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Mass Balance Analysis of Refuse Derived Fuel Production at Material Recovery Facility

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ABSTRACT

Indonesia produces approximately 8,000 tonnes of waste per day, posing a serious challenge for national waste management. The LM & RDF landfill site in west java province indonesia stands as a pioneering facility that transforms waste into Refuse Derived Fuel (RDF) to support renewable energy. This practical work aims to analyse the composition of waste, mass balance, and RDF quality against SNI 8966:2021. The methods include sampling 100 kg in accordance with SNI 19-3964-1994, sorting, process observation, and laboratory testing. The results show a dominance of organic (38%) and plastic (28%) fractions. The mass balance shows that from an input of 354.9 tonnes/day, the final RDF product is only 1.6% (≈5.6 tonnes/day), which is lower than the plant's design of 35%. Laboratory tests showed high moisture content (44–59%) due to the rainy season and waste heterogeneity, and ash content in mixed samples reached 25.66%, slightly exceeding the threshold of <25%. These findings confirm the need to improve sorting and drying efficiency, while positioning landfill site in west java province indonesia as a living laboratory for waste management innovation towards renewable energy.

Keywords: municipal solid waste; RDF; mass balance; RDF quality; landfill

INTRODUCTION

The issue of municipal solid waste has become an increasingly complex global issue in line with population growth, urbanisation and unsustainable consumption patterns. In 2016, global waste generation reached 2.01 billion tonnes and is projected to increase to 3.40 billion tonnes by 2050 [1]. The waste management sector also contributes significantly to greenhouse gas emissions, accounting for approximately 4.8–5.3% of the global total, with methane from landfills being the main contributor. This situation is exacerbated by the high flow of plastic waste into the oceans, which reaches 8 million tonnes per year, causing ecosystem losses worth US$13 billion per year [2].

Indonesia, as one of the most populous countries, faces serious challenges in waste management. National waste production is estimated to reach 8,000 tonnes per day or around 3 million tonnes per year, according to data from the Ministry of Environment and Forestry in 2020. Reliance on landfill disposal remains dominant, putting significant pressure on land and environmental capacity. The problem is particularly acute in the Greater Jakarta metropolitan area, with the landfill site in west java province indonesia as the main disposal site receiving thousands of tonnes of waste every day. This situation has driven the need for more sustainable alternative treatment technologies.

One approach that is being developed is the use of Refuse Derived Fuel (RDF) technology, which converts municipal waste into alternative fuel for industry, especially cement. This technology not only reduces waste, but also produces fuel with a calorific value equivalent to 50-70% of sub-bituminous coal [3]. The Indonesian government has implemented an RDF Plant in landfill site in west java province indonesia, as a pilot project with a design capacity of 2,000 tonnes/day. The final RDF product from this facility is supplied to the national cement industry in an effort to support energy transition and reduce dependence on coal. However, the application of RDF technology still faces a number of challenges, including the effectiveness of sorting combustible materials, the suitability of the moisture content of RDF products to quality standards, and the stability of waste composition as raw material. These conditions raise questions about the extent to which the operational processes at the landfill site in west java RDF Plant have met technical standards and produced RDF of consistent quality.

Based on this background, this study aims to: (1) identify the composition of waste entering the landfill site in west java RDF Plant, (2) analyse the RDF production process through a mass balance approach, and (3) evaluate the quality of RDF products based on moisture and ash content parameters with reference to SNI 8966:2021.

LITERATURE REVIEW

Definition and Characteristics of Waste

Waste is material left over from human activities or natural processes that can no longer be used in its original form [4]. In general, the composition of municipal solid waste (MSW) is dominated by organic fractions (43–54%), plastics (13–24%), paper (14–17%), and other components such as textiles, metals, glass, and inorganic residues [5]. Variations in composition are influenced by geographical, socio-economic, and lifestyle factors. High organic content is usually a challenge in thermal treatment due to the relatively high moisture content (40–80%) [6].

Waste Management and Processing

Waste management in Indonesia is regulated by UU No. 18 of 2008, with two main approaches: reduction through the principles of reduce, reuse, recycle (3R) and handling through containment, collection, transfer, processing, and final processing. Conventional methods such as landfilling still dominate, but are considered unsustainable [7]. Modern treatment technologies include biological methods (composting, anaerobic digestion), thermal methods (incineration, pyrolysis, RDF), and mechanical methods (shredding, compaction). RDF falls under the category of thermal processing, which can reduce waste volume by 75–92% and produce energy with a calorific value of 15–19 MJ/kg [8].

Refuse Derived Fuel (RDF)

RDF is an alternative fuel produced from municipal waste after undergoing a process of sorting, shredding, drying, and separating non-combustible materials [9]. RDF can take the form of fluff, pellets, or bales, with a calorific value of 12–18 MJ/kg, equivalent to 50–70% of the calorific value of sub-bituminous coal [3]. European RDF quality standards stipulate an ideal moisture content of 10–20%, ash content of 5–10%, and sulphur and chlorine content below 0.2% [10]. In Indonesia, RDF quality standards refer to SNI 8966:2021, which sets a maximum moisture content of 15–20% and ash content of <20% depending on the quality class. These parameters are important because they affect calorific value, combustion stability, and acceptance by user industries such as cement factories.

METHODOLOGY

This research was conducted at the LM & RDF Plant in landfill site in west java province indonesia, which has been operating since 2023 with a design capacity of 2,000 tonnes/day. This plant receives 1,000 tonnes of new waste (MSW) and 1,000 tonnes of old waste (landfill mining). The research was conducted during the period of August–September 2025 during the implementation of practical work. This study used a descriptive case study approach using a combination of primary and secondary data. The focus of the analysis included identifying the composition of waste entering the facility, preparing a mass balance to describe the Refuse Derived Fuel (RDF) production process flow, and testing the quality of RDF products through moisture and ash content parameters, which were then compared with the SNI 8966:2021 standard.

Data Collection

Waste composition sampling was carried out in a new waste bunker (Municipal Solid Waste/MSW) using the quartering method in accordance with SNI 19-3964-1994, with a total sample of 100 kg obtained from 10 sacks, each weighing ±10 kg. The collected waste was then sorted into several categories, namely food waste, wood/twigs, paper, plastic, metal, textiles, rubber/leather, glass, and others. Next, laboratory tests were conducted to analyse quality parameters, particularly moisture and ash content, with reference to ASTM D-3173-03 and ASTM E949-88 standards for moisture content, and ASTM D-3175-02 for ash content. Meanwhile, secondary data was obtained from the landfill site in west java province indonesia RDF Plant technical documents, daily operational data, and literature related to RDF quality standards (SNI 8966:2021 and international references).

Data Analysis

Waste composition was calculated based on wet weight percentage (%ww) for each category, while the mass balance was compiled using input-output data for each processing unit (manual screening, magnetic separator, shredder, trommel, SDB, kiln dryer, drying conveyor, and secondary shredder) with a calculation basis of 100% waste input. RDF quality analysis is carried out by calculating the average moisture and ash content, then comparing it with the SNI 8966:2021 quality standard, while all analysis results are presented in tables and graphs to facilitate interpretation.

OVERVIEW

Location and Background of the Plant

The LM & RDF Plant landfill site in west java province indonesia is located in, Bekasi City, West Java, covering an area of approximately 7.5 hectares. Construction of this facility began in 2022, with a trial period starting in early 2023 and official operations commencing in June 2023. The plant is designed with a processing capacity of 2,000 tonnes/day, consisting of 1,000 tonnes of new waste (Municipal Solid Waste / MSW) and 1,000 tonnes of old waste (Landfill Mining / LFW). The final product, RDF, is supplied to the cement industry, namely PT X. (±625 tonnes/day) and PT Y (±75 tonnes/day).

RDF Production Process

The RDF production process at this facility operates 16 hours per day on a two-shift system, starting from the bunker where new waste is manually sorted to separate large, hazardous and incombustible residues.

The main flow then passes through a magnetic separator to separate ferrous metals, followed by a primary shredder to chop the waste into more homogeneous pieces, and a trommel screen that separates organic and inorganic fractions based on particle size. The organic fraction is then dried through a sun-dry bay (SDB) and kiln dryer to a moisture content of <22%, while the inorganic fraction is dried using a drying conveyor. Both dry fractions are then re-shredded by a secondary shredder to a size of <50 mm before being mixed into the final RDF, which is then stored in a warehouse for distribution to the cement industry.

Supporting Facilities and Infrastructure

Supporting facilities for the plant include an RDF warehouse, old and new waste hangars, a wastewater treatment plant for leachate treatment, retention ponds, weighbridges, a truck washing area, a quality testing laboratory, and other supporting areas such as operational offices, workshops, a prayer room, and green open spaces. The laboratory is very important because it is used to test the quality of RDF based on parameters such as moisture content, ash content, and calorific value to ensure that it meets the off-taker's standards.

RESULTS AND DISCUSSION

Composition of Incoming Waste

Sampling was conducted in the MSW bunker with a total of 100 kg of reference waste in accordance with SNI 19-3964-1994. The sorting results showed in figure 1 that the largest fractions were food waste (38%) and plastic (28%), followed by paper (9%), wood/twigs (5%), textiles (5%), glass (5%), rubber/leather (3%), metal (2%), and other categories (5%). The dominance of organic and plastic fractions is in line with the characteristics of urban waste in Indonesia, which is generally rich in organic material but also experiences an increase in plastic waste along with urbanization [6].

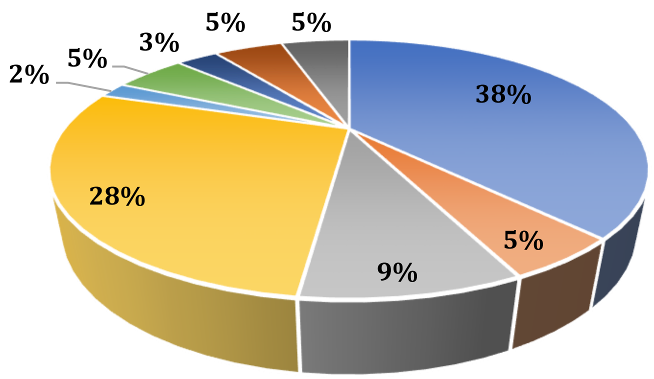

FIGURE 1: Waste Composition.

Mass Balance Analysis

Based on input-output records in each operating unit, the total waste input of 354,913 tonnes/day (100%) only produced RDF products amounting to 1.60% of the input base. This is far below the plant's design target of 35% RDF output from total waste input. In the initial stage (manual screening), approximately 43.86% of the material is passed on to the next process, while 1.88% immediately becomes residue.

After passing through a magnetic separator, shredder, trommel, SDB, kiln dryer, drying conveyor, and secondary shredder, the amount of material is drastically reduced due to the high fraction of water and inorganic residue.

Factors contributing to the low RDF yield include:

- High moisture content in organic waste.
- Inefficient initial sorting, resulting in a high proportion of inert fractions being mixed in.

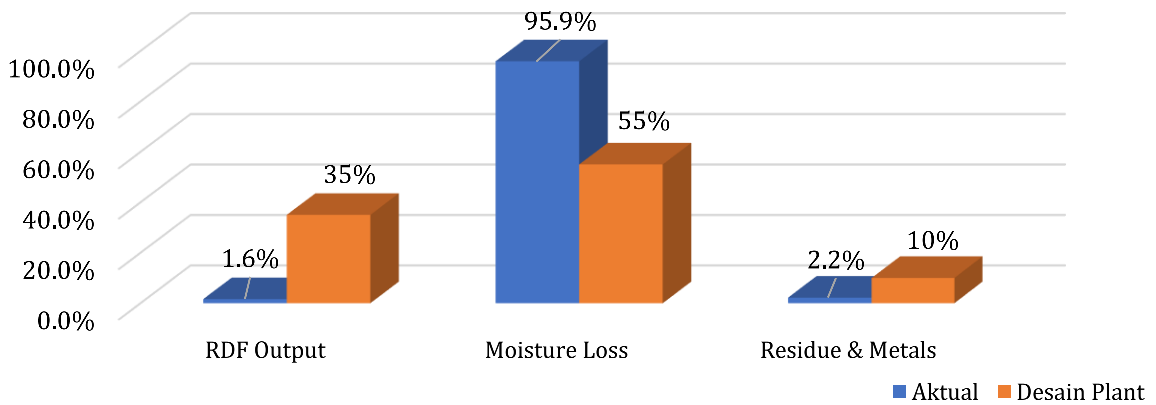

FIGURE 2: Comparison of Research Results and Plant Design.

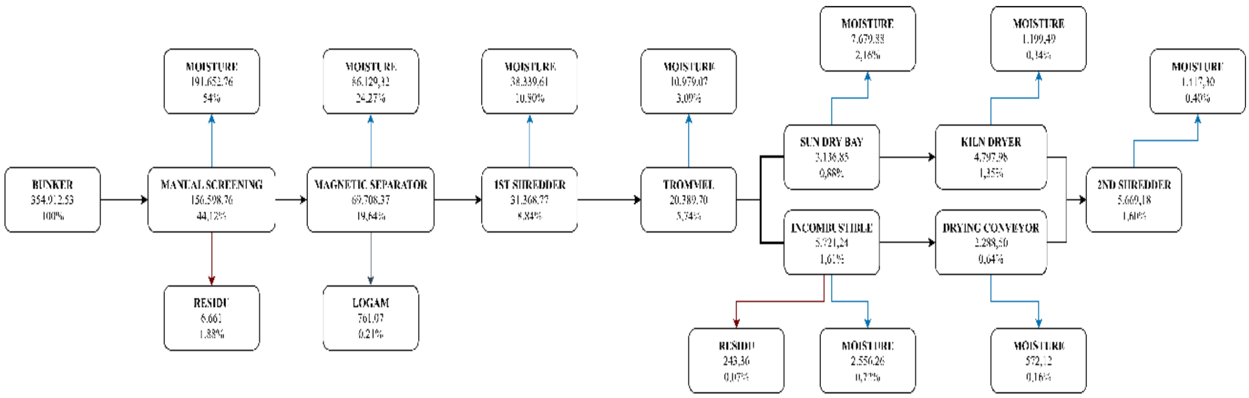

FIGURE 3: Process Flow in Each Processing Unit.

RDF Quality Analysis

Laboratory test results for RDF samples show:

- Moisture Content (Figure 4): average results of around 18–22%. This value is still within the range of SNI 8966:2021 class 2 (≤20%), but exceeds the class 1 limit (<15%).
- Ash Content (Figure 5): average result of approximately 15–25%. Samples with ash content >20% do not meet SNI class 2 and class 3 quality standards, indicating a high proportion of inorganic fractions (soil, sand, gravel) mixed in.

These results confirm that the quality of RDF in landfill site in west java province indonesia does not consistently meet national standards. Improvements to the sorting system, particularly to reduce the inert fraction, need to be prioritised in order to make RDF more competitive for the cement industry.

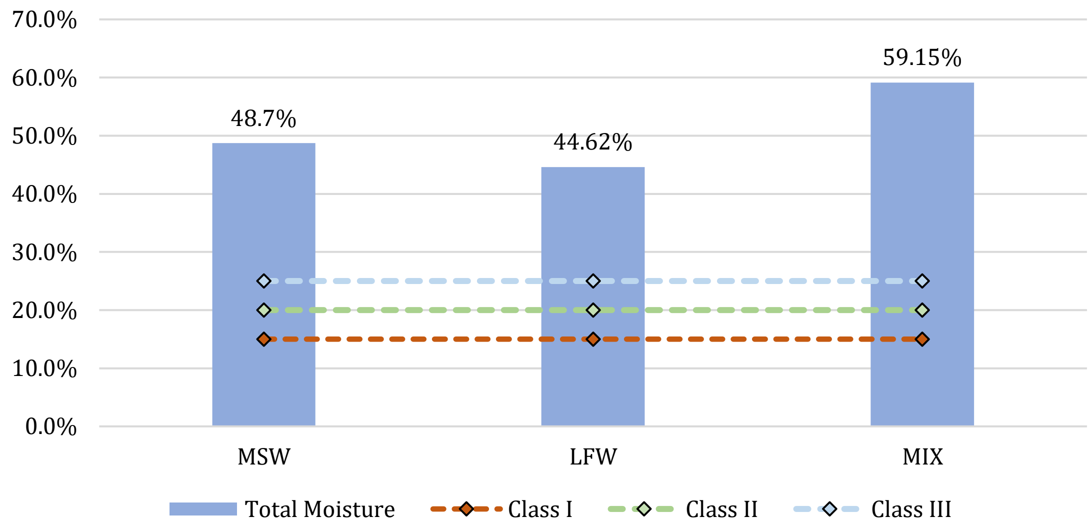

FIGURE 4: Compatibility of Moisture Content Test Results with SNI 8966:2021.

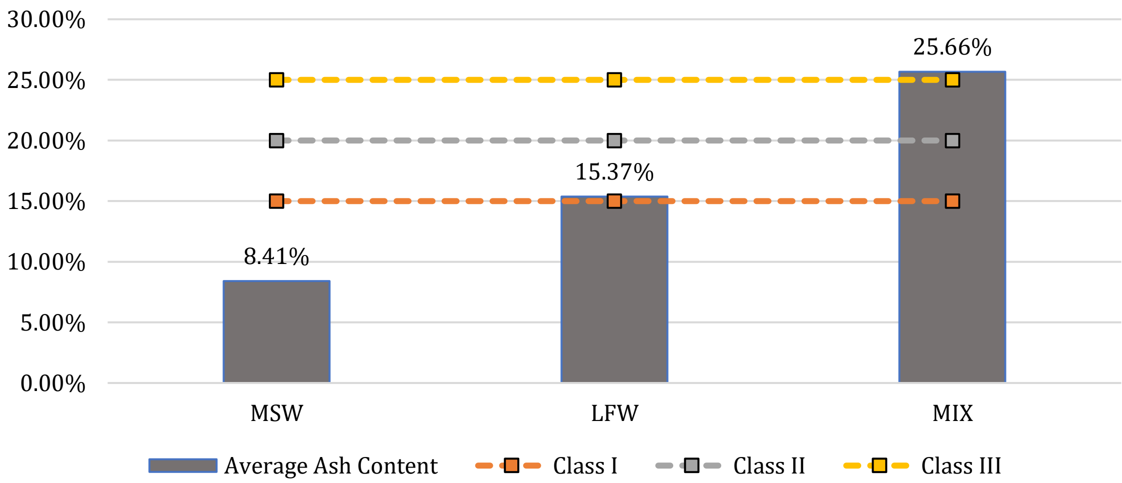

FIGURE 5: Compatibility of Ash Content Test Results with SNI 8966:2021.

CONCLUSIONS

The analysis of waste processing using Refuse Derived Fuel (RDF) technology at the LM & RDF Plant located at a landfill site in West Java Province, Indonesia, indicates that the composition of incoming municipal solid waste is predominantly composed of organic materials (38%) and plastics (28%). The remaining fractions consist of paper, wood and twigs, textiles, glass, rubber or leather, metals, and other minor components. This waste composition is characteristic of urban waste streams in Indonesia, which are typically rich in biodegradable organic matter with a substantial contribution from plastic waste, thereby influencing both the processing strategy and the potential energy recovery performance of the RDF system.

The mass balance assessment of the RDF production process demonstrates that the final RDF output accounts for only approximately 1.60% of the total waste input, amounting to 354,913 tonnes per day, which is significantly lower than the plant's design target of 35%. This substantial discrepancy highlights inefficiencies within the processing chain, primarily attributed to the high moisture content of the incoming waste and the presence of inert materials that remain mixed within the processing stream. These factors reduce the effective conversion of waste into usable RDF and limit the overall productivity of the facility.

Furthermore, the quality evaluation of the produced RDF reveals that it has not yet consistently complied with the requirements of SNI 8966:2021. The measured moisture content ranges from 18% to 22%, which satisfies the criteria for class 2 RDF but exceeds the threshold for class 1. In addition, the ash content varies between 15% and 25%, with several samples surpassing the maximum allowable limit for class 3 RDF. These findings underscore the necessity for improvements in upstream waste sorting, enhanced removal of inert materials, and more effective drying systems to achieve stable and standardized RDF quality.

Overall, the landfill site in West Java Province RDF Plant has demonstrated its role as a pilot facility for converting municipal solid waste into alternative fuel. However, further technical optimization is required, particularly in the areas of waste segregation, moisture reduction, and quality control. Addressing these aspects is essential to ensure compliance with national RDF standards and to enhance the reliability of RDF as a sustainable energy substitute for use in the cement industry.

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