to these considerations, the selection of this sample point also pays attention to the ease of sampling. Based on the results of these considerations, the sampling points obtained are as shown in Fig. 1.

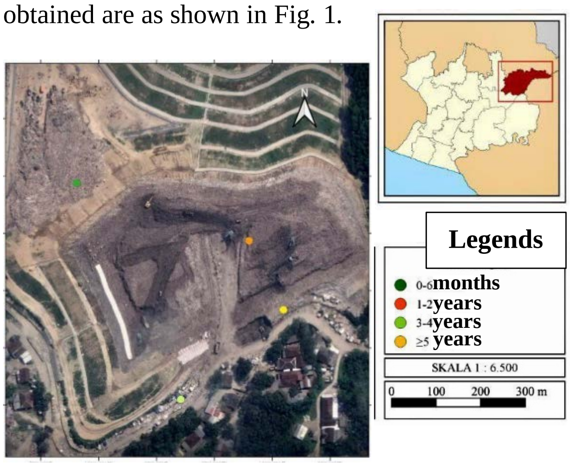

Fig.1 Landfill and sampling location

3.2 Sample Preparation and Laboratory Analysis

Sampling (waste) was carried out at landfill Piyungan Yogyakarta. Test sampling was carried out at 4 collection points based on the age of the waste, namely ≤ 6 months, 1–2 years, 3–4 years, ≥ 5 years in Piyungan Landfill, Yogyakarta. Garbage collection is carried out using a shovel and hoe to dig up the waste pile. Waste samples that have been taken and stored in storage boxes are then tested for samples at the Environmental Quality Laboratory, Environmental Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

This sample treatment is carried out so that the condition of the sample is still in accordance with its characteristics, then the waste that has been taken is put into the box. Furthermore, the waste that has been selected based on the age of the waste will be put into a ± 5 kg plastic clip and labeled with a name that matches the age so that the waste does not mix with other waste.

Testing the shape of the particles using SEM aims to see the shape and gradation of the grains that occur. This can be a comparison of the shape of the grain gradation of each variation in the age of the waste. This observation was carried out after the sieving was completed.

3.3 Specific Gravity (Density)

The specific gravity test will be known after getting the weight and volume of the waste. To find out the weight of the waste is done by weighing the measuring box containing the waste sample with a scale. The volume of waste is calculated by placing the waste in a measuring box and then stamping it 3 times; after that, the waste will be measured in length, width, and height in the box. The specific gravity test refers to SNI 19-3964-1994 about Methods for collecting and measuring samples of urban waste generation and composition.

3.4 Moisture Content

The water content was tested using a porcelain cup as a sample container. The cup is dried in the oven at 103–105 °C for 1 hour. Then, cool the cup in a desiccator and weigh the cup before use. Then, the sample is placed in a cup with a sample weight between 50 and 100 g and put in the oven at a temperature of 103 to 105 °C for 2 hours. Furthermore, the sample will be put into the desiccator and weighed again until the weight remains constant. This process contains material that is lost after the heating process, which is called the amount of water contained in the waste sample. Moisture content test based on Standard Method 2540 B regarding total solids dried.

3.5 Levels of Volatile (Volatile Matter)

Testing for volatile content is based on Standard Method 2540 E concerning laboratory testing procedures for fixed and volatile solids. The test sample that has been dried during the water content test will be reheated using a furnace with a temperature of 550–600 °C for 2 hours. After that, the sample is put into the desiccator and then weighed.

3.6 Ash Content and Fixed Carbon

Ash content testing was based on ASTM E 830-87 (2004) about the Standard Test Method for Ash in the Analysis Sample of Refuse-Derived Fuel standard test methods for ash content in fuel analysis samples originating waste. Heat the remaining samples from the volatile content test. The sample was heated in the furnace at 950 °C for 7 minutes. So, the ash content is expressed as a percent ratio by weight remaining after heating. Then in testing the fixed carbon content, it will leave carbon elements in the form of solids that are left in the sample.

3.7 Microbial Aspect

Media preparation begins with the preparation of the necessary tools and materials. The media prepared for this study were Bacto Agar media and several media for biochemical testing. Each medium is weighed as needed, put into an Erlenmeyer flask, added distilled water according to calculations, homogenized, and heated on a hot plate chain. Next, the Erlenmeyer with the mouth closed with cotton, coated with aluminum foil, and then carried out sterilization.

Preparation of Agar media begins with preparing 0.65 grams of Nutrient Broth liquid media and adding 50 ml of distilled water. Then, take as much as 2.5 ml and add sterile distilled water to 250 ml. Then as much as 5 grams of Bacto Agar is added to the nutrient broth liquid medium.

Then, the Erlenmeyer was closed using cotton and aluminum foil. After that, the media was sterilized using an autoclave. The sterilized solid media is then poured into a petri dish (at ± 50 ºC). 1 mL of each sample was dissolved in sterile distilled water in a test tube, carried out by dilution up to 8x, then planted in NA media (Nutrient Agar) using the pouring method (pour plate) to test the ability of isolates to grow in an environment containing an alkaline source. Then, it is incubated at 30 °C for 2 weeks so that the bacteria grows optimally. Then, 1 ml of the sample that was already in the 10-1 test tube was taken and homogenized into the 10-8 test tube containing 9 ml of distilled water.

Dilution was carried out until it reached a 10-8 dilution test tube. Then, the diluted sample from the test tube labeled 10-5 to 10-8 was put into each petri dish labeled 10-5 to 10-8. Then, the petri dishes were incubated in an incubator at 30 °C. Bacterial colonies growing in the petri dish were transferred to a test tube containing slanted NA solid media. A glass slide that has been sterilized by rotating it 3-4 times over a Bunsen flame and isolated aseptically using an ose needle and placed on a slide.

After that, the isolate was treated with crystal violet for 1 minute and washed using running water, and waited for it to dry. Drop Iodine on the isolate in the slide, leave it for 1 minute, and wash it with running water. Then drop 96% alcohol for 20–30 seconds, then drain the water and let it dry.

Furthermore, the same thing was done, but the isolate was dripped using safranin and dried using drying paper. Furthermore, isolates were observed using a microscope with a magnification of 1000 times [8]. A microscope is an instrument for viewing and determining the morphology of solid or compound surface colonies.

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3.8 Fungal Aspect

The medium used as a place for mushroom growth in this study was Malt Extract Agar (MEA). MEA is commonly used in the isolation of yeast and molds from clinical samples and various environmental sources. In 1926, Thom and Church recommended MEA in the growth of molds and yeast because it contains carbon, protein, and other sources of nutrients [9]. The composition of MEA is 48 grams for 1 liter. In this study, 250 ml of distilled water was used so that the required MEA was 12 grams. The media solution is then stirred using a magnetic stirrer until homogeneous. After that, the media is poured into the petri dish until it covers the entire surface of the petri dish, which is done in Laminar Air Flow (LAF) to avoid contamination, then wait for it to cool.

Samples were taken, weighing 5 grams from each point, and then homogenized with 45 ml of distilled water into a 50 ml Erlenmeyer. Then 1 ml of the sample was taken to be homogenized in sterile distilled water in a test tube in the LAF. Samples are taken every 1 ml. Then the process was repeated until the 10-8 dilution. Samples were treated using the pour plate method as much as 1 ml (dilution concentrations of 10-5 to 10-8 were taken) on a petri dish using a micropipette, then MEA media was poured until the surface of the petri dish was completely covered. The incubation process was carried out at 25 °C for 14 days.

Mushroom macroscopic identification was carried out in several stages such as looking at the shape on the top and bottom surfaces of the fungus, in addition to that, observations were also made on the colony in terms of size, shape of the edges, texture on the surface of the colony, as well as the radical line measured from the center to the edge of the colony, in addition to the appearance circle of concentrations, patterns of fungal growth and the presence of exudate drops in the mushrooms [10].

The medium used for mushroom culturing is Malt Extract Agar (MEA). Add approximately 15 ml per petri dish, then dry for about 30 minutes in Laminar Air Flow (LAF). Inoculate 1 ml of the dilution and spread it over the agar, then inoculate the petri dish upside down at room temperature for 5 days. After growing, the colonies were counted using a colony counter.

4. RESULT AND DISCUSSION

4.1 Analysis of Waste Composition at Various Ages

Before the waste samples from the Piyungan Landfill are tested, the composition of the waste is sorted first. The composition of waste is a depiction of each component contained in solid waste and its distribution, usually expressed in percent by weight. Sorting the composition of the waste sample is done by taking the amount of waste ± 10 kg and then sorting between organic and inorganic waste taken from the Piyungan Landfill with different age variations of the waste and then weighing each composition. The results of the analysis of waste composition at various ages can be seen in Fig. 2: The waste from 0 months–to 2 years is the waste from a controlled landfill that is well-managed and covered by soil for a week to 3 months. Meanwhile, the waste of>3 years is mostly from open dumping sites. It is due to Piyungan Landfill site has mixed method for dispose the waste. Phase 1 is open dumping methods, and the last phase is controlled landfill method.

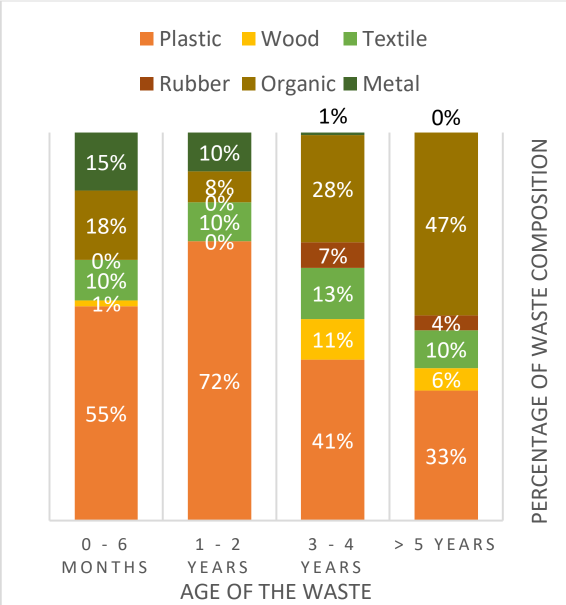

Fig.2 Waste composition based on the age

4.2 Density and Proximate Analysis of the Waste at Various Ages

Analysis of the specific gravity of the 4 age categories (see Fig. 3) of waste results in that the longer the age of the buried waste, the higher the weight of the trash. The results of the specific gravity of waste at the age of 0-6months, 1–2 years, 3–4 years, and > 5 years in a row of 458.85, 380.92, 433.64, and 486.64 kg/m^3.

Waste management at the Piyungan landfill uses a controlled system landfill. The most common waste components in landfills are plastic waste and organic, compared to iron and rubber waste components are found in new and old waste piles. The biggest composition of waste at the age of 0–6 months is plastic waste, 55%; aged 1–2 years, plastic waste, 72%; aged 3–4 years, waste plastic 41%; and aged > 5 years, organic waste, 47%.

Analysis of the physical characteristics of waste in the form of water content, volatile content, content ash, and fixed carbon (see Fig. 4). The percentage value of water content decreases the older the garbage. Volatile content percentage value decreased in percentage value with age; however, at the age < 5 years, it increased. Ash content percentage value decreased with age. The percentage value of carbon still increases because it will be inversely proportional to volatile value. So, it has moderate potency for RDF plants.

Fig.3 Density of the waste

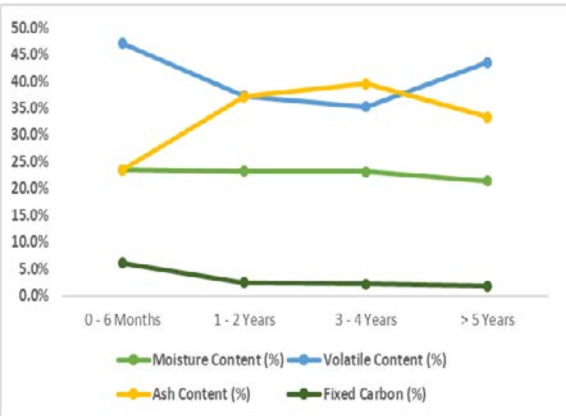

Fig.4 Physical characteristic of the waste

4.3 Waste Morphology Analysis

Scanning Electron Microscope (SEM) is a type of microscope that uses an electron beam to describe the surface profile of objects. The electron beam in SEM is fired at the surface of an object and passes through several electromagnetic lenses so that the beam will bounce back or generate secondary electrons in all directions. But there is one direction where the beam is reflected with the highest intensity. The detector contained in the SEM will detect electrons and determine the location of objects on the screen. SEM testing is carried out to see the surface pattern or description of a sample. From these tests, an overview of the surface pores in each sample of waste age can be seen in Fig. 5 and Fig. 6 with magnifications of 410x and 1500x.

From the data from the SEM (Scanning Electron Microscopy) photo test results, it can be seen the surface shape of the particles in samples from various age variations of the waste. In Fig. 5 and Fig. 6, the surface shape of the particles resulting from the sieving process with variations in the age of the waste ≤ 6 months, 1–2 years, 3–4 years, and ages ≥ 5 years with magnification of 410 times and magnification of 1500 times produces a fairly spherical morphology observed using SEM instruments. This is due to the porosity that occurs in the particles; the resulting particle grains are large and coarse, so they can cause porosity in the sample so that they are easily wrinkled and uneven [11].

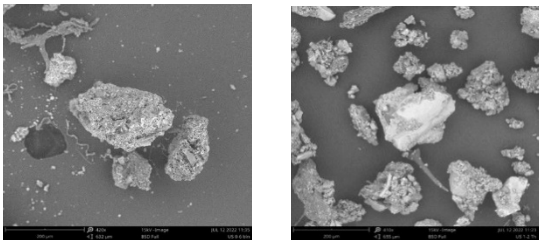

Fig.5 (a) The surface shape of the particles aged ≤ 6 months with 410 times magnification, and (b) the Surface shape of particles aged 1–2 years with 410 times magnification

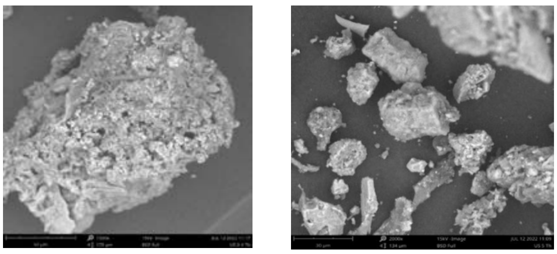

Fig.6 (a) Surface shape of particles aged 3–4 years with 1500 times magnification, and (b) Surface shape of particles aged ≥ 5 years with the magnification of 1500 times

The shape of spherical particles can facilitate interactions between particles, resulting in aggregation, which results in larger particle sizes [12]. Previous studies found that the shape of the surface of the particles is closely related to the size of the grains.

This factor is related to the contact area between the surfaces; small grains have small porosity, and the contact area between the surfaces is large, so the diffusion between the surfaces is also greater [13]. Several factors affect the shape and size of the particles, namely temperature and pH. According to a previous study, temperature can affect particle size [14]. An increase in temperature causes an increase in the growth rate of the particles. In addition, particles with large sizes will be produced at low pH values.

4.4 Dominant Fungus Identification

Based on the identification results, 13 fungal isolates were isolated from the soil of the Piyungan landfill, Yogyakarta. Based on the age of the garbage heap, there were 3 types of fungi, namely the fungus *Penicillium* sp. (10 isolates), *Rhizopus* sp. (2 isolates), and *Mucor* sp. (1 isolate), each of which has different macroscopic and microscopic characteristics. *Penicillium* sp. Become the dominant species among others. Based on the results of the study, *Penicillium* sp. has the benefit of being able to degrade bioplastics. In accordance with the latest research, *Penicillium* sp. has the potential to degrade starch-based bioplastics and the Gunung Tugel Ex- Landfill, Banyumas Regency [15]. However, the ability of *Penicillium* sp. to reduce the weight of bioplastics is still less high when compared to the ability of the *Aspergillus* genus of 21.84%. Other benefits of the genus Penicillium sp. is the process of formation in food and medicine. *Penicillium* sp. can produce penicillin, which is useful for antibiotics which function to destroy and destroying bacteria that grow in the body. *Penicillium* sp. belongs to the Ascomycetous group of fungi. *Penicillium* sp. is a group of fungi that live in the soil where the fungus is in a climate where the temperature is low and the availability of organic matter.

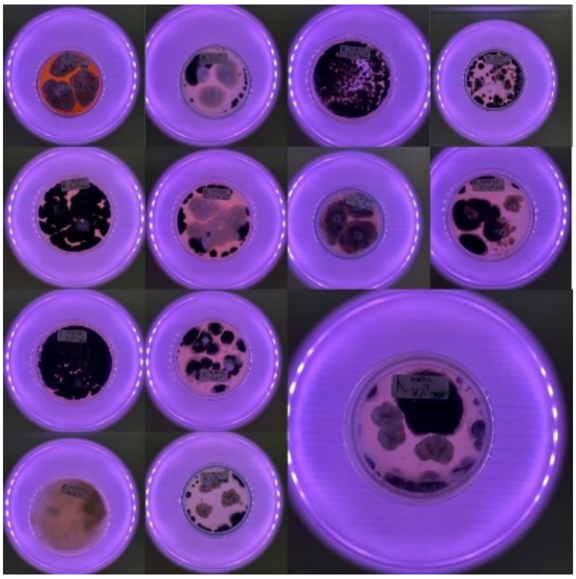

Fig.7 Appearance of pure culture results of fungal isolates with MEA media, incubation period of 7 days, with a temperature of 25 °C

4.5 Dominant Bacteria Identification

Based on the results of observing the types of waste at the Piyungan Landfill, it was found that the dominant waste was organic waste, especially household waste, such as vegetable, fruit, and leaf waste. Thus, bacteria with the genus Acetobacter were found in bacterial isolates (see Fig.8), where these bacteria have the form of bacilli cells belonging to gram-negative bacteria and obligate aerobes.

The next bacteria that can be identified are bacteria with the Genus Staphylococcus, where the results obtained are based on isolates with the characteristics of a circular or round colony shape, the shape of the entire or flat edge of the colony, the shape of the coccus cells has positive gram or purple cell color. This genus is found in bacterial isolates because each bacterial isolate has the same characteristics.

This bacterium grows at an optimum temperature of 37 ºC but forms the best pigments at room temperature (20-25 ºC). Staphylococcus is a gram possitive bacteria. Colonies on solid media are gray to golden yellow, round, smooth, and prominent [16].

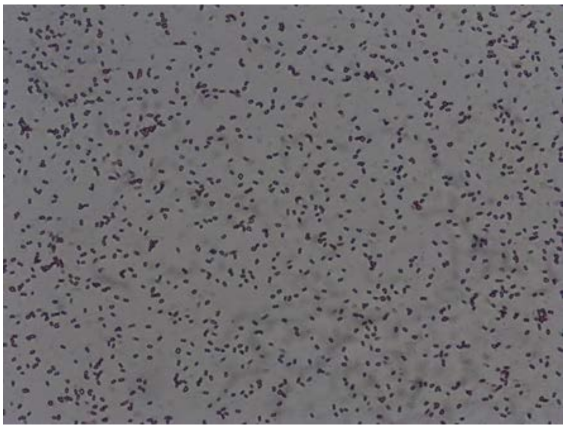

Fig.8 Observation of bacterial morphology based on cell shape and cell wall color with 100X magnification (Coccus cell shape is purple)

4.6 Potential Resource Recovery

From the overall characteristics, the result is that open dumping landfills produce bad waste characteristics, which causes a decrease in the potential for further management to be used as landfill mining with RDF Technology. In terms of the morphology of the old waste particles, the shape of the particles is increasingly difficult to separate the material for further processing. This causes the immediate utilization of waste after stockpiling. In terms of fungi, Piyungan Landfill has the potential to be used as a bioremediation agent for reducing heavy metals. Piyungan landfill also produced beneficial bacteria to degraded some pollutants.

By sorting from the start both from sources and Material Recovery Facility (MRF) facilities before entering the landfill, it will minimize the impacts of decreasing waste characteristics, maximize the technical life of the landfill, and increase the potential for waste to be used as waste to energy, because organic waste will be significantly reduced and all that is left is high calorific value waste.

5. CONCLUSION

In conclusion, this study emphasizes the significance of considering the age of a landfill when assessing waste characteristics. By understanding how waste evolves over time within landfills, sustainable waste management practices can be implemented. No more open dumping that can be built in Indonesia, extra effort to reduced environmental impact and improved resource efficiency should be conducted as soon as possible and give priority to implement the landfill mining to the new close landfill or open dumping rather than the old landfill.

6. ACKNOWLEDGEMENTS

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