



Strategy for Optimizing Urban Waste Management Based on Industrialization Technology: Optimization Strategy for Urban Waste Management Based on Industrialization Technology

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Abstract. The problem of waste management is a problem for every city in Indonesia, including Tangerang City, which is one of the metropolitan cities in Indonesia. As one of the buffer cities of DKI Jakarta which is the capital of the State, Tangerang City has a waste generation of 3.28 L or 0.8647 kg/person/day, higher than the waste generation standard for a Metropolitan City, which is 3 L or 0.7 kg/person/day. With the rapid urbanization, commercial activities and public services in Tangerang City, especially related to the increasing activities of Soekarno Hatta International Airport, will result in an increasing amount of waste generation. As the final handling of waste, the City of Tangerang currently relies on the TPA Rawa Kucing as a final waste processing site which is operated by the landfilling method. By taking into account the level of waste reduction at the source which is still relatively low and the level of waste transportation services is high, it causes the capacity of the TPA to decrease, which based on estimation calculations can only accommodate waste for approximately the next 12 months. Taking into account the above matters, the Tangerang City Government intends to realize a waste processing facility that is able to support the growth of Tangerang city's economic activities within the next 25 years, one of which is by implementing the use of technology that leads to industrialization scale.

Keywords: Waste Management · Final Waste Processing · Industrialization

1 Introduction

Nowadays, waste has become an increasingly complex problem around the world because in addition to the increase in waste generation that increases along with the increase in population, there is also an increase in the types and characteristics of waste that are increasingly diverse due to economic developments in general. This is worsen by the condition that the capacity for waste handling by the government is relatively very limited which results in the emergence of inequality between service needs and increasingly large service capacity. Waste is increasingly difficult to manage because

the level of awareness and participation of the community in managing waste from sources (households) is still low and relies on handling waste centrally, which in turn will become a burden due to limited land for the final disposal, human resources and operational funds.

Waste management problems are a problem of every city in Indonesia, including Tangerang City which is one of the metropolitan cities in Indonesia. The number of residents that continues to increase every year will be followed by an increase in waste generation.

According to the Director General of Waste, Waste, Toxic and Hazardous Material Management (PSLB3) of the Ministry of Environment and Forestry (KLHK), the average daily waste generation in metropolitan cities (population of more than 1 million people) reaches 1,300 tons per day [5].

In relation to waste handling, Tangerang City currently has a Rawa Kucing final disposal (TPA) which is operated by the landfilling method. However, the rapid urbanization, commercial activities and public services in Tangerang City, especially related to the increasing activities of Soekarno Hatta International Airport, have resulted in an increasing amount of waste generation. Without good planning and anticipation, the unpreparedness of waste facilities can result in stagnation of Tangerang city's economic growth.

2 Literature Review

2.1 Existing Waste Management

Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management ("Waste Management Law") states that waste management is a systematic, comprehensive, and sustainable activity and includes waste reduction and handling activities [4].

According to data from the Ministry of Environment and Forestry, as stated in the National Strategy Policy (Jakstranas) in Waste Management, it is estimated that by 2025 there will be around 71.3 million tons of waste generation in a year or around 195 thousand tons per day with a target of reducing waste by 20.9 million tons per day (30%) and handling waste by 49.9 million tons per day (70%) (Presidential Regulation Number 97 of 2017) [5]. Based on an analysis from Sustainable Waste Indonesia (SWI), production, commodity trade, and consumption continue to grow as the economic and population levels in Indonesia grow. Post-consumption, products and their packaging become waste that can become an environmental burden.

The source of waste in Tangerang City comes from various population activities concentrated on residential, commercial and public facilities locations, with the value of waste generation reaching 3.28 L/person/day or 0.8647 kg/person/day (Revision of the Tangerang City Waste Masterplan, 2021) [2]. The value of waste generation is higher than the standard waste generation for metropolitan cities, which is 3 L/person/day or 0.7 kg/person/day (SNI-3242-2008) [3]. Based on this generation figure, currently Tangerang City's waste generation has reached 1,682 tons/day so that in 2022 it is targeted to handle waste by 78% and reduce waste by 22% [1].

Based on data, the realization of the Jakstrada target in 2021 has relatively met the target, where the waste that has been handled reaches 393,715 tons (81.3%) and the waste that has been successfully reduced by 90,581 tons (18.7%) [2]. The waste handling figure is still dominated by waste transportation activities to be landfilled, while the waste reduction figure is obtained from waste generation restriction activities as much 72,951 tons (15.06%), utilized waste as much 890 tons (0.18%), and recycled waste as much 19,739 tons (3.48%) [2].

2.2 The Urgency of Waste Treatment Technology

In the waste management scenario developed for the planning period of 2022–2040, Tangerang City still needs final processing activities, considering that during those 20 years, it is still not possible to carry out waste processing up to 100%. Therefore, it is still necessary to have a landfill or Waste Final Processing Site for the next 20 years. Currently, the mainstay landfill of Tangerang City is the Rawa Kucing final disposal which has been operating since around 1998, in a controlled landfill.

2.3 Waste Processing Industrialization Technology

Considering the importance role of Tangerang City in providing its services to Soekarno Hatta International Airport which is the main gate of the capital city of DKI Jakarta, the waste management project in Tangerang City is:

- a. Designated as a National Strategic Project in the Presidential Regulation of the Republic of Indonesia No. 03 of 2016, and re-established in the Presidential Regulation of the Republic of Indonesia No. 58 of 2017, to facilitate its licensing;
- b. It has been determined to accelerate its implementation in the context of processing waste into energy, in the Presidential Regulation of the Republic of Indonesia No. 18 of 2018 which has been replaced by Presidential Regulation of the Republic of Indonesia No. 35 of 2018 [6].

Tangerang City plans to build Waste Processing into Electrical Energy (PSEL) through Environmentally Friendly Technology using thermal technology, as one of the solutions for overcoming waste in Tangerang City which has been handled at the Rawa Kucing final disposal, where the landfill area is shrinking due to the increasing volume of waste entering. With the current landfill operations, it is replaced using industrialization scale technology.

The technology chosen is thermal-based technology, namely: incineration, gasification, and pyrolysis – which is equipped with the right Air Pollution Control System, making it environmentally friendly. The remaining burning ash, managed with qualified rules, either in the Cat Swamp landfill, or outside the Rawa Kucing, if categorized as B3 Waste. Comparing all the types of thermal technology, incineration technology has the highest track record, so it can be regarded as a proven technology. Gasification and pyrolysis technologies are not considered because the population is not yet high. Environmentally friendly aspects can be achieved by paying attention to the proper air pollution control system and the management of the combustion ash produced.

In addition to thermal incineration technology, there is another option, namely the generation of electricity with anaerobic biological technology at the Rawa Kucing final disposal to cover the shortcomings or obstacles faced by Incineration Thermal Technology related to the proximity of the Rawa Kucing final disposal location to the Soekarno Hatta.

Airport aviation operational safety area (KKOP). However, this anaerobic biological technology is hit by the inability of anaerobic biological technology to manage the entire portion of waste that enters the Rawa Kucing final disposal so that it still leaves a large enough portion of unmanaged waste and still burdens the landfill.

3 Results and Discussion

3.1 Waste Management Solution of Tangerang City

Waste handling targets can be achieved mostly through waste transportation activities to landfill. As for the waste reduction target, it can be achieved with several activities.

TPS3R. Tangerang City has started a waste processing program at source on an area scale in the form of TPS3R that developed from 2012, with an area ranging from 100–200 m² and a workforce of 3–6 people per location and spread across several urban villages. Due to limited land in urban areas, until now it has only been built and operated 8 (eight) TPS3R with a total waste processing capacity of +8.4 tons/day with still leaving 3.5 tons of residue that must be transported to the landfill.

Restrictions on single-use plastic Bags. The Tangerang City Environment Agency has started a program to limit plastic bags/single-use packaging since 2018 [7]. This program started from all employees within the Tangerang City Environmental Agency through the Letter of the Head of the Office Number 660/518-Keb/2018, where all employees and official activities are urged to no longer use beverages and packaged food which are replaced with tumblers and use water stations, glasses, and plates for serving during meeting activities [7].

In the same year, the Tangerang City Environmental Agency through the Letter of the Mayor of Tangerang Number 800/005027-DLH/2018 also began to impose this program of limiting plastic bags/single-use packaging to all Regional Organizations (OPD) and Schools in Tangerang City. Continuing the following year, the Tangerang City Environment Agency began to impose a program to limit plastic bags/single-use packaging for retail circles [7].

Retailers are asked to be able to encourage and socialize consumers to bring their own shopping bags, in addition to that, retailers are also asked to provide reusable shopping bags at affordable prices, and provide cardboard as an alternative for consumers to bring their groceries.

With the implementation of the plastic bag/package restriction program once in Tangerang City, it can reduce waste generation and reduce the burden of landfill from plastic waste. In 2019, it can be reported that the restriction of waste generation in Tangerang City reached 55,149.68 tons [2]. Following the economic growth and population of Tangerang City, in 2020 and 2021 there were 71,770.32 tons of waste generation restrictions in Tangerang City and 72,951.84 tons of waste [2].

Waste Bank Program. In addition to limiting waste generation, the Tangerang City Environmental Agency also continues to strive waste reduction at the source by collecting sellable and recyclable waste through the Waste Bank program. In 2016, the Tangerang City Government launched the 1000 Waste Bank program with the aim of educating the people of Tangerang City that well-managed waste will be able to provide economic value.

Although initially this program was quite successful, so that 350 units of waste banks were formed spread throughout the Tangerang City area in 2018, but currently there are only about 155 units of waste banks that are registered and only about 50 units are actively carrying out transaction activities with customers of local residents. One of the obstacles that arises is the absence of the Main Waste Bank in Tangerang City, so the waste bank units are not facilitated to sell inorganic waste and are forced to still rely on existing stalls. Due to the existence of inorganic waste collection stalls that are limited and not located around the location of existing waste banks, the purchase price of waste offered by stalls is often below market prices because it considers transportation costs.

To overcome this matters, the Environmental Agency began in 2018 initiate the Garbage Pick-up program using a fleet of pick-up vehicles to pick up and help sell to existing stalls [7]. However, due to limited vehicles and human resources, the program is still unable to serve all existing waste banks so that gradually the number of active waste bank units will decrease.

As an effort to maintain and also be able to increase the activeness of the remaining waste bank units, starting in 2022, the Tangerang City Government through the Environmental Agency provides incentives to active waste bank units. It is hoped that the provision of this incentive can increase the enthusiasm of waste bank administrators to socialize the waste bank program to local residents so as to increase the number of waste bank customers.

From the Waste Bank that is already active in Tangerang City, it is expected to extend the life of the Rawa Kucing final disposal with a decrease in inorganic waste that enters. In addition, the community can feel the economic benefits directly through the Waste Bank program.

Waste for Donation Program. Starting from the Waste Bank program that has been running, starting in mid-2017 the Tangerang City Environmental Agency innovated the Waste for Donation program. This program was launched with the aim of providing benefits in financing environmental care, education, health, and to awaken MSMEs in Tangerang City.

The Waste for Donation program has so far been registered to have helped reduce waste from the source by 51,549 kg with a value of Rp. 84,573,000. Through collaboration with Baznas Kota Tangerang, the value collected from the waste for donation program has been distributed to provide scholarships to underprivileged Tangerang City students, help with medical expenses or operations cost for the poor, and to form a Zismart, the sale of basic necessities with inorganic waste exchange.

For the people of Tangerang City who want to participate in the Waste for Donation program, they can contact the call center of the Tangerang City Environmental Agency at 08111-631-631 which will then be scheduled for pick-up of their waste on the condition that the waste has been sorted first.

Used Cooking Oil for Donation Program. Cooking oil is one of the needs of the community that is almost found in every household in Indonesia. The culture of all-fried food makes cooking oil one of the basic needs for the people of Indonesia, which in the end causes problems because most of the remaining products from the use of cooking oil are simply thrown into the sewerage from the kitchen. Used cooking oil waste discharged into these waters can cause an increase in levels of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) due to the high content of organic matter. In addition, it can cover the surface of the water by oil layer, resulting in the death of aquatic biota due to lack of oxygen.

Cooking oil that has been used will contain carcinogenic compounds that arise due to continuous heating at high temperatures, so that used cooking oil which is a waste of cooking oil after heating, when used to fry or reheat will potentially trigger the emergence of cancer. On the other hand, used cooking oil has a very high triglyceride content, which can be processed into biodiesel through a trans-esterification chemical reaction. Biodiesel is currently very rapidly developing in Indonesia because it is driven by government policies to increase the use of biofuels as an energy mix in Indonesia. Compared to palm oil, which is also one of the sources of biodiesel feedstock in Indonesia, used cooking oil has the main advantage of converting waste into products that have use value. This is the essence of the circular economy principle.

The main advantages of biodiesel production using used cooking oil feedstock include (1) the highest percentage of CO₂ emission reduction, ranging from 80–90% and (2) a very low price compared to palm oil. The use of used cooking oil into biodiesel currently still encounters several challenges in the following: (1) uncertain supply, and (2) the quality of feedstock that is not consistent because it is very dependent on the supplier or source of used cooking oil.

However, in order to participate in preserving the environment and preventing the adverse impact of used cooking oil on health as well as an effort to implement circular economy principles, the Tangerang City Environmental Agency facilitates the collection of used cooking oil from the community, both through waste banks and waste for donation program, as well as distributing the oil to CV Jelantah Life, as a used cooking oil processing company, which collaborates through the BETAH (Beli Jelantah) program.

The collaboration, which started from 2019 until now, has succeeded in responsibly managing 1,822 L of used cooking oil (as of June 2021). Through this management, the contribution to environmental conservation in the form of reducing CO₂ emissions from 2019–2021 has reached 4,842 kg equivalent (calculation method based on the Renewable Energy Directive (RED) II policy) and saving clean water ecosystems as much as 911 million liters (calculation method based on a journal entitled Biodiesel: Feedstocks and Process Technology) [2].

UBC Sales Program (Used Beverage Cartons). UBC (Used Beverage Cartons) is a packaging made of 75% paper and 25% aluminum which is usually used as a container for liquid milk or soft drinks such as fruit juice. The type of UBC waste is a type of waste that is commonly found in households, but still has a fairly low economic value, because it is considered low to be reused by stalls.

To overcome these problems and ensure the recycling process of UBC packaging, PT Tetra Pak Indonesia (one of the UBC producers) in collaboration with Waste4Change

(waste management organization/business actor) built the UBC Value Chain System, a system with a collaborative approach of all stakeholders involved from producers to consumers.

At the end of 2019, the Environment Agency also joined this system, where each waste bank unit can receive types of UBC waste from the community which will then be converted into their savings value. As of 2021, 794.35 kg of UBC has been collected with a sales value of IDR 794,000,- [2].

3.2 Waste Treatment Technology in Tangerang City

In relation to waste handling, Tangerang City currently has a Rawa Kucing Final Disposal (TPA) which is operated by the landfill method. However, the rapid urbanization, commercial activities and public services in Tangerang City, especially related to the increasing activities of Soekarno Hatta International Airport, have resulted in an increasing amount of waste generation. Without good planning and anticipation, the unpreparedness of waste facilities can result in stagnation of Tangerang city's economic growth.

The calculation of the projected population is closely related to the amount of waste generation to be managed. The projected population of Tangerang City until the end of the design period in 2040 with a population growth rate in accordance with BPS data of 1.63% and the generation of existing waste in settlements of 3.28 L/person/day, with a domestic waste weight of 0.86 kg/person/day. Can be seen in the Table 1.:

The area of the Rawa Kucing final disposal is approximately 31,125 ha with a total of 7 landfill zones covering an area of 23.39 ha consisting of 1 active zone, 4 non-active zones, and 2 zones that are reactivated to accommodate new waste inputs to the Rawa Kucing final disposal.

By paying attention to the relatively low level of waste reduction at the source and the high level of waste transportation services cause the capacity of the landfill capacity to decrease, which based on the calculation of estimates is only able to accommodate waste for approximately the next 12 months.

Taking into account the matters above, the Tangerang City Government intends to realize a waste processing facility that is able to support the growth of Tangerang city's economic activities in the next 25 years, by implementing the use of technology that leads to the scale of industrialization.

3.3 Waste Processing Industrialization Technology

Taking into account the advantages and disadvantages of each of these technologies, a new option is pursued, namely the hybrid option, namely combining thermal technology and anaerobic biological technology to optimize the final processing of waste so that it is able to manage the entire portion of waste entering the Rawa Kucing final disposal.

In the recommended management system, the entire operation of downstream waste treatment in Tangerang City occurs at the Rawa Kucing final disposal. The waste that has been collected by the Tangerang City Environmental Agency is sent to the Rawa Kucing final disposal. After the weighing and checking process, the waste is received

Table 1. Waste Management Projections

Year	Population	Waste Generation Projections	Service Targets
	(Soul)	(tons/day)	(tons/day)
2022	1.956.142	1.682	1.312
2023	1.986.469	1.708	1.333
2024	2.016.797	1.734	1.353
2025	2.047.125	1.761	1.373
2026	2.077.453	1.787	1.394
2027	2.107.780	1.813	1.414
2028	2.138.108	1.839	1.434
2029	2.168.436	1.865	1.455
2030	2.198.764	1.891	1.475
2031	2.229.092	1.917	1.495
2032	2.259.419	1.943	1.516
2033	2.289.747	1.969	1.536
2034	2.320.075	1.995	1.556
2035	2.350.403	2.021	1.577
2036	2.380.730	2.047	1.597
2037	2.411.058	2.074	1.617
2038	2.441.386	2.100	1.638
2039	2.471.714	2.126	1.658
2040	2.502.042	2.152	1.678

Source: Revision of the Waste Masterplan, 2021[2]

at the MRF Plant facility, where organic materials are isolated with various mechanical machines (shredder, sieve/screen, expeller, etc.). This organic material is then processed in an anaerobic biological system that facilitates the anaerobic decomposition process so that there is an acceleration of decay and produce gases. This gas is then purified and converted into electricity in a Waste Power Plant (PLTSa) Gas.

The MRF Plant facility also isolates unprocessable materials such as sand, building scraps, broken glass, porcelain, and other materials, which because they cannot be reprocessed are directly stockpiled into inert landfills that are also located in the Cat Swamp hoarding zone. This material, after reaching a sufficient volume in the future, has the potential to be further processed into recycle able building material.

The remaining material is a material with a high level of non-recycled plastic, which is then purified and homogenized in RDF production processes such as enumeration, metal picking, and density sorting, into RDF grade that has an efficient calorific value for logistics and combustion processes.

These sorting processes are designed to be able to:

- raising the calorific value of fresh waste, which is 1,400 kcal/kg to 2,600 kcal/kg
- lowering the moisture content of litter from 68% to 48%
- lowered the ash content from 19% to 7%.

The planned combustion system uses stoker grate technology common in boiler waste combustion technology equipped with an Air Pollution Control System that is able to meet European standard air emission levels, with combustion efficiency levels reaching 25%. To minimize the amount of waste to be landfilled, each element of waste processing described earlier, must be designed with a capacity capable of managing all incoming waste.

MRF Plant. The MRF Plant facility has functions to receive all the garbage that goes into the Rawa Kucing final disposal, sorting the initial waste, where the waste will be separated between waste that is easy to decompose and one that is not easy to; waste that is easy to decompose will go to the organic processing facility, while waste that is not easy to rot will go to the RDF production facility.

The components of the MRF Plant consist at least of:

- Tipping floor, waste pit, and feeding system;
- Shredder/Cutter/Bag Opener;
- Organic separators at least can set aside up to 75% of existing organic waste.

RDF Plant. In RDF production facilities, waste not easily decomposed will be processed and further sorted to set aside inert materials, B3, and recycled materials (in this case metal materials), so as to produce RDF product output with controlled quality and high calorific value. The RDF Plant facilities consist of at least:

- Magnetic separator, to set aside metal materials that are not good for combustion;
- Density separator, to separate inert materials that have high type time characteristics so that they are not flammable;
- Secondary Shredder, to chop the RDF into a smaller size, so that there is no material larger than 300 mm.

Biological Systems Circuit. The system will consist of:

- Pre-treatment system that serves to carry out advanced sorting and maintain the quality of waste inputs easily decomposed into the anaerobic system. Reject or the rest of this unit is organic materials that are slightly mixed with other materials (plastic, fabric, etc.) so that they will be returned to the RDF production unit for further sorting so that the waste material can be recovered optimally;
- Anaerobic System, in this unit, the input of easily decomposed organic waste that has gone through the pretreatment system will be processed through anaerobic biodegradation to produce methane gas which will later be used by gas engine generators to produce electricity that will be sold to PLN.

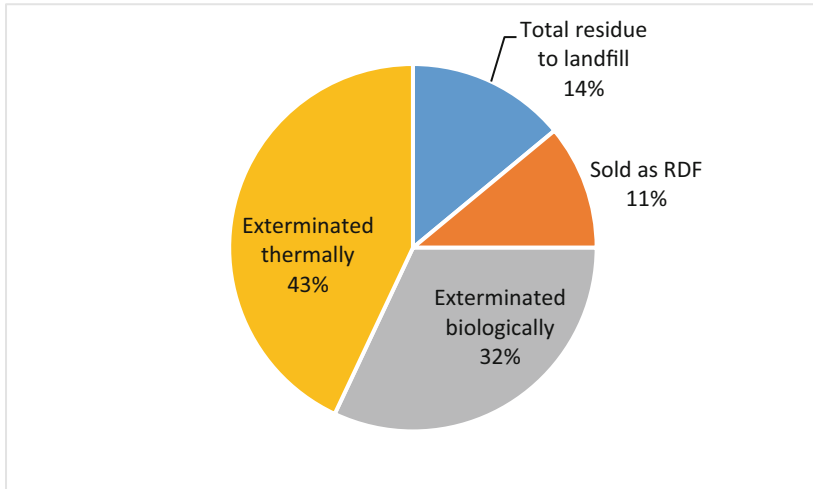


Fig. 1. Material Management in Rawa Kucing Waste Treatment Plant. Source: [7]

- Gas Engine Generator, in this unit will be generated electricity by utilizing methane gas as fuel produced by the anaerobic system unit. The electricity generated will then be channeled to the PLN grid.

The implementation of the project plan as described in the development plan, then the materials that will be permanently landfilled in the Rawa Kucing are inert materials from the main processing facilities and harmless ash left over from the combustion of the RDF (about 14% from the initial period).

The remaining materials of the anaerobic process are in the form of leachate and digestate. Leachate will be treated properly so that it meets quality standards and water can be discharged into water bodies or reused for watering, while digestate is a nutrient-rich humus material that can be used for fertilization in green areas. These two residuals along with the carbon period in organic waste converted into methane gas are considered biologically destroyed materials (about 32%).

RDF delivered and burned at RDF combustion facilities to generate electricity is put into the category of thermally destroyed waste (about 43%) while the remaining RDF is RDF sold to third parties (about 11%) (Fig. 1).

The impact of the implementation of the facility is optimal land use and can maintain the capacity of the Rawa Kucing hoarding until 2047 without the implementation of land restoration.

Based on the results of projections and considering the natural decomposition factor (decay factor). The landfill requirement during the project period until 2047 is 1,023,479 m³ while the remaining stockpiling capacity in the Rawa Kucing final disposal is currently 1,279,635 m³. Thus, at the end of the project period, it is estimated that there will still be a remaining landfill capacity in the Rawa Kucing final disposal of around 250,000 m³.

4 Conclusion

It is time for the waste management system in metropolitan cities to include elements of industrialization-scale technology in the waste processing process so that it is not just hoarded in landfills.

The need for landfill land for landfilling activities is relatively large because waste is not significantly reduced. Just relying on the rate of waste decomposition naturally is not enough because the level of waste generation is increasing as the population grows.

Landfilling alone does not solve the waste problem, it will even become a potential problem in the future if the level of municipal hygiene services and waste transportation cannot be balanced by the availability and adequate landfill capacity.

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