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Preliminary Analysis of the Utilization of PET Plastic Waste in Tourism Areas for Energy Recovery

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ABSTRACT

Waste management at tourist sites is an unavoidable problem due to the massive number of visitors. One of the types of waste is polyethylene terephthalate (PET) plastic bottles. This study aims to analyze the potential use of PET for waste to energy in tourist areas. This research was conducted in a tourist area in Klungkung Regency, Bali Province. This study only uses grab sampling in measuring waste generation and composition. This research was conducted by proximate analysis and thermal gravimetry analysis (TGA). The measurement of waste generation shows that the PET produced is 1.24 kg/day, or about 43.5% of the total waste generation. Proximate analysis measurements show the value of moisture, ash, volatile, and fixed carbon content, which are 1.53, 0.14, 95.92, and 2.42, respectively. Meanwhile, the caloric value of PET waste is 22.71 MJ/kg. The residue from the TGA results showed 2.575%. The thermal degradation process starts at a temperature of 280°C, and the initial temperature of degradation starts at 406 – and ends at 468°C. Utilization of PET waste at this tourist location can also help the purpose of waste management in Klungkung Regency, namely implementing the Waste to Energy concept at the Local Waste Processing Facility (TOSS).

1. INTRODUCTION

The tourist area is a center for the growth of world-class hotels, restaurants, and various trade and business facilities [1]. Therefore, the area should display regional qualities following the image of an international tourist destination. However, the facts that show an increase in the environmental pollution in an area that has developed into economic growth are very concerning [2]. Plastic pollution is one of the biggest problems in Indonesia, especially marine debris [3], [4]. Therefore, it is essential to dispose of plastic waste in bags or bottles by providing information through media that can increase correct knowledge about preventing plastic waste around the beach [5]. Plastic waste is the most common and is difficult to decompose in the soil. Efforts to manage environmental cleanliness and reduce the amount of plastic waste are by processing plastic waste by grouping waste.

One way to reduce the generation of waste that accumulates in landfills is to manage waste at the upstream level, waste producers, or at the source. Regulations related to this can be referred to from several regulations, including Law no. 18 of 2008 concerning Waste Management [6], Regulation of the Minister of Public Works of the Republic of Indonesia No. 03/PRT/M/2013 concerning the Implementation of Waste Infrastructure and Facilities in Handling Household Waste and Waste similar to Household Waste [7]. In addition, regulations at the regional level include Klungkung Regency Regional Regulation Number 7 of 2014 concerning Waste Management [8]. This needs to be understood by anyone or any party who wants to implement integrated waste management at the household and broader scale. With the condition that all plastic waste has not been utilized, capacity building needs to be carried out with recycling efforts. Recycling plastic bottle waste is a solution to process waste with energy recovery to support acceleration of construction of waste processing installations into electrical energy based on environmentally friendly technology. Utilization of the results from recycling used beverage polyethylene terephthalate (PET) bottles can be used for various kinds of products [9], [10].

PET has excellent mechanical and thermal properties. PET is a thermoplastic polymer resin from the polyester group. PET plastic has high mechanical strength, is transparent, is non-toxic, and has no negligible effect on taste and permeability to carbon dioxide. PET plastic has excellent tensile and impact strength, chemical resistance, clarity, processability, colorability, and thermal stability [11]. PET is widely produced in the chemical industry and is used in synthetic fibers, beverage bottles, food containers, thermoforming applications, and glass fibers in engineering resins. PET in packaging applications, especially in the bottled water industry, is huge because of its advantages: softness, biodegradability, lightweight, and good selective gas permeability. Unfortunately, PET is one of the significant compositions of marine waste, which is a problem in Indonesia [3], [12]. This study provides an alternative solution for utilizing waste from tourist sites. Especially supporting the development of the use of waste into energy at the tourist sites of Klungkung Regency. This study's objective is to analyze the potential use of PET for waste to energy in tourist areas.

2. METHOD

This research was conducted by using observation techniques. Observation is an activity to observe a process or object to understand of phenomena based on observations. Observations were made to determine the composition of waste and waste containers at the study site. The observations were then compared with the ideal conditions from the existing literature study. This research was conducted in one of the waterfall tourist areas in Klungkung Regency, Bali Province (Figure 1), in December 2020.

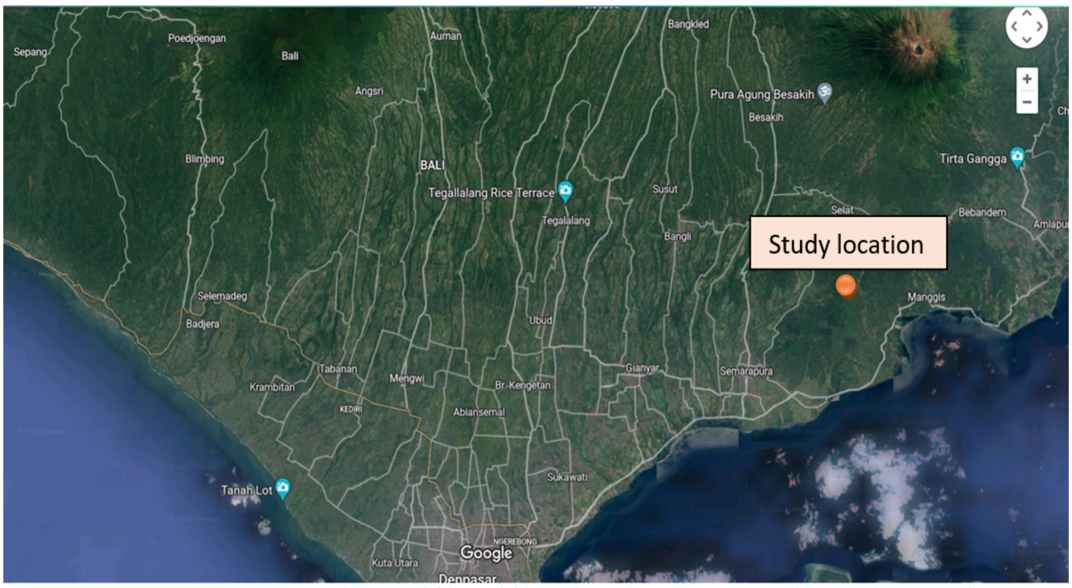

Figure 1. Study Location [13]

PET plastic bottles are cleaned using clean water, then cut into small pieces using scissors or a knife. The small pieces measure + 3 mm x 3 mm. Thermal analysis using Thermo-Gravimetric Analysis (TGA) is a technique to measure the rate of change of sample mass as a function of temperature. This measurement aims to predict thermal stability up to a temperature of 800°C based on the composition of the sample under study. The TGA test was carried out with nitrogen gas at a rate of 10oC/min. The sample of plastic waste used was 9.5 grams of a mixture of all PET plastic waste in the study location which was mixed homogeneously.

This study also analyzes the proximate characteristics of PET plastic waste in the study area. Proximate analysis working procedure with gravimetric and volumetric techniques. The prepared sample was then tested for Proximate analysis in the form of inherent moisture, volatile matter, ash content and fixed carbon. The proximate analysis test refers to the ASTM D 3172 standard. The sample is also tested for its calorific value using a bomb calorimeter.

3. RESULT AND DISCUSSION

There is already a particular grouping of PET trash bins (Figure 2). So that waste is not mixed when processed and is difficult to separate. This can cause waste that can be processed to be wasted. Therefore, besides providing trash cans with separate types of waste, there needs to be further handling of the waste itself, starting with providing education about the definition of waste. Based on the observation by grab sampling, PET waste generation is 1.24 kg/day, where PET dominates 43.5% (w/w) of the total waste in the study site.

Figure 2. PET Waste Storage at the Study Location

This research was conducted by measuring the water content in the sample solids after pyrolysis to determine the remaining proximate analysis in the solids (Table 1). Water content is measured because the stored water content can reduce the calorific value if the sample is used in the combustion process. The ash content of PET plastic is 0.14%, with high volatile content, so it has the potential to produce high gas. Ash content is one of the factors that affect the resulting char production. The higher the value of ash content, the higher the production of solids and gases produced [14].

TGA is also used to characterize various material conditions' decomposition and thermal stability (Figure 3). Especially in the TGA analysis, the change in thermal equilibrium is examined in terms of the percentage reduction in sample weight as a function of temperature. The main parameters are temperature, reactor type, time, pressure, and use of a catalyst [15]. However, the

TGA experiment shows that the rate of temperature increase is essential in the decomposition reaction of plastic molecules [16].

TABLE 1. Results of Proximate Analysis of PET Waste at the Study Location

Parameters	Value
Moisture content (%)	1.53
Ash content (%)	0.14
Volatile content (%)	95.92
Fix carbon content (%)	2.42
Caloric value (MJ/kg)	22.71

In this study, an experiment was conducted on making pellet refuse-derived fuel (RDF) with a mixture of PET and twig waste. This is done because the gas produced is also relatively high. This follows previous research, stating that the composition with 50% PET and 50% twigs makes a high caloric value [17], [18]. In addition, mixing RDF with garden waste will deliver a more elevated and stronger density [19]. The gas content is CO, CO_2, and CH_4. CO and CO_2 gases are produced at low temperatures. In pyrolysis, it is caused by the decomposition of cellulose and hemicellulose at a temperature of 400°C.

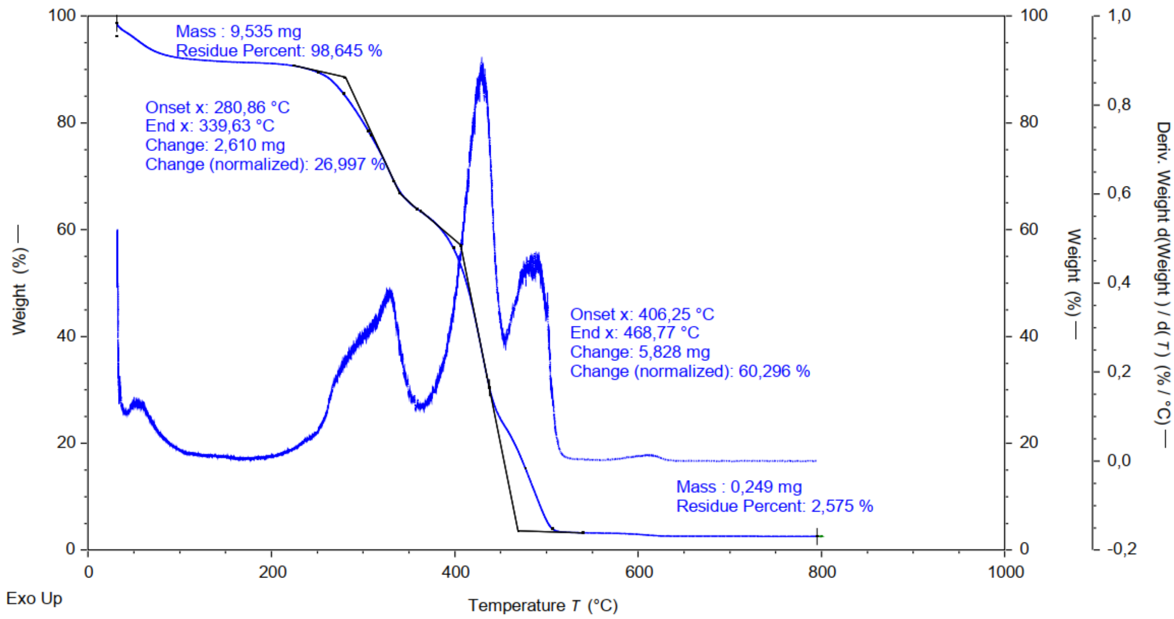

Figure 3. PET Waste TGA Analysis

Figure 3 above shows that the best temperature starting at a starting temperature of 280°C and the initial temperature of degradation starting at 406 – and ending at 468°C with a residue of 2.575%. The residue from burning PET plastic is very small compared to other types of urban waste [17], [18], [20]. The plastic waste processing technology used is a simple technology, where used plastic is separated according to its type, then cleaned [17]. The plastic is then chopped using a machine designed, washed in a water bath, and then a drying process at the material recovery facilities [17]. The process of utilizing plastic waste into Refuse Derived Fuel (RDF) or better known as Plastic Derived Fuel (PRD) is an alternative that can be considered from the results of the TGA test produced. The flow of the plastic waste processing process is shown in Figure 4.

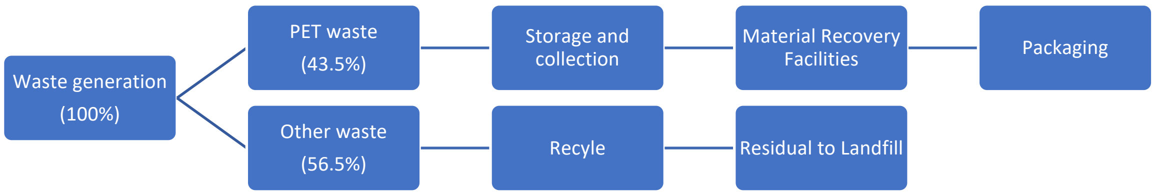

Figure 4. PET Waste Management Material Balance Recommendation

In addition to relying on the existence of landfills, Klungkung Regency also innovates to process waste into pellets as part of the Waste to Energy concept implementation at the Local Waste Processing Facility (TOSS), which is spread in almost every location in Klungkung Regency [21]–[23]. With the potential for using PET waste from tourism, it can also support supplying raw materials to be used as fuel. The benefit or income obtained from TOSS Center Kusamba comes from selling waste pellets to PT. Indonesia Power produces compost and plastic waste sold to APSI (Indonesian Waste Entrepreneurs Association) [24].

The mechanical recycling of PET waste has a little influence on the environment, but well-separated and cleansed PET wastes are necessary, and the mechanical qualities of PET diminish dramatically with each recycle [25]. Pyrolysis is a promising method for converting waste polymers into goods with added value. The development of sophisticated pyrolysis methods, the use of pyrolysis products, and the elucidation of the pyrolysis process have been the subject of extensive study [26], [27]. Multiple pre-processing techniques, such as size reduction and sorting, are required to make municipal solid waste suitable for gasifiers. RDF is a processed form of municipal solid waste that undergoes significant size reduction, drying, screening, sorting, metal and glass separation, and, in some cases, pelletization to improve the handling characteristics and composition of the material to be fed into a gasifier [17], [18], [28]. Due to the fact that, per national regulations, waste with a calorific value greater than 6 MJ/kg cannot be disposed of in landfills, it is crucial to utilize the energy contained in these materials in an industrial, energy-efficient, and environmentally responsible manner [29]. Zhao et al. [36] evaluated the effects of three microwave absorbents (carbon powder, ferroferric oxide, and calcium oxide) on microwave co-pyrolysis of PET and biomass. In addition, plastic bottles are the most prevalent form of plastic waste in our daily lives including tourism activities [37]–[39], and there are only a handful of studies on the microwave pyrolysis of polyethylene terephthalate. To see these opportunities, Table 2 shows the results of several literatures on processing PET waste into energy that meet these standards.

TABLE II. Review of Final Treatment of PET Plastic

No	Calorific Value	Moisture content (%)	Ash content (%)	Volatile content (%)	Fix carbon content (%)	Final Product	Ref.
1	10.1–13.2 MJ/kg	-	-	57.7	-	PET Bottles Washing as A Component of Solid Fuels	[30]
2	10931 cal/gram 45.7 MJ/kg	0.03	0.44	99.53	-	PET bottle caps	[31]
3	25.04	3.83	0.48	-	-	Pellet RDF	[17]
4	-	-	-	-	-	PET type does not produce oil but produces -shaped material	[32]
5	37.5 MJ/kg	-	-	-	-	Polythene with	[33]

						PET plastic at different blends	
6	8.7 MJ/kg	-	-	-	-	Pyrolyses of PET	[34]
7	27.26 MJ/kg	-	-	-	-	Pellet RDF	[35]

4. CONCLUSION

The PET waste generation in the study location is 1.24 kg/day, or about 43.5% of the total waste. However, proximate measurements carried out show the value of moisture content, ash content, volatile content, and fix carbon content, which are 1.53, 0.14, 95.92, and 2.42, respectively. Meanwhile, the caloric value of PET waste is 22.71 MJ/kg. With this calorific value, it shows that there is an opportunity to use PET waste into energy such as Refuse Derived Fuel. The existence of opportunities for the use of PET waste from tourist areas can support the government's efforts in the policy of processing waste into energy.

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