International Journal of Marine Engineering Innovation and Research, Vol. 9(1), March. 2024. 65-38
(pISSN: 2541-5972, eISSN: 2548-1479)

Composting as a Strategy for Biodegradable Marine Debris Reduction and Management in Jakarta

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(Received: 9 February 2024 / Revised: 9 February 2024 /Accepted: 9 March 2024)

***Abstract*— This study explores the potential for managing biodegradable marine debris waste in Jakarta City through composting, aiming to reduce and treat this waste effectively. In Jakarta, river debris predominantly consists of materials that degrade easily and are biodegradable. Composting represents the most straightforward method for processing this type of organic waste. The study's objective was to evaluate the feasibility of composting organic biodegradable river debris as a waste management strategy. Data collection was conducted at Emplacement Pluit, utilizing random sampling with the four quadrants method. Out of the total river debris generated daily, which amounts to 309 m³, approximately 9.07 m³/day was found suitable for composting. The composting process resulted in a significant reduction of river debris volume by 50.15% within a 30-day detention period. This process was facilitated by mesophilic microbial activity at temperatures between 30-38°C. During the first two weeks, the composting environment remained acidic until the pH stabilized to a normal range between 6.8 and 7.49. A notable observation was the high initial water content of the river debris, recorded at 53.846%, which only reduced to 42.857% by the end of the 30-day decomposition period. Therefore, a pretreatment step is recommended to optimize the water content before composting. Despite these challenges, the compost produced met the required standards set by SNI 19-7030-2004. This study underscores the importance of managing biodegradable organic waste at its source to alleviate the burden on landfills, which are currently operating beyond their capacity.**

Keywords— composting, marine debris, river debris, waste, reduction

I. INTRODUCTION

One of the environmental problems that are always a problem today and in the future is the problem of waste and marine debris [1]–[5]. The more the human population, the more debris will be delivered. Zero-waste starts from public places and the community environment. Household activities are one of the largest sources of waste generation, and various types of waste are produced. Waste processing and public awareness to decompose and recycle organic and non-organic waste are still very low. They do not care about the surrounding environment what impact will be caused if the waste is disposed of. The resulting debris is not managed and not disposed of in its place. If not appropriately decomposed, the garbage that exists in the community will lead to big problems, especially in environmental pollution.

The presence of waste in the river also causes changes in river water quality [6]–[8]. The types of waste that enter the river consist of biodegradable organic waste, persistent organic, and inorganic. The organic waste generated in the waters at the Emplacement Pluit has compositions such as vegetable remains, dry leaves from riverbanks, water hyacinth plants, and other plants [9]. Composting is very precise and effective on organic waste such as vegetables, even on food waste. Therefore, proper composting activities are expected to be an alternative for handling waste, especially in urban areas, and can even promote agriculture and plant cultivation, both annual and annual, such as forestry plants.

Another impact of the generation of marine debris is considering the condition of the Bantar Gebang Landfill, which is estimated in 2021 will no longer accommodate the amount of waste produced [9], [10]. Then waste can be a source of disease and dangerous to health and the environment. If not managed, organic waste in waters can also cause pollution by sediment that arises and causes a decrease in dissolved oxygen content and the eutrophication process in the waters [11]. Organic waste can also trigger by-products such as methane gas and leachate [12]. If the pile of waste in the Bantar Gebang Landfill continues to grow, then the methane gas

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produced can be at risk of causing an explosion [13]. This will affect the condition of the Bantar Gebang Landfill and Emplacement Pluit itself, especially with the characteristics of organic waste in wet waters, which can negatively impact it. These impacts can be in the form of water, soil, and air pollution than can also cause disease due to many flies and the appearance of unpleasant odors, which can also cause work accidents [14].

It focuses on biodegradable river debris waste management, which is a specific type of waste that may require unique handling and management techniques. The research investigates the potential of using composting as a treatment method for biodegradable river debris waste management. Composting is a sustainable and eco-friendly technique that has been successfully used for treating organic waste, but its effectiveness for river debris waste management may not have been explored extensively. The research may provide insights into the feasibility and efficiency of composting as a waste management technique for biodegradable river debris waste. If successful, this technique can offer a sustainable solution to the problem of managing the large amount of waste generated in water bodies. The research may also provide recommendations for optimizing the composting process for river debris waste management, which can be useful for waste management authorities and practitioners.

According to SNI 19-2454-2002, composting is an effort of processing organic waste with the help of microorganisms to form compost. The composting process will utilize mesophilic and thermophilic activities to produce several elements such as carbon dioxide, water, minerals, and stabilized organic matter. A composting process has benefits as a material to help enrich the soil by improving the soil's physical, chemical, and biological properties. The many benefits of compost are one of the things that are recommended to support programs regarding 3R waste management sites [15]. However, the application of compost from river debris processing has not yet been made properly. Recycle of the biodegradable waste must be applied to reduce the marine debris generation [9], [16]. For this reason, the purpose of this study was to analyze the process of compost formation and the content of any nutrients found in the composting process of organic matter sourced from river debris.

II. METHOD

A sampling of organic waste was done by random sampling method from Emplacement Pluit. Organic waste samples were taken from the waste pile divided into four quadrants, and 1 m^3 of each quadrant was taken using an excavator, then homogenized. Composting is done using organic waste with a total sample of 25.66 kg that can be processed after the sorting. Then the rest is collected as a residue during processing. The organic waste is chopped up to a size of 3 - 5cm. In composting, use the EM4 bio activator, which is carried out with molasses solution with a ratio of the amount of compost: EM4: molasses that is 20 kg: 20 ml: 700 ml. Bio activators are used because a lot of the content comes from microorganisms, which will help decompose organic waste. As a result, the composting time will be shorter, improving the final product. Therefore, compost shrinkage can occur optimally [17].

Marine debris is a global issue arising from human activities, with one of the largest accumulations found in Jakarta's Emplacement Pluit [18], [19]. This location serves as a specific site for managing marine waste in Jakarta, bearing the city's heaviest burden of urban marine debris. This study focuses on analyzing the generation, composition, and recycling potential of marine debris at Emplacement Pluit, starting with problem formulation, literature review, data collection, and analysis under ideal conditions and planning. The marine debris generation at Emplacement Pluit reaches up to 230 m^3/day or 303.6 tons/day, which is higher than other areas in Jakarta and Indonesia. The composition includes PET straw, food packaging, beverage cups, PET bottles, various packaging, plastic bags (PP), plastic toys (HDPE), metals, styrofoam, and biodegradable waste (wood, branches, and leaves), constituting 0.1%, 3.1%, 2.2%, 22.5%, 4.0%, 0.7%, 0.8%, 0.6%, 3.1%, and 62.8%, respectively [18], [19]. The recycling potential of Pluit's marine debris is 67.86%, mainly from converting biodegradable waste into compost [18], [19].

The compost test was carried out to determine parameters that affect the composting process, such as temperature, pH, water content, color, and odor. The amount of organic waste, bioactivator, and molasses liquid will be used in the composting process. Composting using the simple windrow method was carried out for four weeks. The length of time for composting follows the waste management book and the stages of composting [20]. The independent variables are compost composition, bio activator, and molasses, and then the dependent variables are temperature, pH, water content, several parameters according to SNI 19-7030-2004. Measurement of temperature, pH, and water content was carried out every day in the time range from 11.00 to 14.00 WIB.

The results of the compost quality determine the compost condition that comes from the organic wastewaters of the Emplacement Pluit. Therefore, compost quality results are adjusted to the compost parameters in SNI: 19-7030-2004. The compost quality the based on SNI 19-7030-2004 and the specifications of the enumerator from SNI 7580:2010.

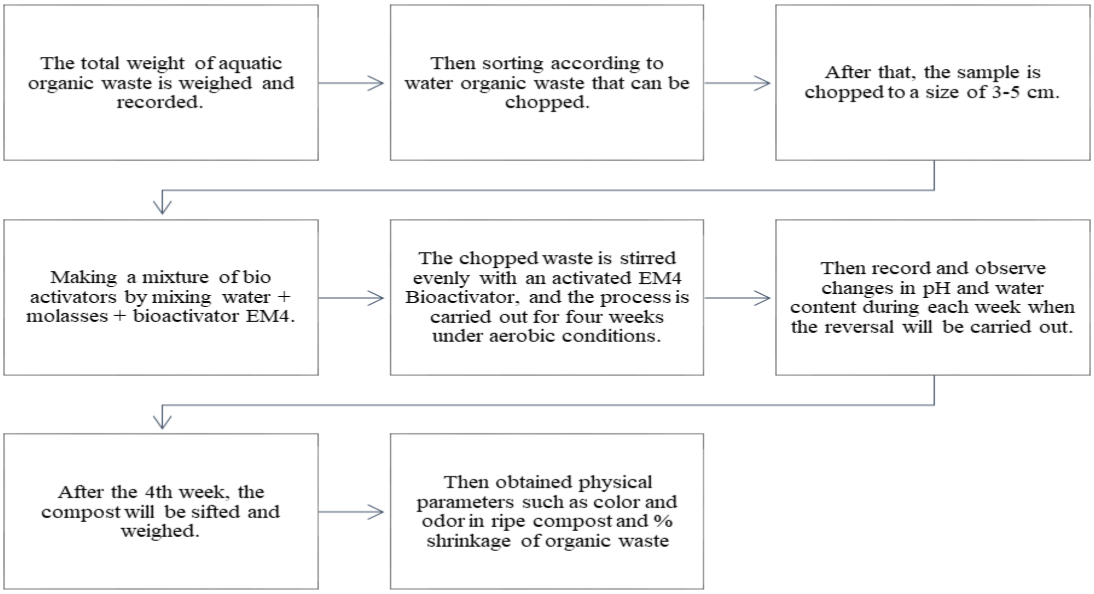

Figure 1. Composting Process in the Windrows Composting Process

III. RESULT AND DISCUSSION

The calculation of the final yield of compost shrinkage is used as a reference to obtain a multiplier factor in land planning after the composting stage. Composting is carried out for 30 days and left in the form of a pile (windrow). The percentage of compost shrinkage is shown in Table 1. Compost shrinkage is included in the shrinkage that meets the standards in organic waste reduction ranging from 40%-60% so that the shrinkage of organic waste in the Pluit Employment is considered to have great potential to reduce the generation of waste transported to the Bantar Gebang Landfill [21].

TABLE 1.
COMPOST DEPRECIATION MASS BALANCE VALUE.

No	Component	Value
1	Organic waste samples (kg)	25.66
2	The initial weight of compost (kg)	20
3	The final weight of compost (kg)	9.97
4	Compost weight difference (kg)	10.03
5	Weigh Loss Percentage (%)	50.15

The recovery factor in processing organic waste enters the Emplacement Pluit and can become organic compost products. Therefore, the recovery factor value can be used to estimate the potential for organic waste that can be processed, waste that becomes residue, waste that can be sorted for other processing processes, and waste that will be transported to the last shelter. The deposition and processed waste results were obtained based on the results of sorting before composting with a total sample taken of 25.66 kg with a potential total of 20 kg of processed and 5.66 kg of untreated. The generation of organic waste can be seen based on the potential of waste that can be processed seen from the area of compost land [22].

The recovery factor is calculated in terms of the percentage and volume of organic waste that has the potential to be treated and not treated [23]. In addition, the potential for organic waste that can be broken down is further divided based on organic waste that can be processed in the composting unit and the potential for organic waste that can be processed but cannot enter the processing unit. The generation of organic waste that is easy to manage is 193.74 m^3/day, and the amount of organic waste that can be processed for composting process is 150.96 m^3/day. Then the organic waste that can be processed according to the existing composting unit is 9.07 m^3/day. The value of the waste recovery factor is shown in Figure 2.

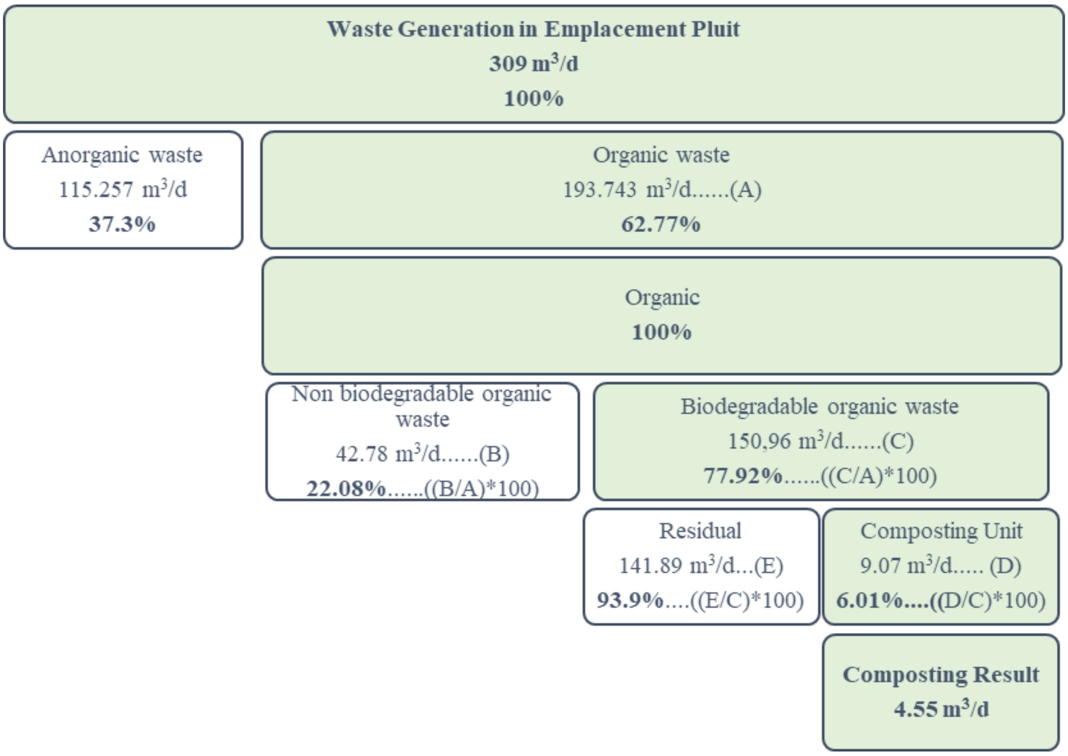

Figure 2. Input and output composting process to generate organic waste recovery factor in Emplacement Pluit

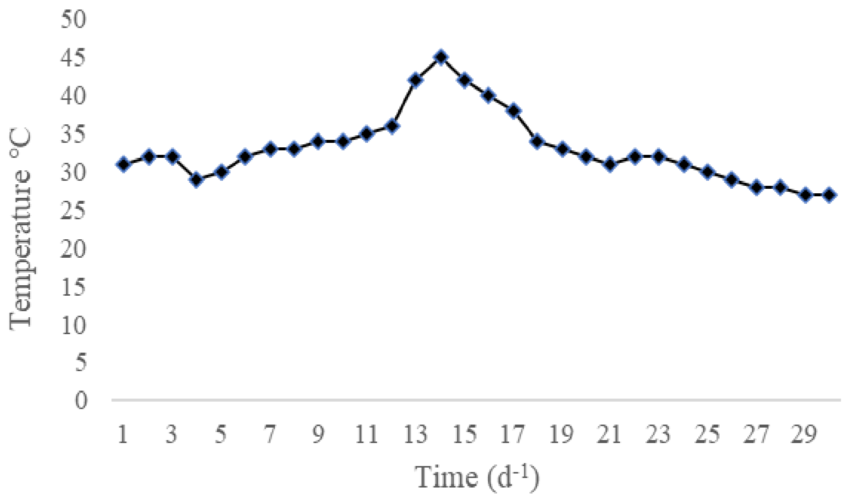

Figure 3. Temperature changes in the windrows composting process.

The increase in temperature indicates that the mesophilic microbial activity works at temperatures of 30-38ºC. The composting that occurs reaches temperatures up to above 40ºC so that the next process occurs due to the activity of thermophilic fungi [20]. Figure 3 shows that the peak temperature increase was reached on the 8th to 16th day. Microorganism activity that occurred in the decomposition process was indicated by the rise in temperature, although the increasing temperature in the compost was slow. Then the peak temperature occurs at 40-45ºC and is influenced by the mesophilic process, but the amount of organic waste can influence the slow increase in the composting temperature rate in the windrow pile. The rise in temperature can be affected due to the decomposition process by microorganisms that produce heat by releasing CO_2 and consuming O_2 [24]. On the 16th to 30th days, the temperature decreases and approaches the soil temperature. One reason is the reversal process and the reduced activity of microorganisms due to the energy needed to be depleted due to the decomposition process. Then a decrease in temperature also occurs due to water evaporation, and the pH begins to stabilize. In addition, other causes that affect the wind row are based on the thickness or thickness of the pile. A too-small pile can affect the expected temperature in composting and the effectiveness of killing pathogenic seeds and insects [25].

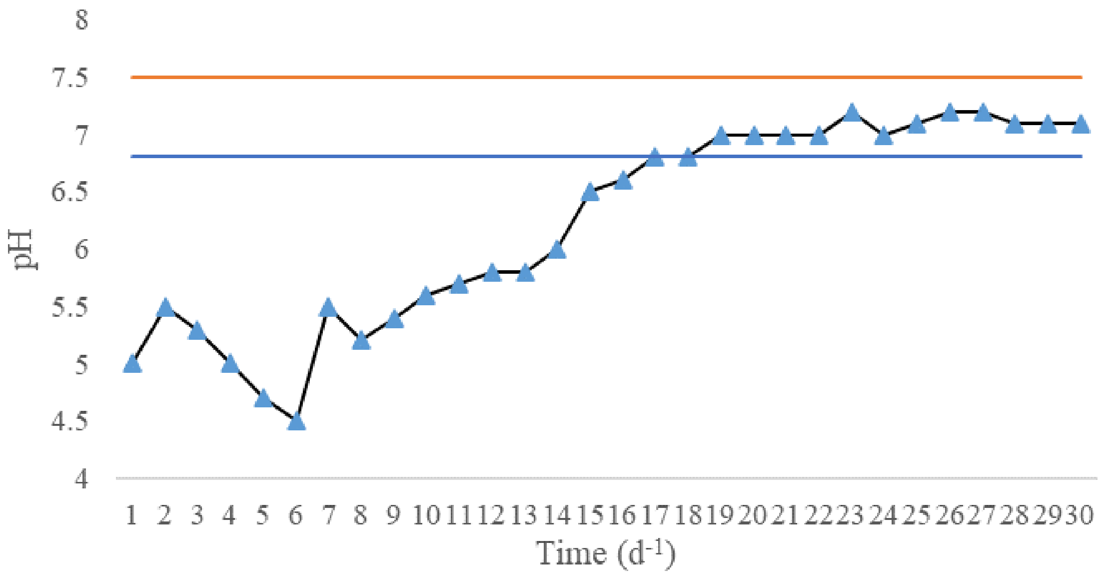

Figure 4. . pH Changes in the windrows composting process.

If composting is carried out in large quantities of organic waste, increasing the temperature can be faster, reaching 70ºC. Then in a large composting scale to maintain the stability of temperature and oxygen in the composting process, the windrows will be placed above the bamboo aerator as a passive air supply and reverse the compost. This is used so that the supply of oxygen or air for the mesophilic and thermophilic processes remains adequate and does not kill the microorganisms needed. Their existence until the decomposition process occurs entirely to the stage of decreasing the temperature for the ripening operation.

Determining the composting process occurs aerobically or anaerobically is pH. Under aerobic conditions, the ongoing pH will not produce much organic acid formation [26]. The aeration process can influence the pH condition and the temperature in the compost. At the beginning of the process, it is proven that the pH is in an acidic state, and its value will increase. However, the unstable pH can be caused by microorganisms' formation of organic acid processes due to the poor aeration process. It was shown that on day 1, the pH was shown to be 5, namely in acidic conditions, and gradually increased after the reversal process on day 7 (Figure 4). The decrease in pH could be due to bacterial activity in mesophilic conditions to decompose organic compost consisting of water hyacinth, leaves, twigs, and other compositions into organic acids. After that, the pH gradually rises due to the production of ammonia. Nitrogen compounds can increase pH because the ammonia formed undergoes a nitrification process [27]. On the 13th day, the pH returned to normal conditions by increasing value. The condition also showed that the temperature began to decrease, the water content decreased, then the pH began to show normal numbers. The standard was determined by SNI 19-7030-2004, where the pH range is 6.8 - 7.49. However, the final pH state on day 30 can be unstable because the compost is still said to be ripe compost and needs to be spread or aerated to obtain pH stability before sifting and

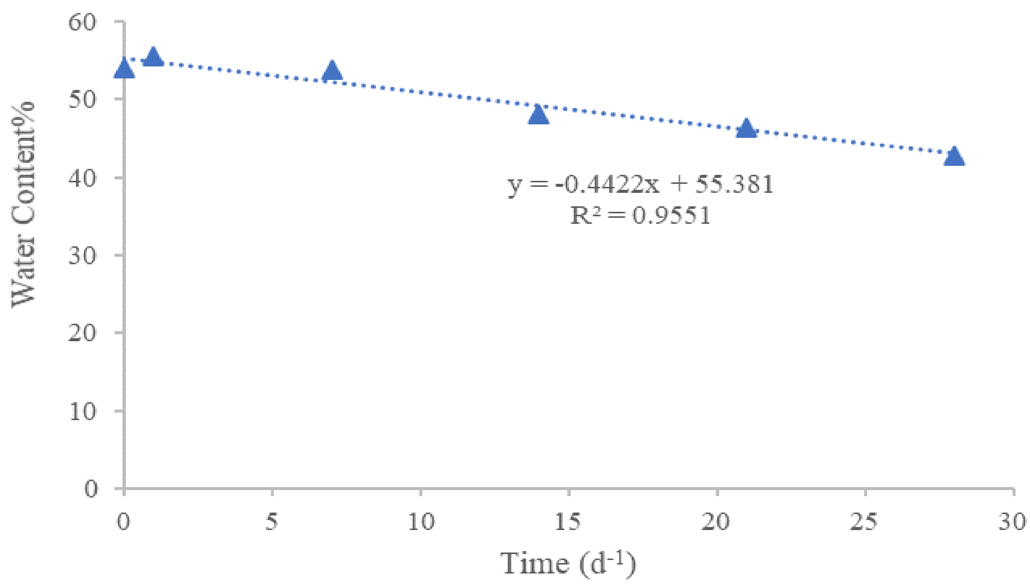

Figure 5. Water content changes in the windrows composting process.

packaging.
Test the moisture content at the beginning of sampling, in the early stages of composting, and at each turn. The increase on the 1st day of composting is due to uneven mixing or weather factors where it rains and the addition of molasses solution and EM4 bio activator so that the water content in organic waste increases. Temperature and weather make the process of evaporation in compost. It can affect the state of the water content in the compost, namely a decrease or increase in water content [28]. The presence of heat, stirring, and oxygen consumption carried out by microorganisms to produce nutrients in compost can affect the decrease or evaporation of water content [29]. The water content in the water waste used can also be affected by a wet location. The decrease in water content from the initial week of composting to the second turning process experienced a significant decrease from 53.846% to 42.857% (Figure 5). This was due to a considerable increase in temperature in 2nd week due to the routine turning and aeration process. After that, the water content will decrease after going through the reversal process and the temperature getting closer to neutral. In addition, the decreased water content of the compost is also followed by the shrinkage of the compost material. Then meanwhile, the water content will continue to meet the Standard of SNI 19-7030-2004.

In large-scale composting, laboratory tests are needed to measure the water content in the compost. However, this will require an expert and require greater funds. Therefore, in large-scale design for the Emplacement Pluit, squeezing compost can still conduct qualitative monitoring. First, additional sawdust or twigs are a base for composting [30]. Then if the compost is dry, it can be sprayed and mixed evenly until the compost is moist [31].

Qualitative assessment of compost by smell and color can be done as a sign of maturity in the compost. The odor can signify that the compost is undergoing an aerobic or anaerobic process in the composting process. The composting results show that the compost's color reaches blackish brown, meaning that the composting is going well, shown in Figures 6. Black compost indicates high water content or low nitrogen content so that this can be overcome by turning it periodically or adding soil, rock, or lime to the compost. Failed compost can be caused because the compost is too moist to cause a foul odor [32]. In addition, other problems can be caused by puddles in the composting process, and it is necessary to slope the composting area to prevent inundation. Besides that, bulking agents or other organic materials can be added with a large surface area to help provide many cavities for the composting process aeration.

Raw Waste | 15-day detention of composting | 30-day detention of composting

Figure 6. The Change of Color of Raw Organic Waste During Windrows Composting Process

The following is the result of compost derived from aquatic organic waste at Emplacement Pluit compared with SNI 19-7030-2004. Comparison of laboratory test results with organic compost from organic waste at Emplacement Pluit. The results of observations on the C and N content of compost material indicate that there is generally a decrease in the C content followed by an increase in the N content. One indicator that shows the progress of the decomposition process in composting is the decomposition of C/N substrates by microorganisms or other decomposer agents [33], [34]. The C/N ratio indicates compost maturity [35], [36]. Changes in the C/N ratio occur during composting due to carbon as an energy source and is lost in the form of CO_2 so that the carbon content decreases over time [37]. The C/N ratio has been widely used as an indicator of compost stability and is expected to remain stable after the compost reaches maturity [38].

The high N content in the raw material for animal feed bokashi compost may come from mixing animal feed ingredients with the urine produced by the livestock concerned [39]. Compost quality is also evaluated based on its nutrient content. In this study, other elements studied were Phosphorus and Potassium. Phosphorus encourages flower bloom and root growth, while potassium helps plants fight diseases and take in other nutrients [40]. This large enough P content will be used by plants more quickly because it is in a form that plants can absorb.

TABLE 2.
COMPARISON OF COMPOST RESULTS WITH PARAMETERS OF SNI 19-7030-2004.

Parameters	**Testing Result**	**SNI 19-7030-2004 standard**
Water content	42.857% ± 3.65	Maximum 50%
Color	Dark chocolate	Maximum black
pH	7.1 ± 0.2	6.8-7.49
Particle Size	4.4 mm ± 0.57 mm	0.55mm - 25mm
Smell	Smell of Earth	Smell of Earth
Nitrogen (%)	2.08 ± 1.07	Minimum 0.4%
Phosphorus (%)	0.94 ± 0.08	Minimum 0.1%
Potassium (%)	1.38 ± 0.65	Minimum 0.20%
C-Organic (%)	27.32 ± 0.91	9.8% -32%
C/N ratio	13.13± 1.07	20-Oct

EM4 can improve health and fertility in soil and plant media in river debris composting base treatment. EM4 contains Lactobacillus, yeast, photosynthetic bacteria, actinomycetes, and cellulose-degrading fungi [41], [42]. In general, microorganisms that play a role in decomposing organic matter in the three treatments consisted of the same groups, namely bacteria, fungi, and actinomycetes, but differed in species and abundance. Environmental conditions strongly influence the activity of these species of organisms. Bacteria act as initiators of the decomposition process of compounds into simple forms. Fungi and actinomycetes can decompose materials that are difficult to decompose. Differences in the characteristics of raw materials will also affect the species and abundance of each microbe that actively decomp Fungi and actinomycetes are both types of microorganisms that play important roles in the decomposition of organic materials. They are known for their ability to break down materials that are difficult to decompose, such as cellulose, lignin, and chitin. Fungi are particularly adept at breaking down cellulose, which is a major component of plant cell walls. They secrete enzymes called cellulases, which break down the cellulose into smaller, more easily digestible molecules. Some fungi also produce lignin-degrading enzymes, which allow them to break down lignin, a complex organic polymer that is also found in plant cell walls.

Actinomycetes, on the other hand, are known for their ability to break down chitin, which is a structural component of the cell walls of fungi, insects, and other arthropods. They produce chitinases, which are enzymes that break down chitin into smaller molecules. The characteristics of the raw materials being decomposed can also influence the types and abundance of microorganisms that are involved in the decomposition process. For example, materials that are rich in lignin, such as wood and bark, are typically decomposed by fungi that produce lignin-degrading enzymes. Materials that are rich in cellulose, such as plant leaves and stems, are typically decomposed by fungi that produce cellulases. In general, the abundance and diversity of fungi and actinomycetes in each ecosystem are influenced by a variety of factors, including temperature, moisture, nutrient availability, and pH. Different species of microorganisms have different requirements for these factors, so changes in environmental conditions can lead to shifts in the microbial community and the types of decomposition processes that are taking placeboes.

The composting of river debris in a Material Recovery Facility (MRF) can provide numerous environmental and economic benefits in developing countries, such as Jakarta. A feasibility study should be conducted to assess the technical, economic, and environmental viability of composting river debris in MRFs in Jakarta. This study can identify potential challenges and opportunities and provide insights on the most effective and efficient composting techniques and technologies that could be implemented. Overall, the future development of composting river debris in MRFs in developing countries like Jakarta will require a concerted effort from various stakeholders.

The application of laboratory biodegradable waste composting from river debris in Jakarta to a field scale requires a carefully planned and executed process. Before scaling up, it is important to conduct a pilot study to test the effectiveness of the laboratory composting process in a real-world setting. This can help identify any challenges or issues that may arise and determine the appropriate adjustments to be made. A comprehensive field-scale composting plan should be developed based on the results of the pilot study. This plan should include provisions for site preparation, composting processes, monitoring and testing, and product handling and distribution. By investing in infrastructure and equipment, developing a comprehensive waste management plan, educating, and engaging the community, and fostering partnerships and collaborations, it is possible to create a more sustainable and efficient waste management system that benefits both the environment and the economy [43], [44].

IV. CONCLUSION

The total generation of river debris in the city of Jakarta reaches 309 m^3/day, of which the composting process can process 9.07 m^3/day. Of the total waste processed by the composting process, 50.15% can be processed into compost. During the composting process, mesophilic microorganisms are measured based on temperature. Based on the pH, it was in an acidic atmosphere at the beginning of processing and became in a standard pH atmosphere at the end of processing. Changes in water content during the composting process only changed from 53.846% to 42.857%. Because the maximum water content is 50%, the pretreatment process for aquatic waste is essential. Appropriate pretreatment research needs to be carried out to achieve optimum conditions for river debris, although the results can reach the quality standards that have been for compost.

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