

The Potential Energy of Plastic Solid Waste as Alternative Fuel for Power Plants in Indonesia

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Abstract. Studies on the potential of plastic solid waste (PSW) as a fuel supplement for power plant was conducted to determine the potential energy and economic value in Indonesia. In analyzing the potential energy and economic value of PSW, 15 cities provinces having municipal solid waste production of greater than 1,000 tons/day were selected. The study showed that with the total potential of PSW of around 693 tons/day, the electrical energy potential available is around 7,987 MWh/day. The PSW equivalent with coal is approximately 1,065 tons/day, and its equivalent to the oil is around 593 tons/day. In conclusion, the PSW is an environmental pollution material but have the energy and economic potential to be used as a fuel supplement for the power plants. Thereby, it can save the use of coal by means co-combustion with PSW and at the same time be able overcome the environmental problems caused by pollution PSW in Indonesia.

Introduction

Plastic solid waste is dangerous to the environment because it pollutes the environment and cannot decompose completely in a short time; it takes ten to hundreds of years to decompose. At the time of degradation, plastic particles will contaminate soil and groundwater. If it is burnt in landfills, incomplete combustion will produce toxic fumes and it is hazardous to one's health because the plastic will break down as dioxin. Dioxin compounds are very dangerous, if inhaled by humans could cause cancer, hepatitis, inflammation of the liver and nervous system disorders. At the stage of landfill disposal, plastic wastes emit greenhouse gases if the plastic bags are left on the landfill ground [1]. While the use of plastic bags in Indonesia cannot be avoided and there is no alternative to that can be used by the public for the purposes of day-to-day activities. Although PSW is a source of pollution, but it also have an economic and energy potential that is, it could be used as fuel due to it high calorific value [2]. To overcome these problems, one alternative that needs to be done so that the plastic waste does not contaminate the environment, the PSW should be utilized as fuel in power plants. The utilization of PSW can be controlled so as to minimize harmful gases produced during combustion. For PSW combustion in boilers, the exhaust emissions can be minimized by using exhaust emission control system [3]. This study was conducted to obtain an overview of the potential of the PSW in Indonesia and is expected to provide information to policy makers and the competent authorities of exploiting energy potential of plastic bags in Indonesia as a fuel supplement on the power plant. It is expected to be one of the methods to overcome the problems of plastic solid waste (PSW) and reduce the use of coal at the power plant in Indonesia.

Materials and Methods

The PSW is selected as the study samples are plastic bags of municipal solid waste (MSW) generated each day. Sample locations were selected as many as 15 cities that have MSW production is more than 1000 tons/day, namely Jakarta, Surabaya, Bandung, Medan, Semarang, Palembang, Makassar, Padang, Denpasar, Pekanbaru, Samarinda, Manado, Pontianak, Kupang, dan Mataram. The city represents the 33 provinces cities in Indonesia. The data used are the statistical data on the

average for the year 2008 - 2010, includes data of MSW production in Indonesia 2008 - 2010 [4] and PSW calorific value data can be obtained from the results of literatures. The data is analyzed to obtain the available potential of PSW in Indonesia.

Result and Discussion

Potential Energy PSW. Energy potential of each fuel is different depending on the calorific value. PSW has the potential energy to be used as a fuel because it has a large calorific value. Calorific value indicate that energy content of PSW (plastic bags and film) about 41.5 MJ/kg which is higher than the other fuel, except fuel oil, Calorific values for several types of fuel can be obtained from the results of previous researches [2, 5-7], as presented in Fig. 1. This indicates that the PSW in particular plastic bag has potential as a fuel or fuel supplement on the power plant.

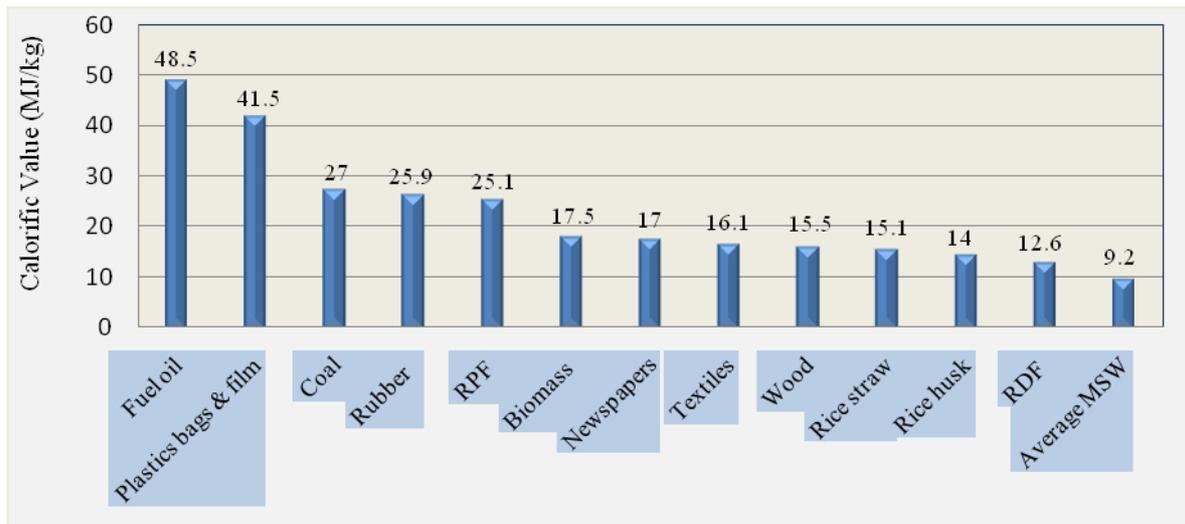


Fig. 1. Calorific values of several types of fuel

PSW potential as reflected in the fuel utilization and production PSW generated every day. In general PSW consumption per capita in each country is different and has increased every period. But in Indonesia PSW production tends to fluctuate during the period 2006 - 2010. In general, the use of plastics in the world increased significantly during the period 1980 - 2010. In 2010, the USA using the largest plastic which is about 150 kg/capita/year, then Western Europe around 120 kg/capita/year and Japan about 100 kg/capita/year [8]. Meanwhile, in Indonesia tend to fluctuate during the period of 2006 - 2010, on average is around 22 kg/capita/year [9]. This value is smaller than the plastics world consumption on average is about 30 kg/capita/year in the period 2000 - 2010 [8], as presented in Fig. 2.

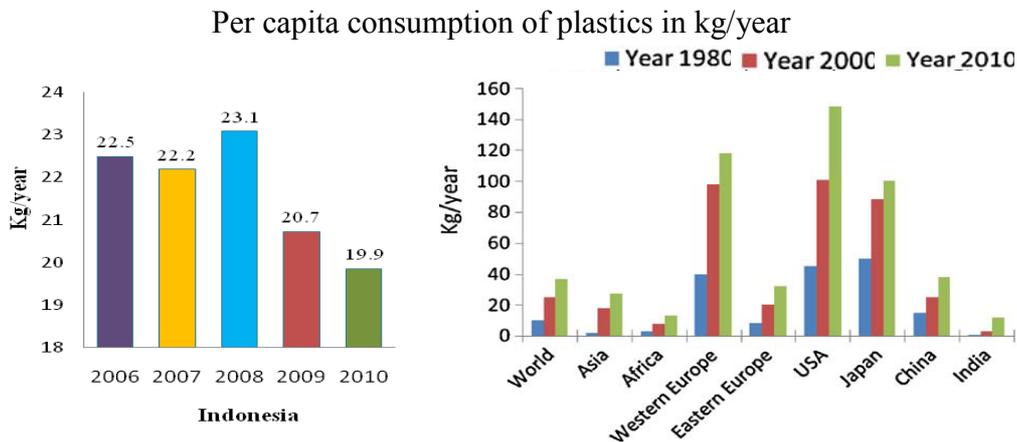


Fig. 2. Comparison of per capita consumption of plastics in Indonesia and several countries in the world

The amount of volume PSW (V_{PSW}) produced can be estimated based on the percentage content of PSW (P_P) in the volume of MSW (V_{MSW}), by using the Eq.1.

$$V_{PSW} = P_P \times V_{MSW} \tag{1}$$

The percentage content of the PSW in the MSW is varied, namely in Malaysia is about 8% [10], in Portugal is around 11% [11], and in United States is around 12% [5], as presented in Fig. 3.

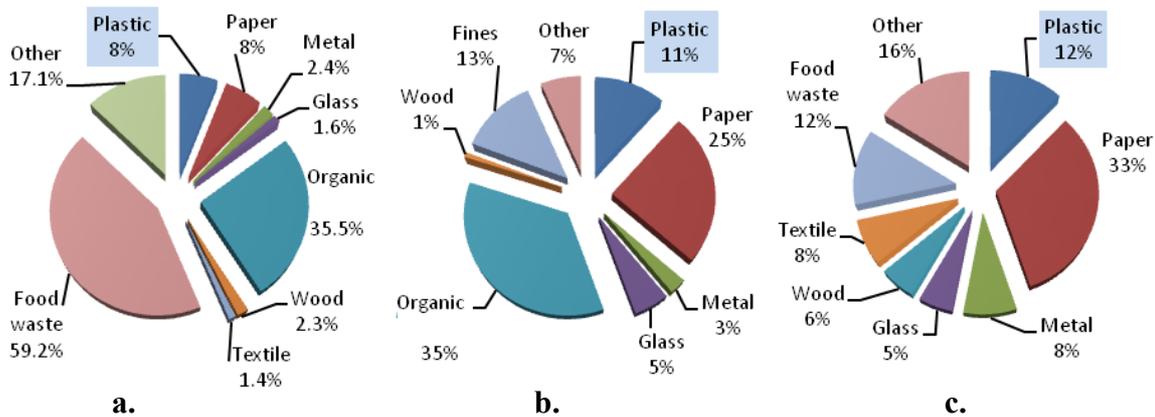


Fig. 3. Composition of MSW in a. Malaysia, b. in Portugal and c. in United States

Conversion of total volume PSW (V_{PSW}) in m^3 into total mass of PSW (W_{PSW}) in kg, can be determined by using Eq. 2.

$$W_{PSW} = \rho_{PSW} \times V_{PSW} \tag{2}$$

where ρ_{PSW} = density of PSW is around 112 kg/m^3 . This value is obtained from the current experiments at the Laboratory of Thermodynamics, Faculty of Mechanical Engineering, UTM. The potential energy PSW (EP_{PSW}) can be determined by using Eq. 3.

$$EP_{PSW} = W_{PSW} \times CV_{PSW} \tag{3}$$

where W_{PSW} = amount of mass in kg PSW and CV_{PSW} = calorific value of PSW, e.g. type of plastic bags and film = 41.5 MJ/kg [2].

The determination of the volume of PSW (V_{PSW}) in 15 cities in Indonesia refers to the value of 8% of V_{MSW} [10]. Thus, the volume PSW of each city can be obtained by using Eq. 1. Meanwhile, the conversion of the volume (m^3) to mass (kg) is calculated using Eq. 2 with a density of PSW (ρ_{PSW}) = 112 kg/m^3 , as well as EP_{PSW} obtained by using Eq. 3. The estimation results are presented in Table 1.

Economic Potential of Utilization the PSW as Fuel Supplements

The economic value of PSW utilization as fuel in a power plant can be determined by the equivalence of the energy content of the fuel. Equivalence of the energy content of the PSW with the energy content of the coal and oil can be performed by using the calorific value of the fuel. The value equivalent to coal (Eq_{Coal}) can be determined by using Eq. 4:

$$Eq_{Coal} = EP_{PSW} \div CV_{Coal} \tag{4}$$

where CV_{Coal} = calorific value of coal is about 27 MJ/kg [12]. Meanwhile, the value of oil equivalent (Eq_{Oil}) can be determined by using Eq. 5:

$$Eq_{\text{Oil}} = EP_{\text{PSW}} \div CV_{\text{Oil}} \quad (5)$$

where CV_{Oil} = calorific value of oil around 48.5 MJ/kg [5]. Furthermore Eq_{Coal} and Eq_{Oil} value can be obtained by using Eq. 4 and Eq. 5. The estimated potential energy and economic values of the PSW can be seen in Table 1.

Table 1 presents the potential energy and economic potential of PSW of each of the 15 cities in the analysis. The potential energy of the PSW is the largest in Jakarta, and the smallest in Mataram. In total, the potential production of PSW (W_{PSW}) is around 693 tons per day with the potential energy (EP_{PSW}) produced is around 28,752,528 MJ/day. This means that if the PSW is used as an alternative fuel for coal, it can save about 1,065 tons/day of coal and about 593 tons/day of oil. The description indicates that if the PSW is used to replace coal in a power plant, it will reduce the operational costs of power plant every day. The potential energy can produce electrical energy (EE_{PSW}) is around 7,987 MWh/day. Meanwhile, the economic value of PSW is equivalent to coal (Eq_{Coal}) with around 1,065 tons/day and equivalent to oil (Eq_{Oil}) is around 593 tons/day.

The potential energy can be used to substitute the use of coal at the power plant with the principle of co-firing with coal for improving the power plant capital costs [13], or can be used as a PSW supplement coal to save the use of coal [14].

Table 1. Potential energy and economic value of PSW is generated every day in 15 cities in Indonesia

No.	City	Average value from year 2008-2010						
		V_{MSW} [m ³]	V_{PSW} [m ³]	W_{PSW} [ton]	EP_{PSW} [MJ]	EE_{PSW} [MWh]	Eq_{Coal} [ton]	Eq_{Oil} [ton]
1	Jakarta	28,464	2,277	255	10,583,496	2,940	392	218
2	Surabaya	8,711	697	78	3,239,656	900	120	67
3	Bandung	7,483	599	67	2,784,152	773	103	57
4	Medan	5,428	434	49	2,017,232	560	75	42
5	Semarang	4,340	347	39	1,612,856	448	60	33
6	Makassar	3,758	301	34	1,399,048	389	52	29
7	Palembang	3,376	270	30	1,254,960	349	47	26
8	Pekanbaru	3,188	255	29	1,185,240	329	44	24
9	Padang	2,760	221	25	1,027,208	285	38	21
10	Denpasar	2,494	200	22	929,600	258	34	19
11	Manado	1,636	131	15	608,888	169	23	13
12	Samarinda	1,604	128	14	594,944	165	22	12
13	Pontianak	1,498	120	13	557,760	155	21	11
14	Kupang	1,439	115	13	534,520	149	20	10
15	Mataram	1,131	91	10	422,968	118	16	9
Total		77,310	6,186	693	28,752,528	7,987	1,065	593

Utilization of PSW as fuel in power plants

PSW utilization as fuel in a power plant in Indonesia is still under study. Based on the data obtained as in Table 1, it appears that some areas that have great potential for PSW, such as Jakarta, Surabaya, Bandung, Medan, and Semarang that have the electrical energy potential of around 448 - 2,940 MWh/day. The potential energy of PSW can be utilized as fuel supplement by co-combustion with coal and biomass at power plants [15]. Similarly, can be used as mono-fuel combustion at power plant in Malaysia which produces 8.9 MW of electricity [16].

Conclusion

The plastic solid waste (PSW) in Indonesia is one of the materials of environmental pollution, but it has potential energy that can generate electrical energy. PSW has potential as an alternative fuel because it has a calorific value of about 41.5 MJ/kg greater than the calorific value of other fossil fuels and waste materials except fuel oil. Potential PSW available in 15 cities, the amount varies on each city depends on the amount of MSW generated. PSW potential analysis results are available in 15 cities is varied, which is about 10 - 255 tons/day which can generate electrical energy is around 118 - 2,940 MWh/day. In total, PSW potential energy obtained is about 693 tons/day, electrical energy is around 7,987 MWh/day, equivalent to coal ($E_{q_{Coal}}$) is around 1,065 tons/day, and equivalent to oil ($E_{q_{Oil}}$) is around 593 tons/day. The PSW utilization as fuel in the power plant can be done by co-combustion with coal, co-combustion with biomass, or mono-combustion. In conclusion, though PSW is a hazardous contaminant, otherwise it has the potential energy and economic potential to be used as an alternative fuel in the power plant. Thus, it can save the use of coal and can overcome the environmental problems caused by pollution of PSW in Indonesia.

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