Potential of solid waste utilization as source of refuse derived fuel (RDF) energy (case study at temporary solid waste disposal site in West Jakarta)

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Abstract. This study aims to measure the volume of solid waste generated as well as its density, composition, and characteristics, to analyze the potential of waste in TPS to become RDF materials and to analyze the best composition mixture of RDF materials. The results show that the average of solid waste generation in TPS reaches 40.80 m³/day, with the largest percentage of its share is the organic waste component of 77.9%, while the smallest amount of its share is metal and rubber of 0.1%. The average water content and ash content of solid waste at the TPS is 27.7% and 6.4% respectively, while the average calorific potential value is 728.71 kcal/kg. The results of solid waste characteristics comparison at three TPS indicate that TPS Tanjung Duren has the greatest waste potential to be processed into RDF materials with a calorific value of 893.73 kcal/kg, water content level of 24.6%, and low ash content of 6.11%. This research has also shown that the best composition for RDF composite materials is rubber, wood, and textile mixture exposed to outdoor drying conditions because it produced low water content and low ash content of 10.8% and 9.6%, thus optimized the calorific value of 4,372.896 kcal/kg.

Keywords: briquette, refuse derived fuel, solid waste

1. Introduction
Related to the increasing energy demand in Indonesia, the current supply of electric power cannot compensate for the high rate of energy demand of 7–8% per year [5] so that an alternative source is needed. Solid waste has a high potential to generate energy and has economic value for society. One alternative to solid waste processing is by applying the concept of Waste-to-Energy, which is a process to produce energy in the form of electricity or heat coming from burning solid waste.

The variety of communal activities in urban areas increases along with the development of technology that further promotes the generation rate of solid waste. The amount of solid waste generated in Indonesia has reached 175,000 tons/day [7]. DKI Jakarta, especially West Jakarta, is one of the areas with the biggest solid waste generation of about 1,574, 92 tons/day [1].

Refuse Derived Fuel (RDF) is a material that has a high calorific value, formed from municipal solid waste that has been separated from its noncombustible materials and metals. Refuse Derived Fuel (RDF) is used as a fuel that is shaped like a pellet/briquette, will not rot even if it is stored for a long time which then makes it quite practical to be transported, and its heating value is greater than the unprocessed waste. Also, the burning results of RDF materials are more environmentally friendly compared to coal use.
Based on research conducted by [2], there are several types of waste that can be used as raw materials RDF seen from the calorific value. Kara's research [4], shows the specification of waste parameters used in the manufacture of RDF, which has a minimum heat value of 4000 Kcal/kg. Research on the utilization of solid waste from the landfill as a source of energy has also been done by [6] which shows that the potential solid waste reduction of 256 tons/day if processed as RDF. In this study, the potential of municipal waste that is used as a source of energy comes from municipal solid waste in the Temporary Solid Waste Disposal Site (TPS). Related to that, the research aims to analyzing solid waste composition in TPS and examine the potential utilization of municipal solid waste, especially from TPS as a new energy source (RDF).

2. Research Method

2.1. Sampling location
The samplings of solid waste were conducted at three Temporary Solid Waste Disposal Sites (TPS) located in West Jakarta area. They are TPS Arjuna in South Tanjung Duren Village, TPS Tanjung Duren in Tanjung Duren Village, and TPS Makaliwe in Grogol Village, West Jakarta. The samples were then analyzed in Environmental Laboratory, Faculty of Landscape Architecture and Environmental Technology, Trisakti University, and in Physical Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology.

2.2. Types of data collected
Types of the primary data collected in this study include data of solid waste generation, solid waste composition, water content, ash content, potential calorific value, and data on the quality of the generated RDF briquettes. The secondary data used are data from RDF-related literature studies, as well as the calorific value data of each component derived from the previous research.

2.3. Making of RDF briquettes
Making of RDF briquettes is done by the following steps:
   1) Preparation of materials,
   2) Shredding,
   3) Drying 1,
   4) Carbonization process,
   5) Sieving process,
   6) Mixing raw materials,
   7) Molding and compaction,
   8) Drying 2,
   9) Testing of RDF briquette quality.

| Treatment | Mixed Composition of Solid Waste | Adhesive |
|-----------|----------------------------------|----------|
| A1, A1, A2 | Plastic : 6.5 gr | 20 gr |
| A2, A2 | Paper : 4.6 gr | 20 gr |
| Rubber : 0.2 gr | 20 gr |
| Wood : 0.5 gr | 20 gr |
| Textile : 0.3 gr | 20 gr |
| Organic : 87.9 gr | 20 gr |
| B1, B1 | Rubber : 20 gr | 20 gr |
| B2, B2 | Wood : 50 gr | 20 gr |
| Textile : 30 gr | 20 gr |
| C1, C1 | Organic : 100 gr | 20 gr |

1= Drying in Outdoor Condition; 2= Drying in Indoor Condition
The drying process in making RDF briquettes has been done in two conditions, namely outdoor conditions and indoor conditions. Furthermore, mixtures were made with a total weight of each 120 grams treatment, consisting of 100 grams of solid waste composition treatment and 20 grams of adhesive. The adhesive was prepared by blending 20 grams of starch and 200 ml of water which then boiled. Treatment variation and mixture composition were determined based on the condition of solid waste composition at the field, as well as the heating value of each component. Three experimental treatments were conducted to obtain the best composition variation of RDF briquette material, each of which consists of two replications that can be seen in Table 1.

3. Results and Discussion

3.1. Waste generation and composition

The solid waste generation data were collected based on the number and the capacity of the carrier vehicles entering the TPS so that the mean daily volume at each TPS could be obtained. Table 2 shows the average number of garbage carts, the amount of solid waste, and the density of solid waste in each TPS.

| TPS        | Number of Carts | Carts capacity (m³) | Solid Waste volume (m³/day) | Density (kg/m³) |
|------------|-----------------|---------------------|----------------------------|-----------------|
| Arjuna     | 19              | 1.5                 | 28.50                      | 147.91          |
| Makaliwe   | 33              | 1.8                 | 59.40                      | 183.17          |
| Tanjung Duren | 23            | 1.5                 | 34.50                      | 189.29          |
| Mean       |                 |                     | 40.80                      | 173.46          |

![Figure 1. Solid waste composition at TPS.](image)

The solid waste composition in this study was measured using SNI 19-3964-1994 regarding the method of sampling and measuring the generation and composition of municipal solid waste samples. Figure 1 shows the average composition of solid waste on all three TPS. The organic waste component
has the highest percentage of 77.9%, followed by the residual waste of 11.7%, plastic waste by 5.6%, paper waste by 3.9%, 0.4% wood waste, 0.2% textile, and the smallest component is metal and rubber waste of 0.1%.

3.2. Water and ash content of solid waste
The average value of ash content for the rubber component in the first order was 1.45%, followed by the plastic component of 1.27%, the paper component of 0.88%, the organic component of 0.84%, wood component by 0.53%, and textile component by 0.43%. The difference of ash measured is due to the content characteristics in the solid waste components, including the high value of ash content since there are inorganic materials that cannot burn at a temperature of 550°C, leaving some remains formed to ash.

Table 3: Average of water content and ash content on TPS.

| TPS        | Water content (%) | Ash content (%) |
|------------|-------------------|-----------------|
| Arjuna     | 29.22%            | 0.96%           |
| Makaliwe   | 28.73%            | 0.90%           |
| Tanjung Duren | 23.67%       | 0.83%           |
| Rata-rata  | 27.21%            | 0.90%           |

Table 3 shows the average moisture content and ash content in each TPS. TPS Makaliwe has the highest mean of the water content of 29.22%, followed by TPS Arjuna of 28.73%, and Tanjung Duren at 23.67%. Meanwhile, TPS Arjuna owns the highest rate of the ash content of 0.96%, followed by TPS Makaliwe of 0.90% and TPS Tanjung Duren with the lowest rate of ash content at 0.83%. The average water content of the TPS is 27.21%, while the ash content is 0.90%.

3.3. Result of solid waste potential analysis based on heat value
Figure 2 shows the ratio of the heating value of each solid waste’s component at all three TPS. It can be seen that the calculated RDF briquette’s calorific value could not comply with the various RDF standards since each component for each TPS still has high water content and ash content. Thus, a scheme to optimize the yielded calorific value needs to be arranged. Besides, components with high calorific values such as plastic and rubber have relatively fewer quantities than the organic waste component in the TPS.

3.4. Quality of RDF
Solid waste samples used for RDF materials are solid waste originating from TPS Tanjung Duren because it has the most suitable potential in terms of calorific value, moisture content, and ash content. Compared to the other TPS, solid waste at TPS Tanjung Duren has the highest calorific value of 893.73 kcal/kg with water content and low ash content of 24.6% and 6.11% respectively. The produced RDF materials are included in the type of RDF-5, which is combustible. They were then compacted and printed in the form of briquettes.

3.4.1. Water content, ash content, and heat value of briquettes
Table 4 shows the means of moisture content, ash content, and heating value of RDF briquette test results in the laboratory. It can be seen that the average water content of the treated briquettes is ranging from 7.36–7.80%, indicating that the moisture content of RDF briquettes has conformed to the maximum water content standard of 15% based on [6].
Table 4. Water content, ash content, and heating value of briquette testing results.

| Treatment | Moisture Content (%) | Ash Content (%) | Heat Value (Kcal/kg) |
|-----------|---------------------|----------------|---------------------|
| A         | 7.80                | 6.10           | 4,168.75            |
| B         | 7.36                | 4.9            | 4,366.66            |
| C         | 7.36                | 5.9            | 4,201.64            |

For ash content of briquettes, the results show that the ash content of each treatment has also fulfilled the maximum standard of 10% as stated in [4] as well. Contrarily, based on Table 4, the calorific value contained in the briquettes of each treatment could not meet the standard of 4,400 kcal/kg based on the regulation mentioned above. However, when compared to the Finnish, English, and Italian Standards of 3,000–4,000 kcal/kg according to researchers’ [2], [6] standard, the briquette calorific value of each treatment can comply well with the criteria [5].

Following the results of moisture content, ash content, and calorific value of each treatment, the best mixture composition can be determined. The treatment that yielded the lowest moisture and ash content while keep maintaining high calorific value is treatment B that is a combination of rubber, textile, and wood with outdoor drying conditions. In 2016, the population in Grogol Petamburan sub-district is 225,038 people. Assuming that the solid waste generation rate is 0.5 kg/person/day, the total solid waste generation in Grogol Petamburan sub-district is 112,519 tons/day. Taking those data into account, if the waste is utilized as briquettes with mixture composition of B1 i.e. rubber, wood, and textile, the potential of the produced energy will be equal to 204.73 kW/hour or 4,913.62 kW/day.

4. Conclusion
The most potential solid waste to be processed into RDF materials is located in TPS Tanjung Duren because compared to the other TPS, it has the highest calorific value of 893.73 kcal/kg and the lowest water and ash content of 24.6% and 6.11% respectively. The best composition mixture for RDF materials concerning the levels of moisture content, ash content, and calorific value is B1 briquette treatment of rubber, wood, and textile with outdoor drying conditions. It produced a moisture content of 6.89%, an ash content of 4.9%, and a heating value of 4,372.896 kcal/kg.

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