Integrated waste management system in Universitas Negeri Semarang, Indonesia

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Abstract. Waste has become a global problem worldwide. Universitas Negeri Semarang (UNNES) also cannot avoid this problem. Therefore, UNNES has included the sustainable waste management system in its long-term target. However, this target will not be achieved if UNNES does not take any real action. Starting this year, UNNES begin to operate integrated, independent, and sustainable waste processing to replace conventional waste processing, which only piled up the waste in the city landfill. This paper aims to describe this new waste management system of UNNES comprehensively. The study found that the system can effectively handle up to 5 tons of various waste that UNNES produces a day. The waste was sorted and classified into four categories, and different treatments processed it. Leaves and food waste were recycled into compost and black soldier fly (BSF) maggots, respectively. While plastic, bottle, and paper waste were distributed to the third party, they managed the waste. Finally, the rest of the unsegregated waste (e.g., twigs or branches, glass fraction, unrecyclable plastic) were turned into the ashes by an eco-friendly incinerator.

1. Introduction
Waste has turned into a complex problem involving the environment, health, and social economy aspects. It can also become a more significant problem if it is not appropriately resolved [1], [2]. The relatively high level of land and sea pollution is due to plastic waste in Indonesia, they need serious attention from the government [3], [4], [5] and [6] also stated that Indonesia had become the second largest after China for plastic pollution to the marine environment. This pollution is also greatly affected by polluted rivers in Indonesia, which flows into the sea [7], [8]. Because of this condition, the Indonesia government has attempted to handle the problem by issuing President regulation No. 97 of 2017 about National Policy and Strategy for Domestic Waste Management. The government targets to reduce domestic waste by about 25% and to handle 70% of midden (piles of trash) by 2025 [9].

In line with government policy, UNNES, as a conservation university, also has a long-term plan on independent and sustainable waste management, which is stated in the UNNES development master plan (RENIP). The plan is divided into a specific interval. It is expected that in 2020-2025, 2026-2030, and 2031-2035, UNNES will have independently managed 50%, 60%, and 80% of campus waste, respectively [10]. However, this target will never be accomplished if UNNES waste management is still based on a conventional method consisting of collecting, transport, and disposal without any initial
treatment to minimize the accumulation of waste in the city landfill [11]. The 3 R (Reduce, Reuse, Recycle) method, such as the information technology implementation for paperless policy, Rector regulation No. 27 of 2019 about the prohibition of using disposable plastic [12], habituation of using a tumbler, leaf recycling into a leaf handicraft (Rasendriya), paper recycling into pulp, have been implemented in UNNES. The method has successfully implemented, but it only reduced a small portion of leaves, paper, and disposable plastic waste. Most of the leaves, paper, food, and other unsegregated waste remain unhandled. Therefore, to accelerate the target achievement on waste management, in 2019, UNNES built integrated waste management (IWM) system that starts operating this year (2020). This paper aims to comprehensively report this system so that UNNES can become a model for sustainable waste management on campus and improve this IWM system in the future.

2. Methods
The research activities were collecting, describing, and interpreting the data about the situations and activities related to UNNES waste management's existing data before and after 2020. We did observation, interview, and discussion with the subdivision of UNNES internal affairs, services, and procurement unit and the IWM operator. The observation is conducted by visiting the UNNES IWM building, observing the flow, process, and output of waste processing. While interview and discussion are conducted by holding questions and answer session with the IWM operator and UNNES internal affairs, services and procurement subdivision about amount of waste produced in UNNES and the waste treatment inside IWM building. The obtained data were analyzed systematically to get comprehensive information and describe the UNNES IWM system and its further potential improvement. The waste management discussed in this paper is limited to solid waste processing, excluding liquid, gas, and hazardous and toxic waste.

3. Results and Discussion
After officially opened in August 2020, UNNES waste is fully processed by IWM. UNNES built IWM in collaboration with third parties as an operator. The waste processing before and after IWM system implementation went through the same collection, transport, and disposal steps, but with significantly different in the disposal process. UNNES waste management system before and after IWM implementation is shown in Figure 1. The source of UNNES waste has started from various activities in the units, lecture building, offices, canteen, and leaf litter in the campus area. UNNES has provided trash bins at different location points by size standards for indoor (inside buildings) and outdoors. Indoor trash is regularly dumped outdoors for more accessible transportation.

![Figure 1 UNNES waste management system](image-url)

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*Note: The image in the original document is not included in this transcription.*
Meanwhile, the scattered leaf litter is swept and collected in several locations or the bins by cleaning officers. All waste from various units at UNNES is transported daily by cleaning officers using large and small pickup cars. Before IWM has been operated, waste was disposed of at the Banaran waste temporary shelter, which was then transported periodically to the Semarang landfill. After IWM implementation, the waste is transported to the IWM building (Figure 2) located only 300 m from the main gate of the UNNES Sekaran campus, Gunungpati, Semarang, without any more being transported to the Semarang landfill. The all processes are conducted and integrated in IWM building starting from waste sorting and treatment for each waste.

In collecting and transporting the waste, ideally, the waste should be separated based on the type in the trash bins. However, unfortunately, some of the trash bins in UNNES have not been separated according to the type of waste. Also, for the effectiveness of transportation, the waste is still mixed in the carload tank. In the carload tank, leaf waste is usually loaded in the front, and the rest of the space is for the mixed waste. In a day, on average, four large pickup cars with a capacity of 10 m³ per car and ten small pickup cars with a total of 5 m³ per car deliver the waste to the integrated waste management location. In a day, the IWM building receives up to 60 m³ or 5 tons of waste in the estimation, 80% of which is leaf waste, and the remaining 20% is a mixture of various waste. Every picked-up waste entering IWM will be recorded in the logbook that shown in Table 1. IWM building operates from 8.am to 4.pm on Monday until Friday and to 1.pm on Saturday.

Table 1. Recapitulation Logbook of UNNES waste in September 2020

| No | Car police number | Source of waste | Kind and amount of waste (m³) |
|----|-------------------|-----------------|-------------------------------|
|    |                   |                 | leaves | Domestic/ food waste | Unrecyclable plastic | Recyclable plastic | Branches/ wood | total   |
| 1  | H-1655            | West campus     | 299.52 | 1.04               | 12.48                | 2.78                  | 38.48            | 315.82  |
| 2  | H-9581            | West campus     | 283.92 | 0.52               | 22.36                | 1.91                  | 35.36            | 308.71  |
| 3  | H-9624            | FE              | 79.04  | 1.2                | 22.88                | 2.96                  | 13.52            | 106.08  |
| 4  | H-9624            | FBS             | 89.96  | 2.18               | 17.68                | 1.91                  | 13.00            | 111.73  |
| 5  | H-9624            | FIK             | 101.40 | 2.08               | 16.64                | 2.95                  | 14.04            | 123.07  |
| 6  | H-9624            | FH              | 75.40  | 3.12               | 22.88                | 3.28                  | 7.80             | 104.68  |
| 7  | H-9624            | FIS             | 89.96  | 1.56               | 30.16                | 2.95                  | 39.00            | 124.63  |
| 8  | H-9624            | FT              | 84.76  | 2.08               | 14.56                | 1.72                  | 6.76             | 103.12  |
| 9  | H-9624            | FIP             | 100.36 | 1.35               | 37.44                | 2.84                  | 7.28             | 141.99  |
| 10 | H-9624            | FMIPA           | 95.16  | 1.91               | 11.44                | 2.82                  | 7.80             | 111.33  |
| 11 | H-9624            | Entrepreneurship| 66.04  | 1.34               | 23.40                | 2.94                  | 7.28             | 93.72   |
| 12 | H-9624            | FIP             | 80.60  | 2.39               | 21.32                | 1.85                  | 7.80             | 106.16  |

| Total |                         |                  |                  |                  |                  |                  |                  | 1,751.03 |

Figure 2. UNNES IWM Building
The waste that arrives is immediately separated using a waste sorting machine (Figure 3), mainly leaf litter and other waste that may still be mixed. Waste that cannot be separated by the sorting machine will be separated manually. Then the waste is classified into four different main types, that is (1) leaves, (2) food waste, (3) bottles, plastic, paper, and (4) unsegregated waste (e.g., twigs or branches, shattered glass, unrecyclable plastic). Each type of waste will receive different treatment.

Figure 3. Waste Sorting Machine in UNNES IWM

Leaf litter is processed into compost. There are five boxes sized 20 m$^3$/box. A box produces 500 kg of compost, which can be harvested in a month—seeing that the large amount of leaf waste that goes into integrated waste management every day, and the limited compost processing box, accelerating the composting process will be an exciting research opportunity. The composting process in UNNES IWM is shown in Figure 4. The composting process is carried out in a box covered with tarpaulin. The leaf litter is chopped by adding one liter of bio activator, molasses, and water to speed up the composting process. The leaf litter is stirred periodically to mix the leave and bio activator.

Figure 4. Composting Process in UNNES IWM

Food waste is processed by feeding it to the black soldier fly (BSF) maggots. Maggots are ecologically useful in the process of decomposition of organic materials. Maggot consumes vegetables and fruit. Not only fresh fruit and vegetables, but maggots also consume vegetable and fruit leftovers. The most important thing is BSF does not transmit bacteria and disease to humans [13]. Therefore, the maggot is very suitable for organic waste management. Maggot also has economic value as a source of animal feed because it provides high protein and nutrition for animals such as fish and fowl. This maggot also has the potential to become human food if it is appropriately processed [14]. Produced maggots in the UNNES IWM were sold for animal feed without any further processing. These maggots can also be
interesting potential research as food sources that can be used in the future. BSF maggot process in UNNES IWM is shown in Figure 5.

Figure 5. Food Waste Processing by BSF Maggot in UNNES IWM

Usually for the collected plastic bottle and paper waste are sold by cleaning officers to the other parties who will further manage the waste. The last type of waste is an unsegregated waste. The waste that cannot be separated any more like a flake of paper, plastic and leaves will be destroyed in an incinerator machine that turns the waste into ashes. The device can incinerate 1m$^3$/hour of waste or 2 tons/day in estimation into 10-15 kg of ashes. The ashes from incinerating can be processed for plant growing media. It can also be potential research to improve its nutrition. The incinerator can be seen in Figure 6.

Waste management in other university just like UNNES usually have been treated various waste separately for instance leaf waste for compost, plastic and paper waste are recycled or distributed to other parties [15] [16]. However, for food waste and unsegregated waste are not treated and still periodically transported into city landfill [15]. While in UNNES food waste are processed for BSF maggots feed and unsegregated waste are incinerated in incinerator machine.

Figure 6. Incinerator Machine in UNNES IWM

4. Conclusion
This paper reported step by step UNNES IWM process. Improvements in waste management and future research opportunities can be carried out from the beginning of the waste generation process to IWM. As described in the introduction, the implementation and research for the 3R program at UNNES will be maintained. It is necessary to provide separate bins in the campus area to speed up the waste sorting process at IWM. The waste entering IWM is classified into four different types, and each class will receive other treatments. There are several interesting research topics from waste management at IWM, such as accelerating the composting process of leaf waste. The processing of maggots as a source of
food for either animals or humans can also be an exciting topic and improving the nutrition of the ashes from incinerating.

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