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Potential Utilization of Plastic River Debris as Electricity Power Plant in Jakarta, Indonesia

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ABSTRACT

River debris is the main problem from the negative impact of poor waste management. The composition of river debris in Jakarta consists mostly of plastic waste. Plastic waste from river debris has an opportunity for energy recovery. This study aimed to see the potential for utilizing river debris in energy recovery in power plants. This research was conducted at three sampling shelter points in Pesing, Pluit, and Perintis. Waste generation and composition were quantified using the load count method on Indonesian state standards for seven consecutive days. River debris generation in Pesing, Pluitm, and Pernting averaged 7.2; 3; and 1.8 tons/day. More than 60% (w/w) of plastic bag waste was found in the Pesing and Pluit shelters, while 67.3% was found in the Perintis shelter. Based on the calorific value of each plastic waste, the energy potential from plastic waste recovery can reach 16,197,109 kWh/year. This is equivalent to an electricity supply of 0.05% of the total electricity demand in Jakarta.

INTRODUCTION

Marine Debris states that marine waste can cause pollution and damage marine life, animals, ecosystems, and human health (Kandziora et al., 2019; van Truong & beiPing, 2019; Vince & Stoett, 2018). The presence of marine debris is a global environmental problem and is a growing concern (Miladinova et al., 2020). River debris or aquatic solid waste is a persistent solid material produced or processed by humans, directly or indirectly, wasted or left behind in the marine environment (Sulistiawati & Eisma-Osorio, 2021). River debris is goods that have been shaped or used and intentionally dumped into the sea or river by humans. Materials that enter or move into the waters from the land through rivers, drainage systems, or wastewater disposal and wind can be said to be Reiver debris. River debris can be classified into two categories, namely organic and inorganic water waste. For Reiver debris, the organic category consists of wood, leaves, and others (Safira et al., 2021). Meanwhile, the inorganic debris category consists of plastic, metal, glass, paper, cardboard, rubber, clothing, textiles, and others (Nadyanti Ivonie et al., 2020).

Debris is a persistent solid material produced by humans, directly or indirectly, disposed of or even left in the aquatic environment (Richards & Beger, 2011). In addition, river debris can be interpreted as a material that is difficult to decompose in the form of processed or manufactured solids that is disposed of or left intentionally or not by humans in the waters (Chen et al., 2021).

Plastic debris is also a non-biodegradable waste that harms the environment (Dwivedi et al., 2019). Plastic debris consists of straws, food packaging, drink cups, pet bottles, another packaging, plastic bags, and other plastics (Chitaka & von Blottnitz, 2019; Clayton et al., 2021; Walther et al., 2018). Plastic waste generally has a high calorific value, so it has the potential to be used as fuel (Sarwono et al., 2021). The utilization of plastic debris as fuel for Refuse Plastic Fuel (RPF) has several advantages (Murakami et al., 2006). This PRF includes reducing the cost of handling plastic debris that has been transported out of the factory using third-party services, reducing the use of fossil fuels, and making the factory clean from plastic waste. Compared to coal, plastic waste energy recovery is more environmentally friendly, and CO_2 emissions are 33% lower (Kumar et al., 2020). On the other hand, the pyrolysis process in PRF is an effective and environmentally friendly option for solid waste treatment to obtain a liquid fuel called pyrolytic oil or bio-oil (Pawar et al., 2020).

With the possibility of greater use of plastic waste, a more in-depth study of the energy potential that can be recovered is needed. This research was conducted in Jakarta, where the problem of marine plastic waste is still severe and considers the policy direction for energy-based waste management. This study aimed to determine the potential use of marine plastic waste as raw material for PRF to generate electrical energy in Jakarta.

MATERIALS AND METHODS

The collection of generated data will be carried out using the load count analysis method following the measurement and analysis method (Damanhuri & Padmi, 2015). This method is carried out by measuring the volume of garbage collection vehicles that carry marine waste to the Reiver debris TPS for one full day. Then the waste generation and composition data will be carried out following SNI 19-3964 1994 concerning methods for collection and measurement of samples of generation and composition of urban waste and the sampling technique used by the World Bank (Shuker & Cadman, 2018). This method is carried out by dividing the pile of garbage into four quadrants. First, 1 m^3 will be taken using an excavator from the four quadrants, then mixing is carried out to make the sample homogeneous. Furthermore, from the 4 m^3 of collected waste samples, it will be divided into four quadrants which will then be chosen one of the quadrants.

The maximum heat energy released by a fuel through a complete combustion reaction per unit mass or fuel volume is defined. The calorific value is the heat transferred when the combustion is complete. The heat energy in question is obtained from calculating the calorific value, which is the product of the specific heat and the composition of the waste.

The heat analysis of fuel is intended to obtain data on the heat energy that power can release by the occurrence of a reaction/combustion process (Sutanto, 2021). The calorific value shows the heat transferred when the combustion product is complete. According to the ASTMD 2015 standard, the calorific value is determined in the standard test in Bomb Calorimeter. There are two kinds of determination: high calorific value (gross) (HHV, higher heating value) where it is assumed that all the vapor formed has condensed; so that in this case, it includes the latent heat of vaporization of water vapor in the product; and the lower heating value (LHV) which does not have the latent heat. In this study, the calorific value used is LHV and HHV, where the sample tested is the original sample. Because plastic waste cannot absorb water or penetrate water, LHV and HHV in Reiver debris are assumed to be the same.

RESULTS AND DISCUSSION

Residents around the riverbanks have carried out the activity of throwing waste into the river for years, so throwing debris and dirt into the river is not a new story (Nugraha et al., 2018; Safira et al., 2021; van Voorst & Hellman, 2015). This habit occurs in the DKI Jakarta area and is almost evenly distributed in all regions in Indonesia. Therefore, it is not uncommon for garbage to accumulate and blockage at several points on rivers in cities in Indonesia. Thus, the waste will flow downstream along with floods during the rainy season. The findings in our study on the average peak condition of waste generation at Pesing, Pluit, and Perintis monitoring points were 7.2; 3; and 1.8 tons/day (Table1).

Table 1. River Waste Generation in Three Locations Jakarta

Location	Plastic waste generation
Pesing	7.2
Pluit	3.0
Perintis	1.8

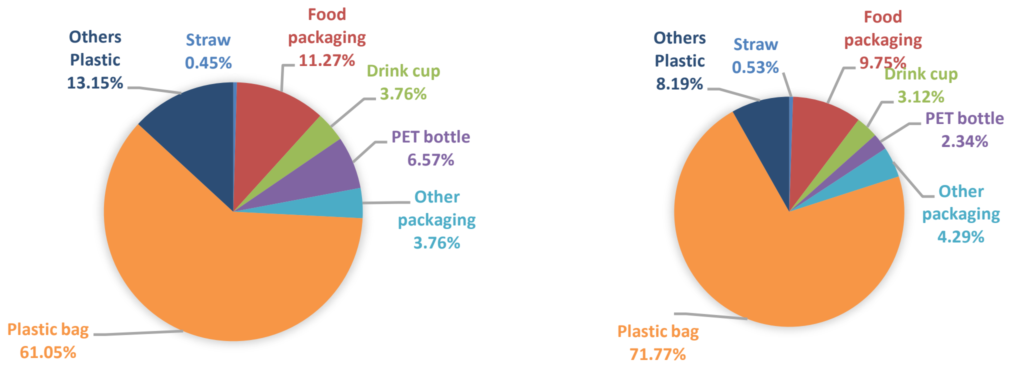
Source: Sari, Andarani, et al., 2022

Daily human activities have indirectly increased the amount of waste in the aquatic environment, such as the disposal of household activities such as kitchen waste food or beverage packaging into the waters. The most common inorganic waste dumped into rivers in the Jakarta area is inorganic waste in plastic cups, plastic bags and wrapping materials, fast food wrappers, plastic bottles, and other plastic packaging. River debris collection also usually requires heavy equipment because the amount is very large every day.

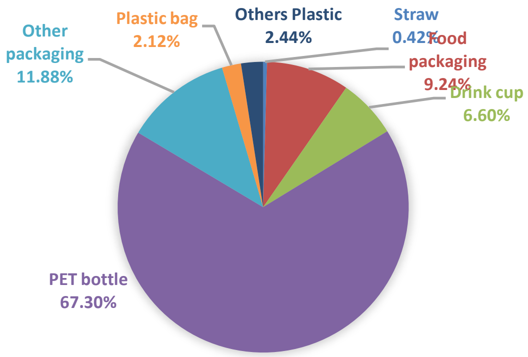
River debris samples taken will be sorted according to the type or classification of waste at each TPS for Reiver debris. This sorting results in a category based on the type of plastic waste. The plastic class currently used globally by SPI (Society of the Plastics Industry) is a resin identification code (RIC), which is a plastic classification based on the resin used (Khajuria et al., 2017). Types that can facilitate recycling the plastic waste produced plastics are classified into seven groups (Faraca & Astrup, 2019; Kazemi et al., 2021; Klemeš et al., 2021), namely polyethylene terephthalate or PET/ PETE (01), high-density polyethylene or HDPE (02), polyvinyl chloride, or PVC (03), low-density polyethylene or LDPE (4), polypropylene or PP (05), polystyrene or PS (06) and others or Others (07). However, the composition is too complex with the existing conditions; therefore, the distribution of the dominant waste in the study location is carried out (Figure 1).

The plastic collected is domestic waste or a type of household waste in product packaging, plastic bags, household appliances (mats, toys, kitchen utensils), and food packaging (styrofoam). In addition, several objects from shipping activities were also found, for example, the remains of fishing gear and pieces of cooling boxes. The amount of polypropylene and polyethylene plastic waste collected reflects the surrounding community's waste management and consumption patterns (van Emmerik, Loozen, et al., 2019). So, the primary sources of plastic waste come from packaging and consumer goods in households (Schwarz et al., 2019).

A study conducted in the Cimandiri watershed, West Java Province showed a smaller abundance and density of plastic waste than in the Baturusa watershed (Taryono et al., 2020). A higher population will produce more plastic waste (Lebreton & Andrady, 2019; Mongtoeun, 2019). Still, the amount of plastic waste in waters is influenced by various factors, namely the type of waste management, the location of the city, dams and garbage traps, seasons and seasonal river discharges, and flood events (van Emmerik, Tramoy, et al., 2019). These factors show the complexity of the problem of plastic waste in rivers.



Pesing Pluit



Perintis

Figure 1. River Waste Composition in Three Locations Jakarta

Plastic waste in rivers requires serious handling by various parties. One way to manage plastic waste is to recycle waste according to the 3R principles, namely reduce, reuse, and recycle (Kabirifar et al., 2020). The waste bank program is implemented to recycle plastic waste generated from domestic activities. The Waste Bank Program is community-based waste management by integrating the 3R principles and managing as close as possible to the source (Kubota et al., 2020).

The calorific value contained in plastics with other energy sources in this study can be seen in Table 2. Given the high energy content of plastic materials, the potential for its use as an energy source has good prospects in Indonesia. This can get two advantages at once, namely reducing the problem of plastic waste and producing energy that can reduce dependence on conventional energy sources (Gopinath et al., 2020).

Energy recovery is converting plastic waste into a form of electricity (Lombardi et al., 2015; Zahra et al., 2022). This step is the main topic of this study, especially converting plastic waste into electrical energy. Although this process is not well known in Indonesia itself, especially by the public, several theories, studies, and methods are used to study ways to convert plastic waste into electrical energy. In general, plastic waste cannot be converted directly into electrical energy but is first converted into liquid, solid, or gas fuel, then converted into electrical energy using a generator. Several technologies can convert plastic and biomass waste into fuel, including conversion to solid fuel, liquid fuel, and conversion to gas fuel (Cheong et al., 2022; Gasim et al., 2022; Koko et al., 2022; Raksasat et al., 2021; Septiariva et al., 2022; Suryawan et al., 2022). Overall, the use of marine plastic debris in Jakarta can indeed supply 0.05% of Jakarta's total annual energy demand if carried out.

Table 2. Potential Energy Recovery from River Debris in Jakarta

Plastic Composition	Caloric Value (MJ/kg)	Caloric Value (kWh/kg)	Electricity Generation Potential (kWh/day)		
			Pesing	Pluit	Perintis
Straw	10.9	3.03	96.50	47.78	22.62
Food packaging	5.63	1.56	1,261.89	452.39	253.96
Drink cup	12.2	3.39	911.48	313.71	393.08
PET bottle	16.6	4.61	2,170.41	320.10	5,455.50
Another packaging	18.1	5.03	1,352.27	639.94	1,049.75
Plastic bag	14.7	4.08	17,846.84	8,693.46	151.94
Others Plastic	8.63	2.40	2,256.67	582.48	102.89
Total Electricity Generation (kWh/day)			25,896.05	11,049.86	7,429.74
Total Electricity Generation (kWh/year)				16,197,109	
Total Electricity Consumption (kWh/year)			32,194,867,748		
Electricity Supplied from River Plastic Waste Potential (%)			0.0503		

Source: Calculated based on (Sari, Andarani, et al., 2022)

Research that examines the construction of a waste power plant in terms of fulfilling electrical energy for the community and in terms of reducing environmental problems due to waste (Qodriyatun, 2021). The construction of a waste power plant is expected to contribute to meeting the electricity needs of the community. This research is interesting because the potential for energy production from fossils is starting to decrease and the global community has committed to reducing Greenhouse Gas (GHG) emissions from marine debris generation. On the other hand, several cities in Indonesia are already in a waste emergency condition, such as Jakarta (Koko et al., 2022; Rahmalia et al., 2022; Sari, Andarani, et al., 2022; Sari, Inoue, et al., 2022).

CONCLUSION

River debris generation in Pesing, Pluitm, and Pernting averaged 7.2; 3; and 1.8 tons/day. Plastic bag waste was found in more than 60% (w/w) in the Pesing and Pluit shelters and 67.3% (w/w) in the Perintis shelter. Based on the calorific value of each plastic waste, the energy potential from plastic waste recovery can reach 16,197,109 kWh/year. This potential energy recovery finding is equivalent to an electricity supply of 0.05% of the total electricity demand in Jakarta.

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