The design of Material Recovery Facilities (MRF)-based Temporary Disposal Site (TDS) at Universitas Airlangga campus C

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Abstract. Material Recovery Facility is a waste management method applied to solve the solid waste problem. This plan uses a sampling method to determine the generation, composition, material balance, and volume of solid waste, as well as for the determination of MRF-based Temporary Disposal Site design at Universitas Airlangga Campus C. Sampling results indicated that the solid waste generation rate in administrative and learning activities were 0.081 and 0.018 kg/person/day; gardening 0.0035 kg/m²/day, and street sweeping 0.66 kg/m/day. The percentages of organic waste component of administrative and learning activities were 28.01% and 58%, 96% for gardening, and 100% for street sweeping. The material balance of waste processed at the temporary disposal site and waste disposed to landfill by 612.19 and 259.56 kg/day or 70.23 and 29.77%. The total waste volume was 19.43 m³/day. Therefore, it can be concluded that the design of MRF-based temporary disposal site at Universitas Airlangga Campus C may reduce the waste generation rate disposed to landfill.

1. Introduction

Based on Law No. 18 of 2008, solid waste is the residue from daily activities of humans and/or natural processes in solid form [1]. One source of solid waste that needs observation on its management is institutional solid waste, such as schools, colleges, hospitals, and prisons [2]. Solid waste in higher education such as colleges and university, of which from the composition has more than 65% could have been diverted through waste reduction, recycling and composting activities[3,4].

The composition of solid waste in the Faculty of Science and Technology, Universitas Airlangga (FST UNAIR) comprises plastics, organic materials, food packaging, styrofoam, infectious waste, Hazardous and Toxic Materials, and leaves and branches from the garden [5]. The composition of FST UNAIR waste has a similarity to the composition of campus waste at UPS "Veteran" Jawa [6].

A Material Recovery Facility (MRF) is a place where solid waste are delivered to be separated, processed and stored for later use as raw materials for remanufacturing and reprocessing [7]. MRF is a method of integrated waste management, which is able to reduce the waste generation rate entering landfills. The utilization of the facility is expected to optimize solid waste management in order to maintain the surrounding environment. Therefore, it is necessary to design appropriate MRF-based temporary disposal sites in Universitas Airlangga Campus C as an institutional solid waste source.

2. Research Methods
The study was conducted at Campus C, Universitas Airlangga, Surabaya from March 2012 to July 2012. The instruments used in this research are 100 kg Camry weighing scale, 2 kg Oxone weighing scale, broom, 20x20x50 cm density box, 30 cm ruler, 450 cm Krisbow meter tape, HOL walking measurement, 200x200 cm tarpaulin base for sorting, digital camera, and AutoCad 2010 software. The materials used are black and white plastic bags with the size of 60x100 cm and 40x65 cm, rubber gloves, and masks. Sampling was conducted for 8 (eight) days.

2.1. Waste generation
The method used was weight-volume analysis [2]. Waste generation calculated using Equation (1) and (2).

\[
\text{Growth Rate (kg/person/day)} = \frac{\text{Mean of Waste Generation (kg day\(^{-1}\))}}{\text{The number of persons in UNAIR Management Office}} \tag{1}
\]

\[
\text{Waste generation (kg/day)} = \text{Generation Rate} \times \text{Number of Persons in Campus C} \tag{2}
\]

Solid waste from street swiping was calculated per 5 meter using the equation (3) and (4).

\[
\text{Waste generation rate (kg/m/day)} = \frac{\text{Generation rate (kg/5m/day)}}{5} \tag{3}
\]

\[
\text{Waste generation (m)} = \text{Generation rate (kg/m/day)} \times \text{length of road (m)} \tag{4}
\]

2.2. Waste component
The determination of waste composition was done by sorting waste from source and classifying by component. Subsequently, it was measured by weight and calculated using the equation (5).

\[
\text{% Composition} = \frac{\text{Component weight}}{\text{Total weight}} \times 100\% \tag{5}
\]

2.3. Waste density
The density of solid waste was obtained by (1) weighing an empty box, (2) putting waste into the box and weighing it, (3) compressing the solid waste in the box by dropping it from 30 cm high for 3 times, (4) weighing the box with compressed waste, (5) measuring the height of the waste after it was tapped, and (6) calculating using the equation (6) until (9).

\[
\text{Waste density (kg/m\(^3\))} = \frac{\text{Weight after tapping}}{\text{Waste volume (m\(^3\))}} \tag{6}
\]

\[
\text{Waste volume (m\(^3\))} = W \times L \times H_{\text{waste}} \tag{7}
\]

\[
\text{Weight recovery} = \text{Waste generation per component} \times \% \text{ Recovery} \tag{8}
\]

\[
\text{Weight of waste to landfill} = \text{Waste generation per component - Weight recovery} \tag{9}
\]

The data was analyzed using descriptive analytical method and applied to the design of MRF-based temporary disposal sites at Universitas Airlangga Campus C.

3. Result and Discussion
3.1. Waste generation
Waste generation is the amount of waste produced by a community in units of volume and weight per capita per day, or per building width, or per road length [8]. Universitas Airlangga Campus C is a source of institutional waste with a waste generation rate of 0.081 and 0.018 kg/person/day, 0.0035 kg/m\(^3\)/day and 0.17; 0.05; 0.16; 0.03; 0.02; 0.00; 0.03; 0.03; 0.17 kg/m\(^3\)/day for administrative activities, learning activities, gardens, and street sweeping. Based on SNI 19-3983-1995, the waste generation rate at UNAIR Management Office was still in the range of 0.025-0.100 kg/person/day, or 0.081 kg/person/day. Similarly, the waste generation rate in FST UNAIR is in the range of 0.010-0.020 kg/person/day, which is 0.018 kg/person/day [9]. Meanwhile, the total amount of waste generated at Universitas Airlangga Campus C for administrative activities, learning activities, gardens, and street sweeping activities were 49 kg/day, 122 kg/day, 974 kg/day, 77.7 kg/day.

The waste generation of Universitas Airlangga Campus C is influenced by existing activities. If there are special events, waste generation for the education and administration building will increase. Another factor that affects waste generation is the work hours at UNAIR Management Office, which is 8 hours/day. The more time spent for activities, the higher the waste generation rate per person. Meanwhile, the waste generation rate in FST UNAIR is lower because not everyone in the faculty has a full schedule during working hours. There are some people who only follow learning activities, so
the waste generation rate per person is low. These circumstances do not apply to an average of waste generated from gardens and street sweeping as it is not affected by human activity, but by the surrounding environmental conditions. For example, leaves that fall from the trees and plants along the way, which are affected by the density of trees and plants.

3.2. Composition and percentage of waste component
The solid waste sorting at UNAIR Management Office resulted in 15 (fifteen) components of waste that consisted of paper, plastic, paper towel, plastic bottle, styrofoam, Hazardous and Toxic Materials, organic waste, food packaging, oil-paper, cardboard, glass, tin, water, cloth, and residue. Whereas, the components of waste from FST UNAIR building consisted of 8 (eight) types, namely organic waste, plastic, paper, Hazardous and Toxic Materials, infectious waste, food packaging, styrofoam, and residue (paper towel, cotton, tin, stationery, and stone) [5]. Besides these components, there were also waste in the form of plastic bottle in FST UNAIR building [10]. For the waste composition from the garden of FST UNAIR, it comprised organic waste, paper, plastic, and others (metal, brick, shoes, sandals, can, glass, and cloth) [5]. Meanwhile, the component of waste from street sweeping in Universitas Airlangga Campus C area was leaf. The percentage (%) of waste composition at UNAIR Management Office, FST UNAIR building, FST UNAIR garden, and street sweeping in Universitas Airlangga Campus C is shown in Figures 1 and 2.

Based on the data of waste composition from FST UNAIR garden in percentages as in Figure 2 (a), the design of the MRF-based temporary disposal site should be considered because the garden is quite extensive and has many plants. Therefore, the percentage of organic waste component produced by the garden, which consists of leaves, is very high with 96% [5]. The same also applies to the waste components from street sweeping at Universitas Airlangga Campus C, with 100% of its components being organic waste in the form of leaves that fell from plants and trees. Based on the figures of UNAIR Management Office and FST UNAIR building waste composition, the biggest component was organic waste in the form of food leftovers. Both figures show that food consumption at UNAIR Management Office was higher than at FST UNAIR building. The number of people in FST UNAIR is 2387 persons, and the organic waste it produced amounted to 58% of the total waste weight. Meanwhile, UNAIR Management Office with 375 people produced 28.01% organic waste and 24.96% solid waste in the form of food containers (cardboard, oil paper, and styrofoam).

![Figure 1. Waste Composition in (a) UNAIR Management Office and (b) FST UNAIR](image)

### 3.3. Waste with economic value
The potential economic value of organic waste can be processed by making into compost through a process of composting. The potential of paper waste is that it can processed into recycled paper by carrying out specific processes. Bottles and plastic waste have two potential economic values. They can be converted into other items/new products with other functions, such as by merging several plastic pieces or bottles into crafts. They can also be sold in their original form.
Material balance calculation was performed to determine the amount of waste to be disposed into landfill and what amount to be recovered. Based on the calculation, the waste weight per day that can be recovered in temporary disposal sites was 70.22% of 871.74 kg/day. Whereas the waste disposed to landfill amounted 29.78% of the entire Universitas Airlangga Campus C solid waste. Based on the selling price of compost/5 kg on the market and other components, the gross revenue from waste recovery in MRF-based temporary disposal sites might reach Rp 425,411 or approximately Rp 8,508,212/month.

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3.4. Material Recovery Facilities (MRF) pre-design
Density calculation is useful for obtaining data of waste generation rate in units of volume (m$^3$/person/day and m$^3$/m$^2$/day). The waste density was 38.35 kg/m$^3$ at UNAIR Management Office, 78.20 kg/m$^3$ at FST UNAIR building, and 85.36 kg/m$^3$ at FST UNAIR garden. Waste from street sweeping in Universitas Airlangga Campus C quite varied depending on the condition of the streets. The south gate (in front of UNAIR Educational Hospital) has the highest density, which was 61.80 kg/m$^3$, and the front street of FST-FUNAIR has the lowest density, which was 4.59 kg/m$^3$.

Based on the known density values, the waste volume per day was 0.80 m$^3$/day for UNAIR Management Office, 0.54 m$^3$/day for FST UNAIR, 0.33 m$^3$/day for FST UNAIR garden, and 7.77 m$^3$/day for street sweeping in Universitas Airlangga Campus C area. The volume of waste generation was 0.002 m$^3$/person/day for UNAIR Management Office, 0.0002262 m$^3$/person/day for FST UNAIR building, and 0.00346 m$^3$/m$^2$/day for FST UNAIR garden.

3.5. Material Recovery Facilities (MRF) design
The facilities at the MRF-based temporary disposal site at Universitas Airlangga Campus C are
determined based on recoverable waste components. The planned facilities at the MRF are compost houses (enumeration, composting, maturation, sifting, and packaging area), reception and separation of mixed waste, packing of inorganic goods, warehouses (compost and inorganic goods), and septic tanks for leachate containers. The facilities at the MRF should also support all existing activities, such as workers’ bathroom, composting equipment warehouse, and waste cart parking area. The land of the MRF-based temporary disposal sites is planned to be 1309.61 m$^2$ and 949,135 m$^2$ is needed for processing facilities.

3.5.1. Compost house land. The land needed for composting house is 867.66 m$^2$, consisting of enumeration area, composting and maturation area, sieving and packing area, and compost warehouses of 52.56, 766.5, 37.35, and 11.25 m$^2$. Another part land is allocated only for accepting, sorting, and enumerating waste from street sweeping and gardens. They are not processed in the same facilities that process waste from administrative activities and learning activities because 90% of its components are in the form of organic waste. In the composting area, the distance between the pile of waste and workspace is planned to be 1 and 2 m to ease control and carry the carts. Composting is done directly beside the soft compost pile after sieving, so the waste can be directly weighed and packed without having to be moved to another room. The area of compost warehouse is planned to accommodate the compost for 5 days before it is sold on the 6th day. The stack height of 1.5 m is planned in order to ease the workers in performing the loading and unloading of compost with a workspace of 1 m.

3.5.2. Inorganic waste management land. On this land, the whole sorting is done with the capacity adjusted based on the total waste generated. Manual sorting is done at specially designed sorting tables. Furthermore, the sorted waste is placed on a container or sorting bin. The required land for this inorganic waste management facility is 46, 345 m$^2$. 25.72 m$^2$ is for land sorting and 20,625 m$^2$ is for storage warehouse. The table is placed in the middle of the room with a waste sorting bin around the table and the sorting workers. Determination of the land area for the warehouse is done to accommodate all the land needs for the placement of recovery materials and workers.

3.5.3. Area of containers of residue and hazardous and toxic materials. Containers with the capacity of 1100 L and dimension of 2 x 0.55 x 1 m are used for residue and containers with the capacity of 110-120 L and dimensions of 0.4 x 0.4 x 0.75 m are used for Hazardous and Toxic Materials. The distance between containers would be 0.3 m, the container edges would be 0.5 m, and the worker movement space would be 1 m. Thus, the total area needed for placing containers containing residue and Hazardous and Toxic Materials is 4.44 m$^2$.

3.5.4. Supporting land. Supporting land consists of composting equipment warehouse, bathroom, cart storage area around the composting area, and motorcycle parking area. The composting warehouse is planned to be 70 x 150 cm with a 90 cm door, so it can reach all sides of the warehouse. Bathroom area would be 110x130 cm with 1 closet and water tub. The parking area is planned for 2 carts, 1 cart for transporting waste from the source and the other for operation during composting. The cart parking area is 2.6 m in length and 2 m in width for 2 carts. The motorcycle parking area is to be made based on Parking Space Unit for motorcycles, which is 200x70 cm [11] and is planned to accommodate 10 motorcycles. Therefore, the area is 3.5x5.5 = 19.24 m$^2$.

3.5.5. Septic tank. A standard-sized septic tank is planned to accommodate rinse water from sorting containers and streams from the leachate of the composting area. The septic tank is expected to process wastewater from the temporary disposal site to make it harmless for the environment.

4. Conclusion
The conclusion of this research is the design of MRF-based temporary disposal sites at Campus C Universitas Airlangga has several processing facilities, namely compost houses (52.56 m$^2$ for enumeration area, 766.5 m$^2$ for composting and maturation area, 37.35 m$^2$ for sieving and packaging,
and 11.25m² for compost storage warehouse), inorganic waste management area (25.75 m² for sorting area, and 20.675 m² for storage warehouse), residue and Hazardous and Toxic Materials container area (44.4 m²), supporting area (12 m² for office space, 9 m² for locker room, 6.6 m² for toilet, 19.24 m² for motorcycle parking area, 1.05 m² for composting equipment warehouse, and 5.2 m² for cart parking area), and septic tanks.

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