STUDY ON WASTE BANK ACTIVITIES IN INDONESIA TOWARDS SUSTAINABLE MUNICIPAL SOLID WASTE MANAGEMENT

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Chapter 1 Introduction

1.1 Introduction of waste management in Indonesia

Indonesia is an archipelago country inhabited more than 260 million people. According to Ministry of Environment and Forestry (MoEF) and the Ministry of Industry in 2016, the number of waste generation in Indonesia has reached 65.2 million tons per year (BPS-Statistics of Indonesia, 2018). Improper solid waste disposal and management cause all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and groundwater supplies. In urban areas, Municipal Solid Waste (MSW) clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of MSW and improper incineration contributes significantly to urban air pollution. Greenhouse gases are generated from the decomposition of organic wastes in landfills, and untreated leachate pollutes surrounding soil and water bodies. Health and safety issues also arise from improper municipal solid waste management (MSWM). Insect and rodent vectors are attracted to the waste and can spread diseases such as cholera and dengue fever. Using water polluted by MSW for bathing, food irrigation, and drinking water can also expose individuals to disease organisms and other contaminants (Alam and Ahmade, 2013).

In line with that, environmental and health problems due to waste also increase. River water quality in Indonesia is generally in a heavily polluted state. In 2017, there are 25,1 percent of villages experienced water pollution, and around 2.7 percent of villages experienced land contamination. Waste also contributes to flood and continue to increase, in 2016 and 2017 there were 1,805 floods event in Indonesia and caused 433 fatalities. An alarming condition is the death rate (CFR) due to the extraordinary incidence of diarrhea in 2016 of 3.04 percent, even though the CFR is expected to be less than 1 percent (BPS-Statistics of Indonesia, 2018).

Waste management has a complex problem to be resolved and requires a long process, especially in Indonesia. The problems have several aspects associated with them, such as technical, institutional, financial, environmental, and social aspects (Damanhuri and Padmi, 2012). The solid waste management activities in Indonesia consist of its collection, transfer and transportation, and final disposal. Indonesia has a legal framework for solid waste that was prepared by its Ministry of Environment, written into the Waste Management Law No. 18/2008, requiring the local governments and stakeholders to comply with the rules regarding disposal sites, and providing for the closure of non-complying disposal sites.

Municipal solid waste management in Indonesia is the responsibility of municipalities (local government). There is a city/district cleanliness division within the municipality organization. Some big cities contract out part of the services to third parties. Most of the municipalities still give low priority to solid waste services. The general method currently observed in waste management is collect-transport-dispose. The authorities in urban municipalities transport the waste from designated collection points to a location for its final dumping. Most of the local authorities practice crude open dumping, creating a desperate situation at the landfill sites. The potentials for reuse and recycling have not been fully realized because of a multitude of problems (Damanhuri and Padmi, 2012).

Indonesia's Law 18/2008 on Waste Management stated the need for a fundamental paradigm change in waste management. Changes in the paradigm of collect – transport - dispose to processing that relies on reducing waste and handling the waste. All levels of society, both government, business and the wider community, carry out activities to reduce the waste generation, recycle and reuse the waste or known as Reduce, Reuse and Recycle (3R) (KLH, 2013). The government has set a target in the form of a National Strategy Policy on Waste Management, which sets 30% through reduction and 70% handling activities in 2025 (KLHK, 2018). In 2017, the achievement of reducing household waste had only reached 2.12 percent. This figure is far below 15 percent in Presidential Regulation number 97/2017 concerning National Policies and Strategies for Household Waste Management and Household Waste (Susanto and Adi, 2018).

The government has facilitated recycling activities performed in several regions in the country. However, recycling in Indonesia still relies on the informal sector, which has its hierarchy and conducts activities that are conducive to its economic interests. Informal sector recycling in Indonesia often involves multiple stakeholders, including scavengers and waste traders (Damanhuri and Padmi, 2012). Waste bank (WB) is one of community-based waste management in Indonesia that enables people to earn money in the form of savings by depositing their recyclable wastes. The waste bank is believed to overcome environmental issues, especially related to waste management. Waste bank activities could increase recycling rate and reduce the amount of waste into landfill. Waste bank is a place that is used to collect recyclable wastes. They operate by adopting the banking system. Each customer gets a savings book to record the transaction. The waste bank weighs and assesses the recyclable wastes carried by the customer, then being rewarded with a sum of money. Furthermore, waste banks sell the collected recyclable waste to recycling industries. In 2017, Indonesia had 5,244 waste banks spread across 34 provinces or 219 regencies/cities. The contribution of waste reduction from 5,244 waste banks in 2015 was only 0.01 percent, 2016 rose 0.14 percent, and 2017 rose significantly 1.7 percent. (BPS-Statistics of Indonesia, 2018). The distribution of waste bank in Indonesia is presented in Figure 1.1.

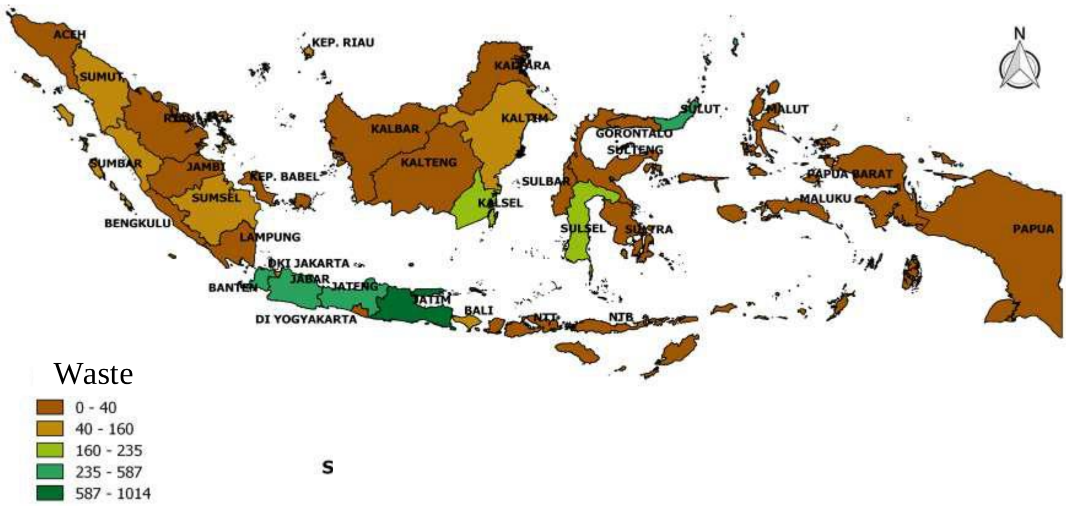

Figure 1.1 Distribution of waste bank in Indonesia

(BPS-Statistics of Indonesia, 2018)

1.2 Review of existing research

Sustainable development, as initially defined by the Brundtland Commission in 1987, aims to ensure that"... it meets the needs of the present generations without compromising the ability of further generations to meet their own needs." (Ludwig, Hellweg and Stucki, 2003). There are three main objectives of sustainable development are "the protection of man and environment," "economic compatibility" and "social compatibility." They are connected in a dynamic triangle and interdependent; they are of equal significance and are to be respected equally. In the process of achieving sustainability in waste management, it requires balancing social, economic, and environmental perspectives constrained by environmental limits over an inter-and intra-generational timeframe, and possible conflicts of objectives related to the three pillars of sustainability would be inevitable. It is necessary to acknowledge and deal with these conflicting objectives across domain boundaries in the diverse spectrum of projects with system thinking (Chang and Pires, 2015). Figure 1.2 illustrates three pillars to approach sustainability.

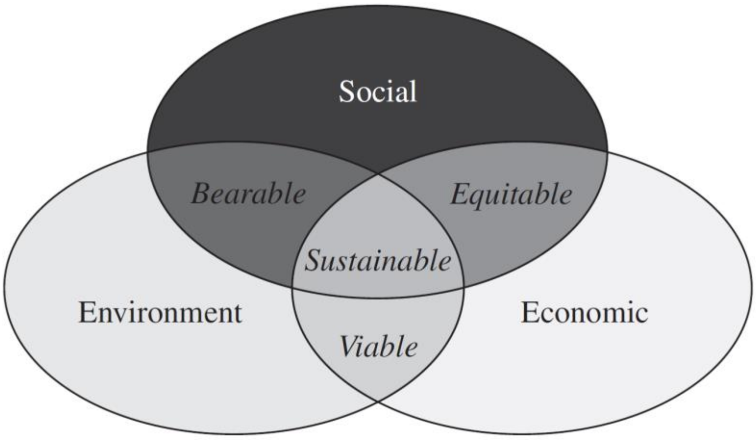

Figure 1.2 Three pillars approach to illustrate sustainability

(Chang and Pires, 2015)

In the context of the sustainability of waste management (SWM), the concept of sustainability applies to the whole SWM industry sectors, process technologies, and individual process plants. In assessing sustainability performance from storage and collection to routing and shipping, to separation and treatment, and final disposal, a system boundary should be well defined. Besides, suitable sustainability indicators to quantify the performance and monitor the progress related to economic, environmental, and social perspectives may be selected for a holistic assessment up front (Chang and Pires, 2015). Several key indicators may be proposed as options to support a sustainability assessment (Brennan, 2012).

- Environmental indicators, for example, resource depletion, global warming potential, ozone layer depletion, photochemical smog, and human and ecotoxicity.
- Economic indicators, such as value added, capital expenditure (including that on environmental protection), environmental liabilities, and ethical investments
- Social indicator, for example, income distribution, the satisfaction of social needs, including work and stakeholder inclusion and participation.

In forming SWM policies are necessary to define waste stream. Waste streams are started at municipal solid waste, it can be present in packaging waste (which is even divided by materials like paper, cardboard, glass, plastic, liquid carton beverages packaging, ferrous metals, nonferrous metals), batteries, food waste, biodegradable waste, green waste, waste of electrical and electronic equipment, construction and demolition waste, and domestic hazardous waste, and many others may appear. Recycling industry wanted the source-separated materials to be recycled in their process. The separation of waste through its properties, mostly, can impulse its environmental sound management of waste, with financial revenues and positive social impacts. The separation of waste leads to its management without being contaminated with hazardous (or nonhazardous) materials or allowing its maximum use. Separation helps to increase the value of recyclables, resulting in value-added by-products. The social well-being reached with integrated solid waste management and with the source separation of waste is notable, although source separation of waste requires citizens' participation, which can be demanding and challenging for waste system managers. The public participation in the decision-making process on waste management is also a reality nowadays, where waste players, from products life cycle, can be brought to deliver strategic plans and actions plans to prevent and manage waste (Pires *et al.*, 2019).

Wijayanti (Wijayanti and Suryani, 2015) studied the role of social resource development in a community-based environmental governance system through waste bank mechanism. Sustainable development paradigm is translated as community empowerment with the waste bank as a part of the waste management system. The key factors of succeeding waste bank as community-based environmental governance, such as:

- Financial, educational, social, and technological instruments are used well in community empowerment, as an effort of public participation in environmental governance.
- The role of local government as a regulator, facilitator and stimulating the other stakeholder is well played.
- Strong will and collaborative environmental governance with no gap or discrepancy between stakeholders.

Wulandari (Wulandari, Hadi Utomo and Narmaditya, 2017) revealed that waste bank management model not only beneficial in making a clean environment but also has an impact on the local economy by increasing the income of homemakers around the waste bank. The community expected more support from the government to improve the mechanism of waste bank and a better pricing model for the waste.

Raharjo (Raharjo *et al.*, 2016) studied in the development of community-based waste recycling (waste bank and 3R waste treatment facility) for mitigating greenhouse gas emissions. They suggested to increase the number of the waste bank, community waste treatment facility (TPS 3R), integrated waste treatment facility (TPST) and to install landfill gas recovery.

Purnama (Purnama Putra, Damanhuri and Sembiring, 2018) identified informal sector activities (waste bank), among others, in Yogyakarta, the ability of waste banks to accept waste and an increasing percentage of waste management services in Yogyakarta. They found that the percentage of waste services has increased after being integrated with the waste bank in waste management.

Raharjo (Raharjo *et al.*, 2017) suggested that the WB system can be integrated to local MSW management as a method to increase the people participation in separation, collection, and recycling of generated solid waste.

Community-based management (CBM) program for municipal solid waste (MSW) activities have been proved to provide the co-benefit of a reduction of the financial burden for administration and operation from the minimization of landfill for MSW and the generation of income from sales of recyclables from CBM members. Another benefit from CBM is the lowering of GHG emissions in non-landfilling scenarios compared to the completely landfilled scenario. Findings from the study suggested that key success factors may stem from the synergism between curbside recycling services, community-wide collaboration, understanding of benefits from recycling, and fair pricing of recyclables purchased at the waste bank, which help to sustain participation in CBM activities (Challcharoenwattana and Pharino, 2015).

Participants in the waste bank are dominated by the community from lower education background and income. It is related to the main reason for participating in the waste bank, that is economic profit. People from a lower education background and income use waste bank as a mean for increasing their income (Maryati *et al.*, 2018).

Sulami (Priyo *et al.*, 2018) found that there is lack of awareness about the waste management options, negative perception of recycled materials, limited capacity of the informal sector, and unavailability of clear guidelines and systems.
In order to improve the community activity in 3R, the collaboration between the government and community, private sector, and NGOs have to be conducted. Four strategies to achieve the goal of community participation in HSW reduction are (Dhokhikah, Trihadiningrum and Sunaryo, 2015):

- to intensify the HSW reduction training for community and environmental cadres
- to increase the information through mass media and campaign about the household waste handling and reduction
- to multiply the number of environmental cadres from the community and the local leaders
- to increase the number of waste bank and their functions (as a waste bank which accepts the recyclable waste; and an organization for environmental campaign and training).

Asian countries have the potential to demonstrate sustainable SWM systems through an integrated approach. A systematic effort is necessary to improve various factors, including policy and legal frameworks, institutional arrangements, financial provisions, technology, operations management, human resource development, and public participation and awareness of SWM systems. The SWM system should be compatible with both the financial capacity of a given society and with the assimilative capacity of its adjoining environment (Shekdar, 2009).

Pambudi (Firdaus Pambudi, Dowaki and Adhiutama, 2016), sustainability and availability of waste separation infrastructure must be maintained in order to support the plastic recycling system in the community. Furthermore, promotional activities in the waste bank and plastic recycling system are necessary to be conducted by using social media, a local newspaper, and other information infrastructure.

The success of waste bank revitalization will require government support to make special regulation related to waste bank so that the managers and customers of the waste bank have more certainty and also the spirit to continue to play an active role in this realm (Samadikun, Handayani and Laksana, 2018).

Another study suggested investigating the about cost and benefits aspect, human resources, social conflicts, and government policy related to waste bank system. These are interesting in being identified as a consideration to waste bank development.

1.3 Objectives of research and dissertation structure

1.3.1 Objective and scope of this study

Medan, as the Capital City of North Sumatra Province, plays a role as the gate of west Indonesia regional. It has a very strategic position as an entrance gate for tourism, business, and industry sector. In another hand, Medan is facing environmental issues; one of them is MSW management. The waste bank is one of the efforts to overcome the waste problems. The study of waste bank activities as a part of municipal solid waste management could provide a better insight into decision maker in deciding how to improve waste bank activity and overcome the municipal solid waste issues.

Mainly this research aims at:

1. Study on the current situation of municipal solid waste management in Medan, its generation and the composition of HW
2. To study and investigate waste bank activities and its material flows
3. To evaluate the environment and the economy of waste bank activities

The data of this research were gathered from government report and publication such as Regional Development Planning Agency, Cleansing Agency, Regional Environment Agency, Public Work Agency, Statistics of Indonesia. Another data was completed by doing some field observations and interviews. Data collection of this research was conducted in Medan City started from April 2017 to May 2018. To obtain the target of studies, some objectives and their methodologies can be shortly explained in Table 1.1.

Table 1.1 Data collection of this research

Objective (s)	Data collection or methodology (ies)
To study and investigate the existing of MSW management	
Demography and statistical data	Data collection from local government and statistical bureau
Government support like Policies, financial and inventory in solid waste management	Data collection, observation, and interview from related stockholder (Environmental Bureau, Regional Development Planning Agency, Cleansing Agency, etc.)
Current community involved in MSW management	Data collection on all sectors, data from government and other informal sectors
Waste generation and composition	Sampling waste generation refers to Indonesia standard SNI 19-3964-1994
To study and investigate waste bank activities and its material flows	
Existing waste bank activities	Data collection from government and observation to the waste bank covering background information, waste bank profile, and its activities
Material flow analysis of WB	Defining process of waste bank
	Type of waste that accepted by the waste banks
	The use of materials and substances
	Input and output through the waste bank processes
To evaluate the environment and the economy of waste bank activities	
Conducting environmental assessment	Adopting LCA methodology to estimate greenhouse gas (GHG) in carbon dioxide (CO_2)
Conducting economic assessment	Using Cost-benefit analysis (CBA) to assess the economic performance

1.3.2 Structure of dissertation

Structure of the dissertation is described in Figure 1.3 below.

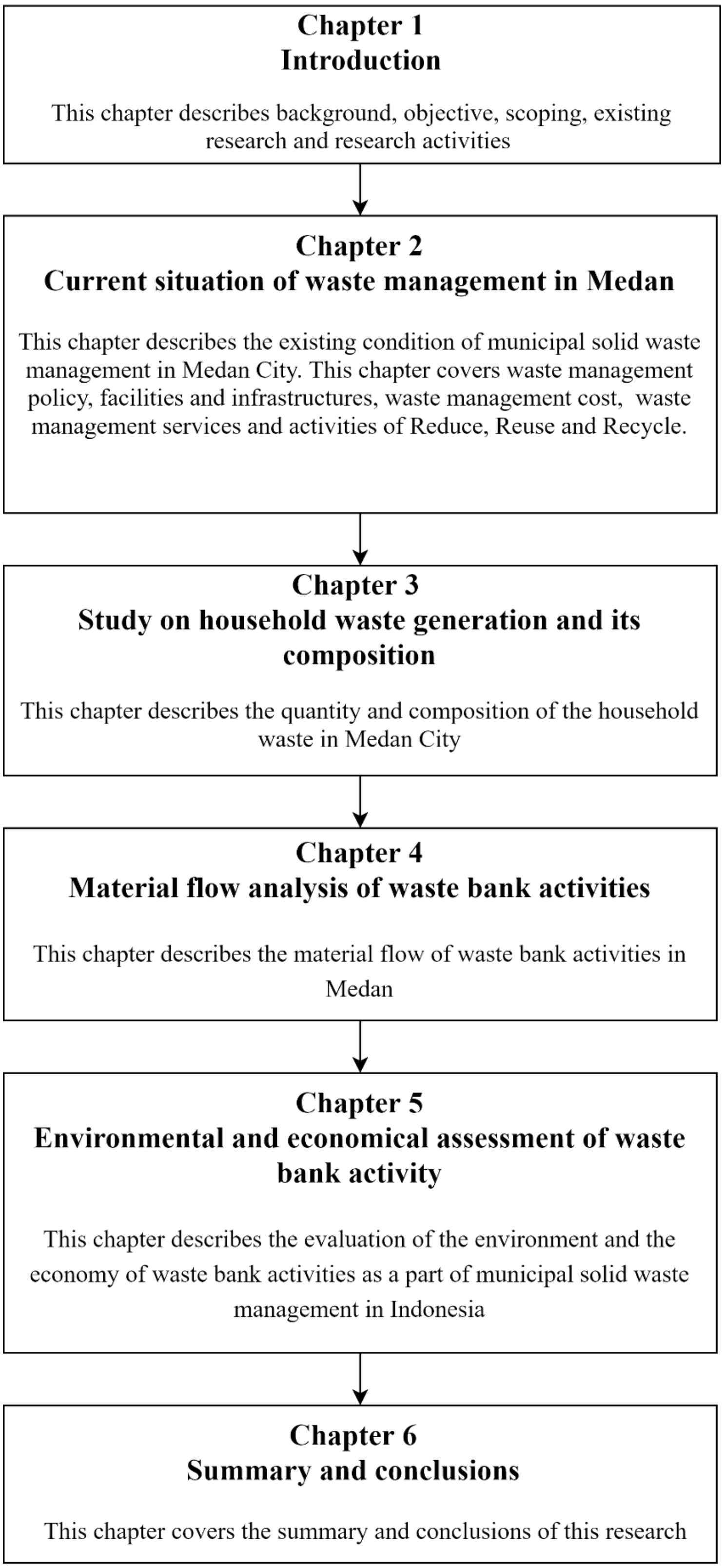

Figure 1.3 The structure of dissertation

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Chapter 2 Current situation of waste management in Medan

2.1 Introduction

Medan City is a city located in the northern part of the island of Sumatra. Medan is the capital of North Sumatra Province with a population of 2.2 million and has an area of 265 sq.km. The city of Medan currently has 21 sub-districts covering 151 villages (Pemerintah Kota Medan, 2013). The city is listed as the fourth largest city in Indonesia after Jakarta, Surabaya, and Bandung. Along the northern region, the city is bordered by the Malacca Strait, which is one of the most densely populated sea traffic lanes in the world.

Geographically, the city of Medan is located at 3 ° 30 '- 3 ° 43' North Latitude and 98 ° 35 '- 98 ° 44' East Longitude. Located near the equator, Medan has an entirely tropical climate with two major seasons; dry season (February–July) and the rainy season (August–January). The minimum and maximum temperature was 21.2° and 35.1°C. The area's relative humidity is quite high; it receives an average of 2808 mm with 189 days rainfall per year (Statistic of Medan Municipality, 2017).

Figure 2.1 Geographical location of Medan City

According to Statistics Municipality (Statistic of Medan Municipality, 2016), Medan's economic growth rate in 2015 slowed compared to the previous year. In 2015 the economic growth of Medan City was 5.74%, while in 2014 it reached 6.05%. Amid the slowdown, there are several sectors that have increased, including the water sector, waste management, and recycling. These sectors recorded growth of 8%.

The urban activity in Medan City is affecting the generation of solid waste. The increasing volume of waste generation without proper management will contribute to environmental threats and water resources conservation and left a huge pollution problem in air and esthetic. Medan has three major rivers, Deli, Belawan, and Babura Rivers. Citing the data from The North Sumatra Environmental Impact Control Agency, estimated one ton of dangerous waste is dumped into the Belawan River in Medan municipality every day. The level of pollution in the river exceeds government standards, and the water from the Belawan is no longer safe for human consumption or use. The pollutions are coming from the people who are living along riverbanks that threw their household waste into the rivers; also, most industries do the same way.

2.2 Waste management policy

Indonesia Law No. 18/2008 on Waste Management is a reference for waste management policies in Indonesia. This law mandates the need for fundamental changes in waste management that have been carried out. Article 19 states that waste management is divided into two main activities, waste reduction and waste management. Article 20 describes three main activities in the implementation of waste reduction activities; limitation of waste generation, recycling and reuse of waste. The three activities are an embodiment of the principles of environmentally sound waste management called 3R (reduce, reuse, recycle). In Article 22, five main activities are described in the implementation of waste management activities, which include sorting, collecting, transporting, processing, and final processing of waste. In Article 22 outlined five primary activities in the implementation of waste management activities, including sorting, collecting, transporting, processing, and final disposal (Indonesia Government, 2008).

Law No. 18/2008 also regulates the responsibilities of the central, provincial, and city governments in Indonesia. City/regency governments can form a kind of municipal/regency or provincial scale waste management forum. This forum consists of the community in general, universities, community leaders, environmental/solid waste organizations, experts, business entities, and others. The things that can be facilitated by the forum are: providing suggestions, considerations, and suggestions on the performance of waste management, helping to formulate waste management policies, providing advice and being able to resolve waste dispute resolution. Other responsibilities charged to the city government are building Communal container, integrated waste management site, and final processing site, including monitoring and evaluation of its activities (Indonesia Government, 2008).

Government Regulation No. 81/2012 concerning Management of Household Waste and Similar Waste Household Waste is issued as implementing regulations Law No. 18/2008, as well as strengthen the legal basis for dealing with waste management in Indonesia, particularly in the regions. There are several important subject matters mandated by these government regulations, namely (Indonesia Government, 2012):

1. Providing a stronger foundation for local governments in the implementation of environmentally sound waste management from various aspects including legal, management, operational, technical, financing, institutional, and human resources;
2. Provide clarity regarding the division of tasks and the role of all relevant stakeholders in waste management starting from ministries/institutions at the central level, provincial government, regency/city government, business, area managers to the community;
3. Providing an operational foundation for the implementation of the 3R (reduce, reuse, recycle) in waste management replacing the old waste paradigm;
4. Providing a strong legal foundation for the involvement of the business communities to take responsibility for waste management following its role.

In its implementation, the Medan City Government has issued several Regional Regulations and Mayor Regulations regarding waste management, such as:

- Mayor regulation of Medan No. 73/2017 concerning the implementation of the partial delegation of mayor's authority to sub-district head in the implementation of government affairs in the field of waste management
- Mayor's Decree No.15 / 2016 concerning the unification of the Sanitation Agency with the Gardening Service being the Sanitation and Gardening Agency
- Medan City Regulation No. 6/2015 concerning Waste Management, and
- Medan City Regulation No. 10/2012 concerning Retribution for Cleaning Services.

In the Medan City Sanitation Strategy 2017-2021, there are five targets related to waste management (Pokja Sanitasi Kota Medan, 2017):

- Municipal waste services serve 100% of the city's area
- Reduction waste to landfill by 10%
- 5% of the city budget is allocated to waste management
- Initiated operational controlled landfills in 2021 and sanitary landfills after 2022
- Stopping waste disposal in drainage, rivers, and open areas.

The solid waste management system is managed by Dinas Kebersihan dan Pertamanan (DKP, Sanitation and Gardening Agency) of Medan City, mandated by local government regulation Mayor Regulation No. 1/2017. In addition to managing municipal waste, this agency also manages city parks.

2.3 Facilities and infrastructures

Every day there are more than 200 trucks that operate serving waste collection in the city of Medan. Medan city government has various types of trucks, including dump trucks, container trucks, compactors trucks, and arm-roll trucks. Yet, DKP's staff said that these trucks is still not enough to collect all generated waste in Medan (Benny & Zaenal, 2017).

Truck depot

Compactor truck

Figure 2.2 Truck facilities of Medan City

To make it easier for the public, the city government provides pedicabs. Around 214 pedicabs are operating. This pedicab has the role of collecting waste from the community, which is far from the communal container. Also, the city government of Medan has several units of heavy equipment for operation in landfills, consisting of 3 units of bulldozers, three units of wheel loaders, 1 unit of excavators and two units of bobcat (Pemerintah Kota Medan, 2013). The number of trucks is presented in Table 2.1.

Table 2.1 Truck facilities of Medan city

	Dump truck	Container truck	Compactor truck	Arm-roll truck	Other
Number of facilities	162	14	9	11	12
Number of trips	327	78	27	72	13
Amount of waste (ton/day)	865	325	92	279	34

Source: (Dinas Kebersihan Kota Medan, 2016)

Medan City has two landfills. Terjun landfill is located in Medan Marelan Subdistrict with an area of approximately 14 Ha and Namo Bintang landfill located in Pancur Batu District, Deli Serdang with an area of 25 Ha. However, operationally the landfill that operates is only the Terjun landfill that holds all the trash from 21 sub-districts in Medan City. Terjun landfill has been operated from the beginning using open dumping. Before being dumped into a landfill, sometimes waste is collected temporarily in the communal container. Until now, the city of Medan only has 82 communal containers that scattered in several locations. Also, the city of Medan does not yet have incineration facilities, bulky waste facilities, and recycling facilities. Figure 2.3 shows the condition of Terjun landfill.

Figure 2.3 Condition of Terjun Landfill

2.4 Waste management cost

The total Sanitation and Gardening Agency budget for 2017 Fiscal Year was around 224 billion rupiahs. Around 213 billion rupiahs were explicitly allocated for programs to improve the performance of waste management, which includes funding for activities such as procurement of facilities and garbage collection facilities. The total budget of the city government itself in the 2017 fiscal year was around 5.1 trillion rupiahs. From this data, an estimated 4.4% of the city budget is allocated for waste management. However, this percentage is still lacking when compared with the 2017-2021 Sanitation Strategy target, which is 5% of the total city budget. Figure 2.4 shows the percentage of Sanitation and Gardening Agency expenses.

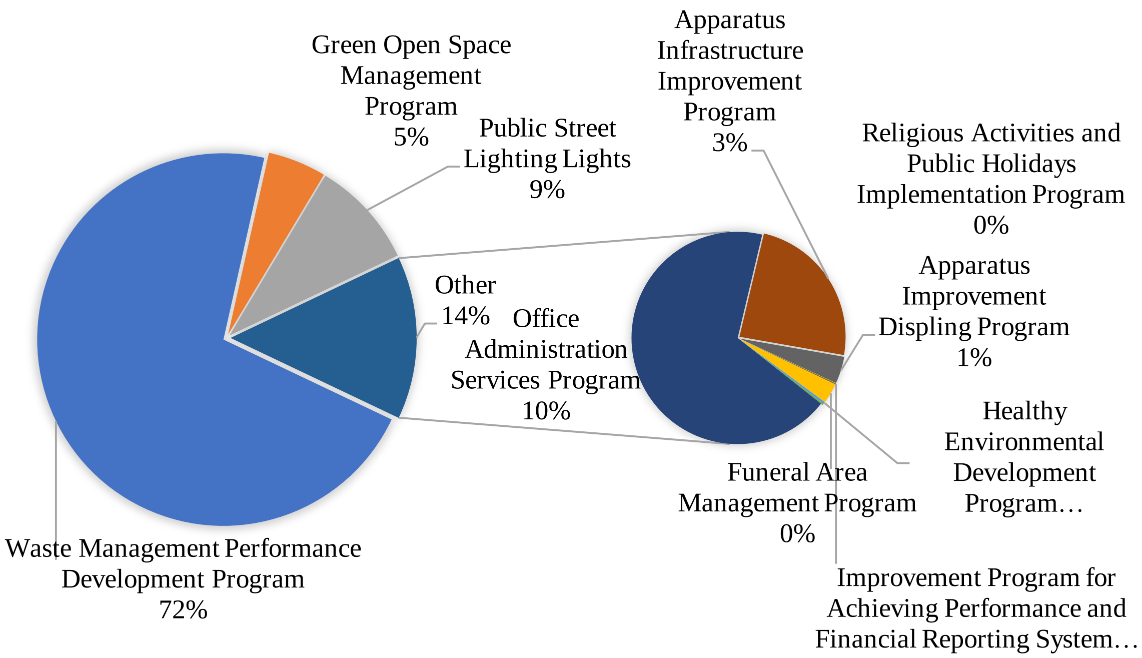

Figure 2.4 Percentage of Sanitation and Gardening Agency expenses

Of expenses of 213 billion-rupiah, waste-related expenses that managed by Sanitation and Gardening Agency in 2017 reached to 166.7 billion rupiahs. Personal expenses were the most expenditure, 55% (91,509 million rupiahs) of the total budget. Transportation and collection expenses accounted for 19% (31,800 million rupiahs). Facility and infrastructure expenses accounted for 17% (28,717.20 million), while total waste management expenses accounted for 9% (14590,50 million rupiahs) of the total budget. Figure 2.5 shows the expenses of waste management of Medan in 2017.

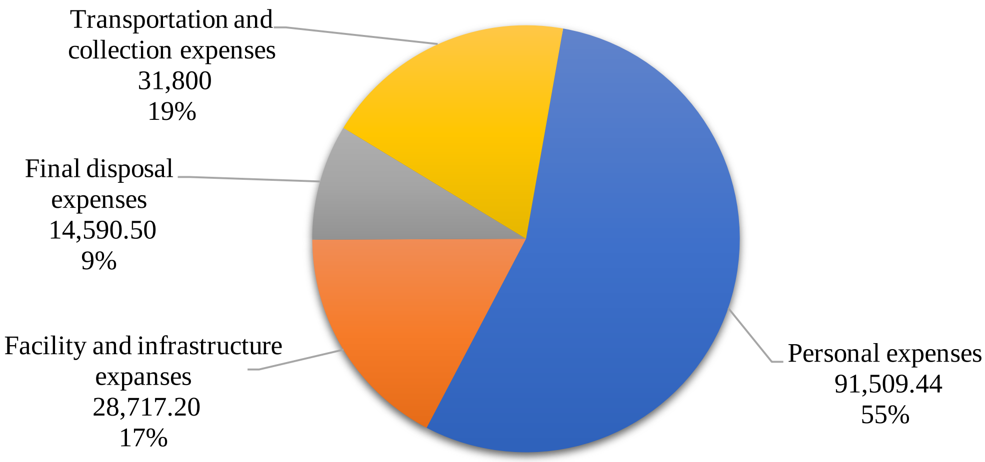

Figure 2.5 Waste management expenses of Medan City in 2017 (in a million rupiahs)

2.5 Waste management services

Household waste (HW) management in Medan City is managed by the municipality. There is no separation of different types of HWs at the source; all of them are mixed into a bag and put out in the waste container. The government divides the solid waste management service area into two operating areas, the first area consisting of 10 sub-districts and the second of 11 sub-districts. The HWs are collected daily in all areas. There is no specifical difference in term of service between the areas; the division area aims to ease the city in providing waste management services to the people. Figure 2.6 shows the service area of HW management.

In the downtown area, waste is collected by a door-to-door trucking service and taken directly to the landfill without sorting it first. The door-to-door service not only serves residential areas but also picks up waste from markets, roads, public facilities, industry, and business/commercial units. In the suburbs, however, the government implements an indirect service system. Communities transport their waste directly or communally by pedicab to containers at certain locations, and the municipality discharges the waste collected in the containers into the landfill.

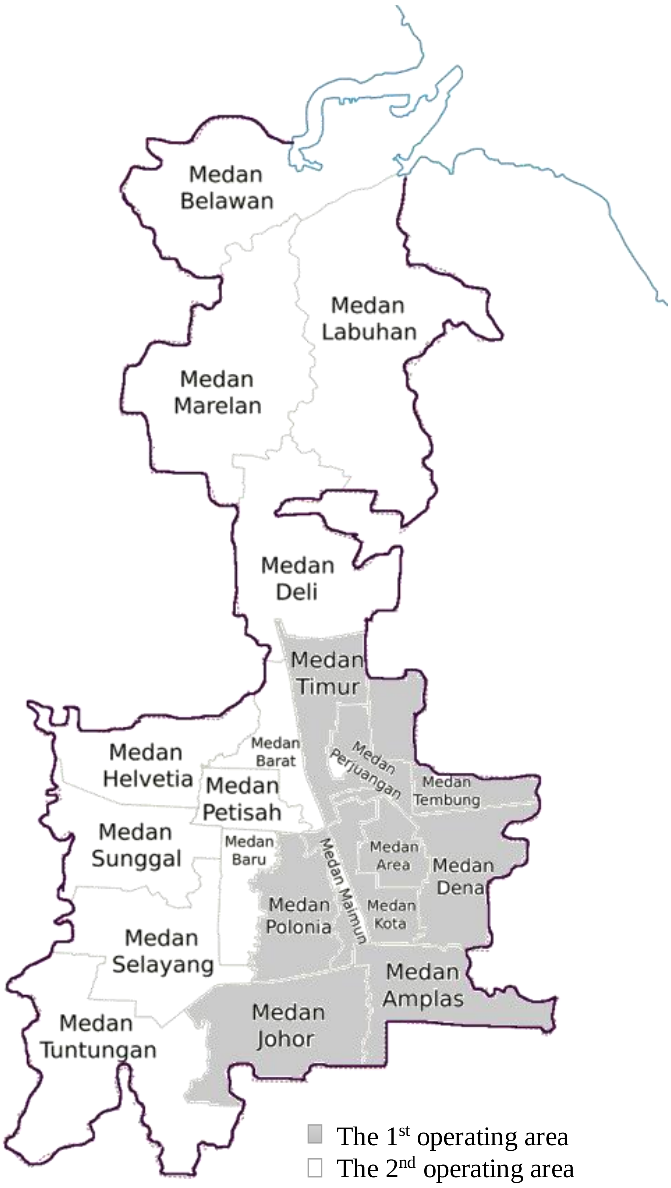

Figure 2.6 Service area of HW management

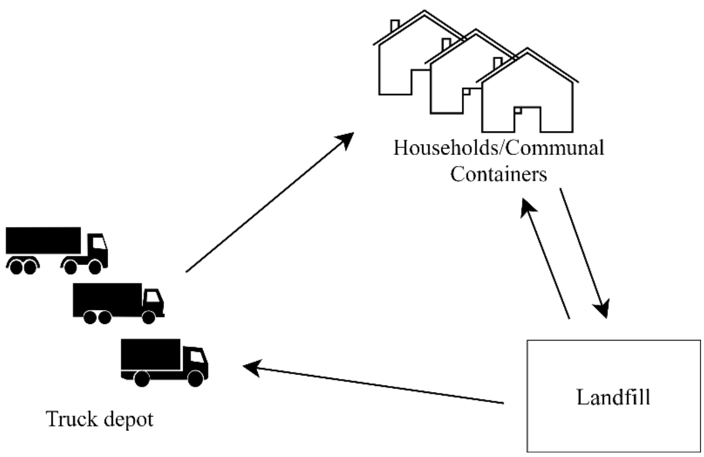

Figure 2.7 Waste transportation route scheme

Trucks depart from the depot to the households / communal container to collect waste. From households / communal containers, the wastes are transported to landfills. Every day, every truck conduct 2-3 trips. One trip is waste transported from the communal container and delivered to landfills. Waste transport route scheme is presented in Figure 2.7.

2.6 Reduce, Reuse and Recycle activities

Until now, the city government has not been able to implement 3R in municipal waste management system although the Law 18/2008 has mandated it 10 years ago. 3R in the city of Medan is limited to concepts, discourse, socialization and campaigns. One example of this activity is the Implementation of 3R to 100 teachers and students in Medan Selayang District (Tonggo, 2016).

Some central government programs on 3R have reached the regions, including promoting and implementing 3R through waste bank, capacity development project for national and local government on 3R and solid waste management system, supported by Japan International Cooperation Agency (JICA). As a result, a JICA's Grassroots Project "Improvement of Waste Management in Medan City" with the Government of Medan City between 2013-2015 brought an increase in the number of waste banks in Medan (Pemko Medan, 2018).

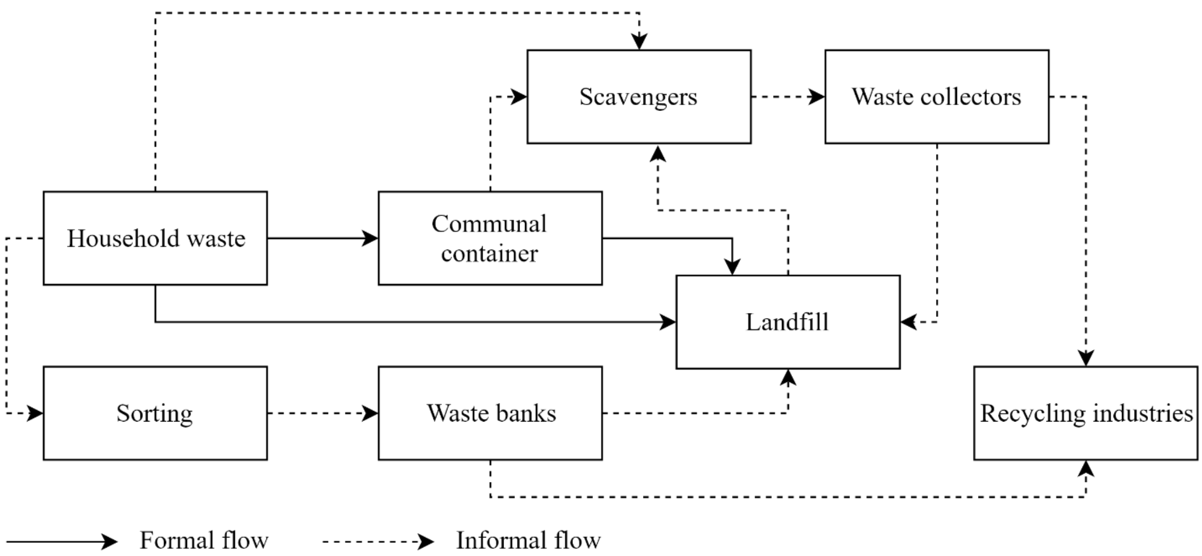

Figure 2.8 Role of formal and informal sector in Medan

Besides the formal sector, the informal sector in Medan city plays a vital role in waste management activities. Communities and scavengers drive the informal sector. The community aims to educate the community to reduce and separate recyclable waste materials at the source. The sorted recyclables waste is sold to the waste bank. Waste banks will do further sorting before reselling it to recycling industries.

Due to economic interest, scavengers are present to find the recyclable material that is worth money. Scavengers sell recyclable materials to the waste collector. From the waste collector, recyclable material is sold to recycling industries. Scavengers operate in almost all locations, starting from residential areas, communal containers, even in the landfills site.

However, there is still much waste that is dumped into the environment (rivers, empty land, etc.). The government stated that the service area had covered more than 80%. People still keep dumping their waste into the environment because they do not want to pay waste retribution fee every month (Benny & Zaenal, 2017). A study of how to treat waste at the household level found that 63.2% of the community disposed of their waste into communal containers. As many as 23.4% of the people still do waste burning, and 3.7% of people dispose of their waste into the river.

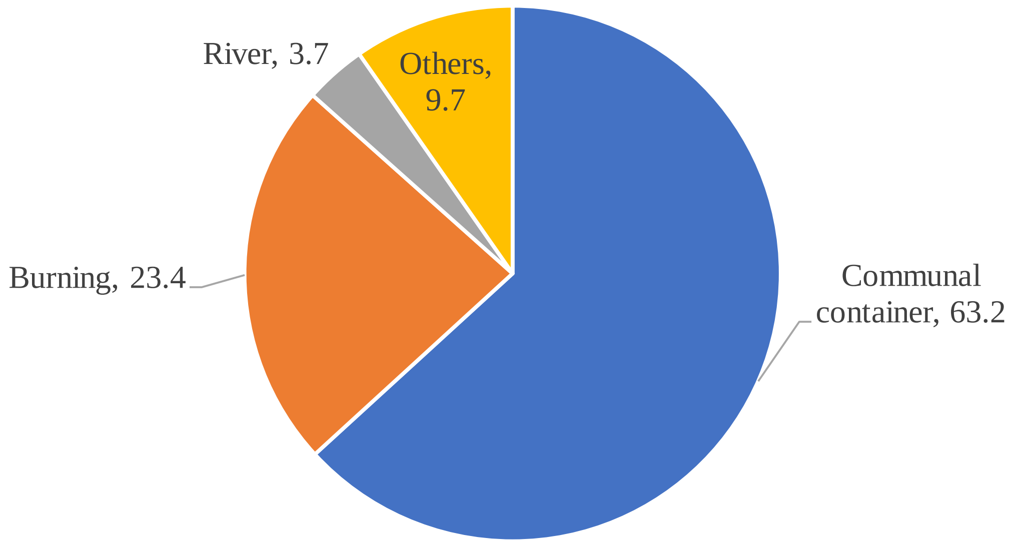

Figure 2.9 How to treat waste at the household level

(Pokja Sanitasi Kota Medan, 2016)

2.7 Waste bank activities

Reduce, reuse, and recycle (3R) activities in Medan City is implemented in the form of a waste bank program. This program was inspired by the success story of other cities in Indonesia in carrying out 3R activities through waste banks. As recorded, the first waste bank was established in Medan city in 2011 (Dinas Lingkungan Hidup Kota Medan, 2017). The number of waste banks in the city of Medan has been increasing since the presence of the central waste bank in 2014. Until now, this is the only central waste bank in Medan. The central waste bank is the result of a cooperation program between the Medan city government and the city of Kitakyushu, Japan. The "Improvement of Waste Management in Medan City" program, which began in 2014 until 2016 (Dinas Lingkungan Hidup Kota Medan, 2016).

The waste bank obtains the wastes from its members. To depositing recyclable wastes, a member waste bank candidate needs to open an account. Afterward, they can deposit the recyclable wastes to the waste bank. Waste bank weights and calculate the value of wastes for exchange money. Activities in waste banks generally consist of waste collection, sorting, and cleaning, waste selling to third parties. The flow of waste bank activities is shown in Figure 2.10.

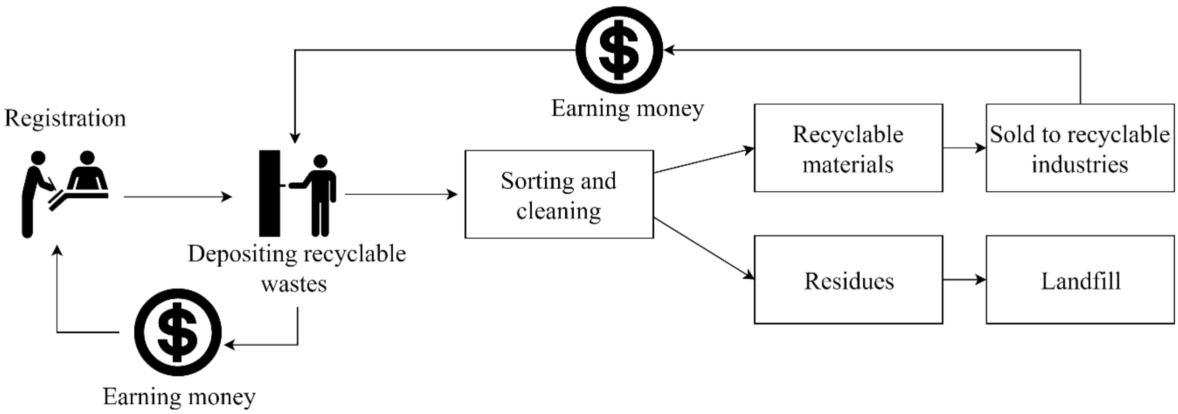

Figure 2.10 Waste bank activities flow

Sicanang waste bank, the only one central waste bank in Medan, is managed by an NGO. The central waste bank operates clinics that provide clinical and health care services to the community using waste bank savings. They also assist in the establishment of other waste banks, collects, buys recyclable items from other waste banks, and organizes regular meetings between all waste banks. At the beginning of its formation, the Environmental Agency of Medan City provided financial assistance for the operation of the central waste bank. However, gradually decreases and stops when the waste bank delegated responsibility from Environmental Agency to the Department of Cleanliness and Park of Medan City. Approximately, the total amount of waste collected from the waste bank was 76,100 kg in 2016 (IGES, 2019).

In general, waste banks in Medan City could be classified based on the type of management. There are three types of waste banks in Medan; they are institutions, schools, and communities. They provide services to exchange recyclable items with money in a savings system that adopts a simplified version of the formal bank system. This waste banks use temporary places owned by individuals or organizations. Received recyclable items from the communities are weighed and recorded in the savings book, and the amount of money equal in value to the item will be given a certain period. Until 2017, there were 142 waste banks in the city of Medan. However, only 97 garbage banks are active (Dinas Lingkungan Hidup Kota Medan, 2017). Based on 97 units of active waste banks, only 13 waste banks were fit for a "good" rating, and the rest were below until 2017 (Dinas Lingkungan Hidup Kota Medan, 2017). The number of waste banks for each group can be seen in Figure 2.11.

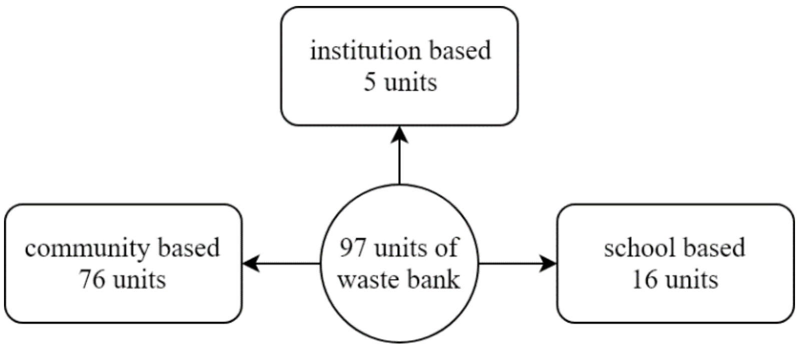

Figure 2.11 Group of waste banks in Medan

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Chapter 3 Study on household waste generation and its composition

3.1 Introduction

The quantity of household waste (HW) has continued to increase in many cities in developing countries during the last few years. Population growth, changing lifestyles, economic growth, increasing social activities, etc. are the main factors contributing to the accretion of HW in such quantity. In developing countries like Turkey, the quantity of HW has increased due to industrialization and increase in living standards (Arıkan, Şimşit-Kalender, & Vayvay, 2017). Unmanageable accretion of HW will harm our environment, destroy the urban landscape, and spread diseases and threaten human health (Santibañez-Aguilar, Flores-Tlacuahuac, Rivera-Toledo, & Ponce-Ortega, 2017). The composition of HW is directly affected by several factors: socio-economic and cultural conditions, food habits, seasonal variation, geographical location, etc. The composition of HW also reveals the trends in waste reuse/recycling, practiced informally in many parts of the developing countries (Suthar & Singh, 2015). Waste quantity and composition are the main aspects used in the assessment and planning of solid waste management and disposal.

Availability and accuracy of data on HW generation and composition become very important and useful in environmental planning and assessment, as well as in evaluating and improving the efficiency of solid waste management services. Many cities in Indonesia still lack reliable data on solid waste, its generation, and composition.

The solid waste management activities in Indonesia consist of its collection, transfer and transportation, and final disposal. Indonesia has a legal framework for solid waste that was prepared by its Ministry of Environment, written into the Waste Management Law No. 18/2008, requiring the local governments and stakeholders to comply with the rules regarding disposal sites, and providing for the closure of non-complying disposal sites.

Globally, there is a drive for sustainability, and efforts are on to reduce material consumption. Accordingly, so-called 3R initiatives have been introduced to "Reduce, Reuse and Recycle" waste materials, thereby reducing the final volume of waste that enters landfill sites. The

Indonesian government has introduced the zero-waste concept in 2016 (Jong, 2016), the plan is to set Indonesia as a country free from waste by 2020 (Kementerian Lingkungan Hidup dan Kehutanan, n.d.). The local governments have to be cooperatively involved. Each local government needs to enact a new policy regarding waste management.

Currently, not much research related to solid waste management is available for the city of Medan. A study in Japan showed that the separation of recyclables from non-recyclables may improve the efficiency of intermediate treatment facilities but should not be expected to improve the efficiency of overall waste management services. This study also found that waste management cost can be reduced by 26% if there is management coordination among adjacent municipalities. Furthermore, if municipalities could reduce the volume by 1%, the collection cost per unit could be lowered by 4%, and the disposal cost per unit by 27% (Chifari, Lo Piano, Matsumoto, & Tasaki, 2017).

Medan is a metropolitan city located on Sumatra Island. It is the largest city on the island and the third largest city in Indonesia following Jakarta and Surabaya. It is one of the fastest growing cities in Indonesia and an economic hub and commercial center for the region. The last census reported the population of Medan City as 2.4 million, with a population growth rate of 0.89% in 2015 (Statistic of Medan Municipality, 2016). Medan City has become a migration destination for the region, with unplanned urbanization and growth of slum areas causing problems for the municipality.

The municipality needs data based on the quantity and composition of the solid waste in order to improve its service. This paper presents findings of a study on the current situation of solid waste management in Medan and the composition of HW. Furthermore, the report also analyzes the differences and similarities in HW among three different socio-economic groups and elaborates on the options for solid waste management in Medan.

3.2 Materials and Methods

3.2.1 Study area

The study collected data from samples distributed in Medan City, which is located in the northern part of Sumatra Island, Indonesia. The city has an area of about 265.1 sq. km. Medan is the capital city of North Sumatra and a business hub within the triangular region marked by

Medan, Kuala Lumpur, and Singapore. Located near the equator, Medan has an entirely tropical climate with two major seasons; dry season (February–July) and rainy season (August–January). The minimum and maximum temperature was 21.2° and 35.1°C. The area's relative humidity is quite high; it receives an average of 2808 mm with 189 days rainfall per year (Statistic of Medan Municipality, 2017).

3.2.2 Current household waste management practices

Household waste (HW) management in Medan City is managed by the municipality. There is no separation of different types of HWs at the source; all of them are mixed into a bag and put out in the waste container. There are several types of collection services used in Medan. The solid waste management system is managed by Dinas Kebersihan dan Pertamanan (Sanitation and Gardening Agency) of Medan City, mandated by local government regulation Perwal Nomor 1 Tahun 2017.

Solid wastes are collected daily in all areas. However, not all household waste in Medan City is dumped into landfills. There is still much waste that is dumped into the environment (rivers, empty land, etc.). The government stated that the service area had covered more than 80%. People still keep dumping their waste into the environment because they do not want to pay waste retribution fee every month (Benny & Zaenal, 2017). The government divides the solid waste management service area into two operating areas, the first area consisting of 10 sub-districts and the second of 11 sub-districts. There is no specifical difference in term of service between the areas; the division area aims to ease the city in providing waste management services to the people. The two operating areas are presented in Figure 3.1. In the downtown area, waste is collected by a door-to-door trucking service and taken directly to the landfill without sorting it first. The door-to-door service not only serves residential areas but also picks up waste from markets, roads, public facilities, industry, and business/commercial units. In the suburbs, however, the government implements an indirect service system. Communities transport their waste directly or communally by pedicab to containers at certain locations, and the municipality discharges the waste collected in the containers into the landfill.

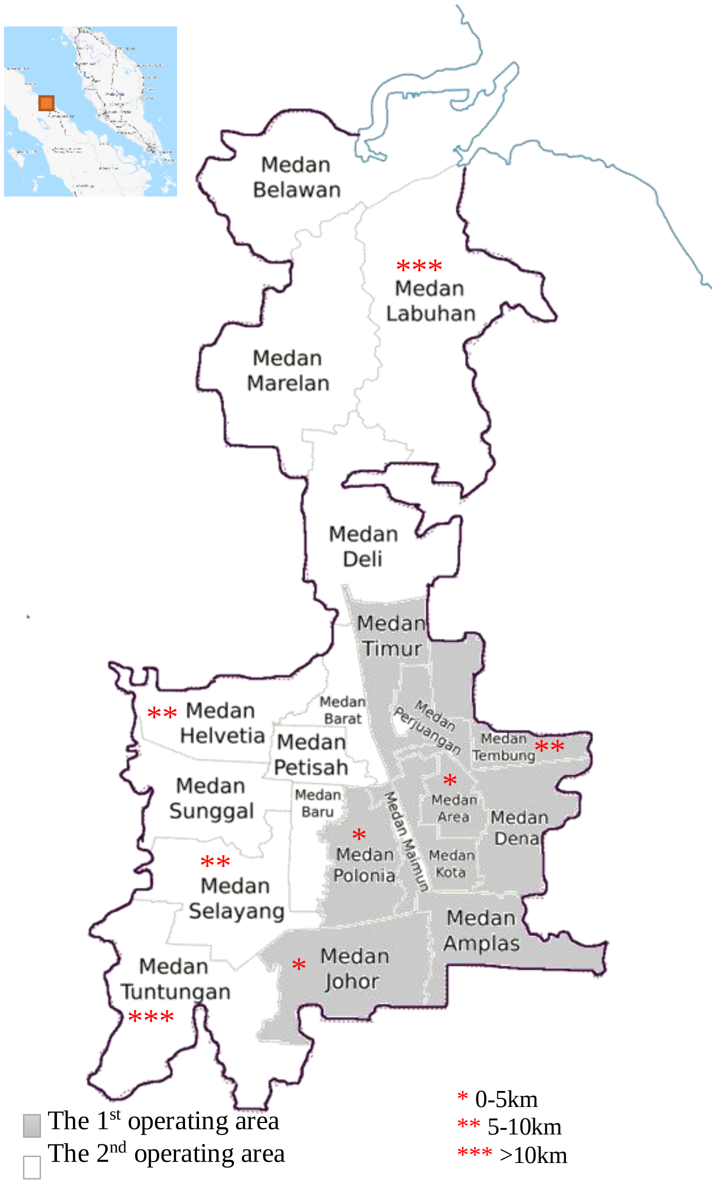

Figure 3.1 Operating and sampling area of waste management system in Medan City

The infrastructure for the waste collection system is provided by the central and local government, with funds from the central government, from local government, and also from the tariff collected from the people of Medan City, who have to pay from IDR 3,300 to 38,500 per household per month. The tariffs are calculated based on the type of house, area, and location (Pemerintah Kota Medan, 2012). These tariffs are regulated as per local regulation Peraturan Daerah Kota Medan No. 10 Tahun 2012.

Regarding transportation facilities, each sub-district has at least one truck that operates daily to transport waste to the landfill. Formally, there is no sorting at the source or the communal container. The mixed waste is directly disposed to the landfill. Informally, parties such as scavengers try to find items of economic value that are then sold to collectors. The flow of waste in the waste management system in Medan can be depicted as in Figure 3.2.

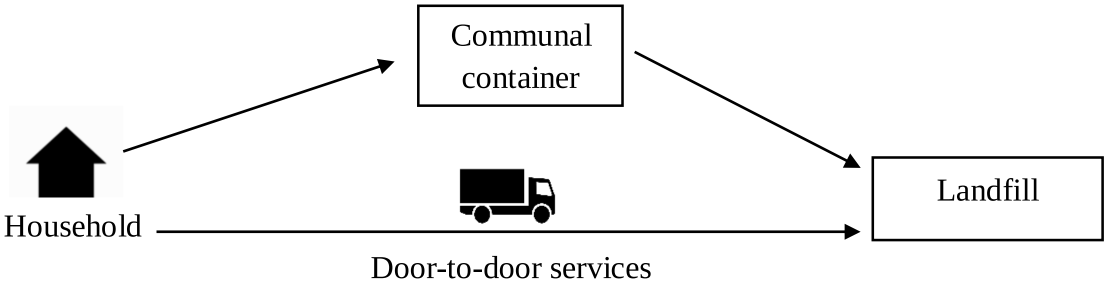

Figure 3.2 Existing waste management flow system in Medan

Waste in Medan City is disposed to the Terjun landfill, which is managed by the municipality, and located in Medan Marelan sub-district, approximately 15 km from the city center. At Terjun landfill, there is also no waste processing; the waste is just dumped without treatment. Only scavengers are involved in the collection of recyclable items here. Data from the sanitation agency in 2016 estimated that as many as 1600 tonnes of waste from various sources are disposed of at this landfill every day, while in 2017 the number waste transported to landfill increased to 2000 tonne/day (Naipospos, 2017a). The activities in Terjun landfill can be seen in Figure 3.3.

Figure 3.3 Activities of Terjun Landfill, Medan

In the absence of the government's role, the informal sectors play an essential part in the recovery of usable materials from waste. They collect recyclable waste from the communal container and the landfill for resale. They sell the collected valuable waste to collectors who then sell them on to recycling plants.

Currently, the problem of solid waste collection is defined by low levels of service quality and weak financial sustainability. The low levels of service are indicated by the shortage of facilities and infrastructures in waste management. Without increasing revenues from solid waste management services, the municipality cannot finance improvements to service provision. At the same time, there is also low awareness of community participation and also willingness to pay among residents.

3.2.3 Sampling methodology and data collection

The procedure for sampling waste generation refers to Indonesia standard SNI 19-3964-1994. The number of sample size was determined by Equation 3.1, which is also provided in the standard (Badan Standarisasi Nasional, 1994).

$$S = C_d \sqrt{P} \tag{3.1}$$

Where S = sample size, C_d = household coefficient (in this study, C_d = 1), and P is the population in the study area. Referring to a statistical data of the province, an average each household was inhabited by four people (BKKBN, 2016). This number was used to estimate the needs of the number of sampled households.

The estimating of the household sample is presented below.

Medan population = 2.4 million

$S = 1 \times \sqrt{2400000} = 1549$

By an assumption that an average each household was inhabited by four people, the number of household sample will be 1549/4= 373 households.

Furthermore, the household size followed the result of the questionnaire that was distributed to them. According to the SNI, wastes were collected in 8 consecutive days, and the wastes collected from each household was analyzed on the same day (Badan Standarisasi Nasional, 1994). An overlap in one day in the week of the survey is used to obtain a correction factor. The samplings were started on the weekday for each sub-district.

Stratified and purposive sampling technique was applied in this study to distribute sample households. In total, the 424 sample households were distributed among 8 of the 21 sub-districts in Medan City. The following criteria were used as a basis in the selection of sub-districts; population density, the condition of the area (coast, mountains or plains), city center/suburb, government activity, economic activity, and education activity. This study classified the sub-districts into three groups based on its distance to the city center (as can be seen in Figure 3.1). The first group is 0-5 km from the city center: they are Medan Polonia, Medan Area, and Medan Johor. The second group contains the areas 5-10 km from the city center, Medan Tembung, Medan Selayang, and Medan Helvetia. The last group consists of the sub-districts located more than 10 km from the city center, Medan Tuntungan, and Medan Labuhan. The number of sample households and its distribution is presented in Table 3.1.

The selection of sample households was divided into three different classes: high-income class (HI), medium-income class (MI), and low-income class (LI). The high-income class consists of households that have a permanent building and a good supply of electricity and water. These houses commonly are single or multi-story buildings and also have good road connection and services of school and supermarket. The medium-income class is identified by bungalows, semi-detached or detached houses with the single or multi-story building, and a sufficient supply of electricity and water. These households also have access to the services of supermarket and school. The low-income class is characterized by poor access to social services and poor economic condition. They are housed in non-permanent buildings, with below average access to services like water and electricity, school and supermarket. Those criteria are used to identify the selection of household samples. Based on economic condition approach (Widiatmanti, 2015), this study used the proportion of sample ratio 25% for HI, 30% for MI and 45% for LI, that is distributed evenly in each the study area.

Table 3.1 The number and distribution of sample households

Sub-district	Population	HI (household)	MI (household)	LI (household)	Total (household)	Sampling duration (day)
Medan Polonia*	55949	8	9	14	31	8
Medan Area*	98992	10	13	22	45	8
Medan Selayang**	106150	12	18	20	50	8
Medan Helvetia**	150721	17	25	30	72	8
Medan Tembung**	137178	15	20	31	66	8
Medan Johor*	132012	16	19	28	63	8
Medan Tuntungan***	85613	10	12	19	41	8
Medan Labuhan***	117472	14	17	25	56	8
Total		102	133	189	424	

*distance 0-5km from city center

** distance 5-10km from city center

***distance >10km from city center

The method of waste composition analysis also used Indonesia standard SNI 19-3964-1994 as a reference. The measurement of household waste composition was calculated based on a percentage of weight, as shown in Equation 3.2.

$$\textit{Percentage of waste fraction} = (B/BBS)\times 100\% \quad (3.2)$$

(Badan Standarisasi Nasional, 1994)

B = weight of waste fraction, kg

BBS = total weight of HW, kg

The wastes were sorted into various sub-fractions, analyzed by their weight and presented as the percentage composition. The type/sort of waste compositions was mainly adapted from (Pichtel, 2005) and (Gidarakos, Havas, & Ntzamilis, 2006), they were sorted into:

a. Paper – magazine, newspaper, book, packaging paper and cardboard
b. Plastic – PETE, HDPE, PVC, LDPE, PP, PS and other
c. Organic – food waste, yard waste, and leaves
d. LWTR – leather, wood, textiles, and rubber
e. Glass
f. Metals – metal and aluminum
g. Inert – stone, ground, construction and demolition waste
h. Miscellaneous.

Waste generation was obtained by analyzing waste in each household, while the composition was obtained by analyzing it into strata HI, MI and LI.

The survey on household waste was conducted from April to July 2017. This study focused on domestic waste. Therefore solid wastes generated by flats, hotels, restaurants, shops, markets, commercial buildings, and offices were not included in data collection. Flats do not exist in Medan as a dwelling house. Until right now, flats are managed like hotel management, rented to the people for short periods. Before collecting the wastes, the households were informed about what we are doing and inform the aim of the research. Authors also asked their willingness in the participation of this research. At that time, plastic bags and questionnaires were distributed. Questionnaire data is needed to determine the economic situation and its household size. Targeted households were asked to put their waste into the plastic bag and place it in front of their home.

Besides collecting primary data, the study also collected secondary data such as city statistics, government reports, waste bank activity reports and documents, academic papers, and many others. Those data can be obtained from many stakeholders in waste management in Medan City such as statistic agency, the municipality, private informal sectors (waste banks), communities, internet sources, etc. A total of 20 trained university students were involved in assisting this research. They got waste management courses in the classroom and practical work related to how to analyze waste.

3.2.4 Statistical analysis

The statistical analysis used in this study included a descriptive analysis of essential information from the collected data, presented in graphic and tabular forms. An analysis of variance and t-test was used to obtain the relationship between waste generation rate, household income, and geographical locations. All the analysis was at the $p < 0.05$ levels.

3.3 Results

3.3.1 Household waste generation and composition

The HW generation is calculated on a weight basis. This study collected and analyzed as much as 2,956.77 kg of household wastes. Based on questionnaire data, an average each household has 4 people with a standard deviation of 1.2. This result is obtained from the response of 424 sample households. This study found that the generation rate of HW in Medan City is 0.222 ± 0.191 kg/person/day, not much different from other similar cities in Indonesia. Table 3.2 shows the comparison of waste generation in various cities in Indonesia.

Table 3.2 Comparison of waste generation in various cities in Indonesia

City	GDP (million rupiah)[1]	Population[1]	Population Density[1] (persons/sq.km)	Generation rate (kg/person/day)	Sources
Medan	83.45	2210624	8342	0.22	this survey
Jakarta	142.58	10177924	15367	0.26	[2]
Bandung	45.07	2483977	14646	0.27	[3]
Surabaya (eastern)	128.92	2848583	72297	0.33	[4]

[1](Statistics Indonesia, 2017)

[2](Dinas Lingkungan Hidup Jakarta, 2016)

[3](LPPM ITB, 2007)

[4](Dhokhikah, Trihadiningrum, & Sunaryo, 2015)

Table 3.3 Household waste composition in Medan City

Composition	%	
Paper		8.20
Magazine	0.25	
Newspaper	0.83	
Book	1.31	
Packaging paper	4.54	
Cardboard	1.26	
Plastic		17.55
PETE	2.60	
HDPE	4.11	
PVC	0.15	
LDPE	8.60	
PP	1.55	
PS	0.18	
Other	0.35	
Organics		61.35
Food waste	57.40	
Yard waste	1.62	
Leaves	2.33	
LWTR		1.53
Leather	0.02	
Wood	0.22	
Textiles	1.15	
Rubber	0.15	
Glass		1.48
Metal		1.48
Metals	1.29	
Aluminum	0.19	
Inert		0.15
Stone	0.05	
Ground	0.04	
Construction	0.05	
Demolition waste	0.01	
Misc.		8.27

The composition of HW in Medan as observed in this survey is shown in Table 3.3. Organic waste was found to form the largest fraction at 61.35%, followed by plastic, 17.55% and paper, 8.20%. The organic waste came predominantly from food waste. Plastic wastes were commonly found to be of LDPE type plastic (from shopping bags, plastic wrapping, plastic bags, bottles, storage boxes, and toys), and HDPE type (from household and kitchenware waste, milk bottles, shampoo bottles, carrier bags, food wrapping materials, and others). The third fraction is paper waste, from wrapping papers, cardboard, books, and others. The other materials like LWTR (leather, wood, textiles, and rubber), glasses, metals, and inert material form 12.90% of the HW composition. The composition of HW in Medan is not much different from that in other cities in Indonesia, as can be seen in Table 3.4.

Table 3.4 Comparison of solid waste composition in various cities in Indonesia

City/Area	Paper (%)	Plastic (%)	Organic (%)	LWTR (%)	Glass (%)	Metal (%)	Inert (%)	Misc. (%)	Sources
Medan	8.20	17.55	61.35	1.53	1.48	1.48	0.15	8.27	this survey
Jakarta	14.92	14.02	53.75	2.50	2.45	1.82	0.01	10.54	1
Bandung	10.10	12.09	52.00	5.45	3.65	4.37	1.64	10.70	2
Surabaya (eastern)	9.24	10.79	67.56	2.09	0.79	0.50	-	9.03	3

[1](Dinas Lingkungan Hidup Jakarta, 2016)

[2](LPPM ITB, 2007)

[3](Dhokhikah et al., 2015)

3.3.2 Effect of geographic location on waste generation

Different economic, business, governmental, educational, and industrial activities may affect the waste generation. The sub-districts within a radius of 0-5 km of the city center are dominated by businesses, offices, and government centers. The 5-10 km belt is dominated by residential and shopping areas. The last group of the study area is occupied by many housing and industrial estates.

Based on the geographical location, the area within 5 km of the city center has a waste generation rate of 0.300 ± 0.274 kg/person/day. The second group has an HW generation rate of 0.159 ± 0.118 kg/person/day while the third group has a generation rate of 0.255 ± 0.088 kg/person/day. Within the three groups of this study, the areas located 5-10 km away have the lowest generation rate, and this could mean a low level of consumption compared with the first and third group. The results of waste generation in a different location can be seen in Figure 3.4.

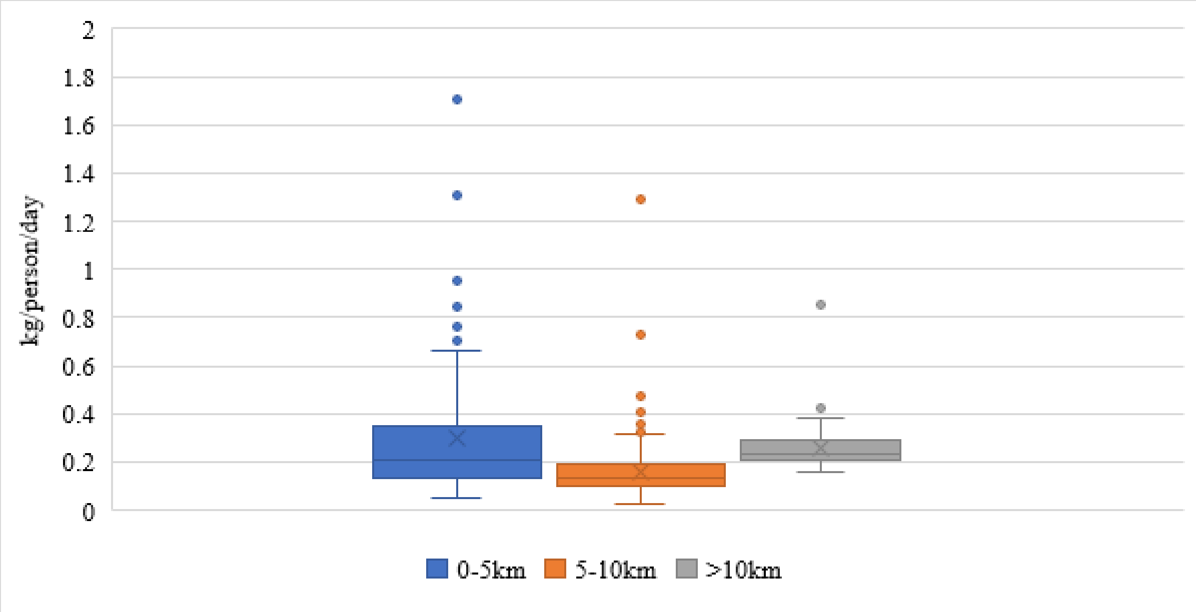

Figure 3.4 Box-Whiskers plot of household waste generation in different locations

The result of the statistical analysis in Table 3.5 shows that there is a statically significant difference in waste generation rates between 3 groups. The sample sizes for each group is unequal. A post hoc test was carried out to confirm where the differences occurred between groups. The difference occurred between the areas located 0-5 km and 5-10 km, and the areas located 5-10 km and > 10 km. However, there was no difference in waste generation rates between the areas located 0-5 km and more than 10 km. Table 3.6 shows a post hoc test result of waste generation in the different groups.

A low level of waste generation in the area 5-10km shows a low level of consumption. An existing land-use map of Medan city shows that housing predominates area 5-10 km. While the area 0-5km is a downtown containing office complex and commercial area where people work and do daily activities. The results of this study indicate that people who live in areas of 5-10 might spend more time at work rather than at home resulting in reduced waste generated in homes.

Table 3.5 ANOVA analysis results

Variation	df	MS	F	P-value	F crit
Household location	423	0.838	25.658	3.06E-11	3.017
Household income level	423	0.072	1.976	0.1400	3.017

Table 3.6 T-test analysis results for different locations

Variation	df	P(T<=t)	Significant point
0-5km and 5-10km	176	6.104E-08	0.0167
5-10km and >10km	248	2.370E-13	0.0167
0-5km and >10km	176	0.07790	0.0167

The composition of HW in our study is dominated by organics, plastics, and papers for all locations. The organic fraction is the main component overall. Figure 3.5 and Table 3.7 show that the composition of waste located within 5 km and 5-10 km away have almost the same result. In the area located more than 10 km from the city center, the plastic fraction is higher compared to the two other locations, but the organic is still the highest fraction. The preponderance of plastics in the third group was caused by the high use of food packaging. The differences in the composition of wastes between these groups indicate the influence of consumption level, lifestyle, and culture.

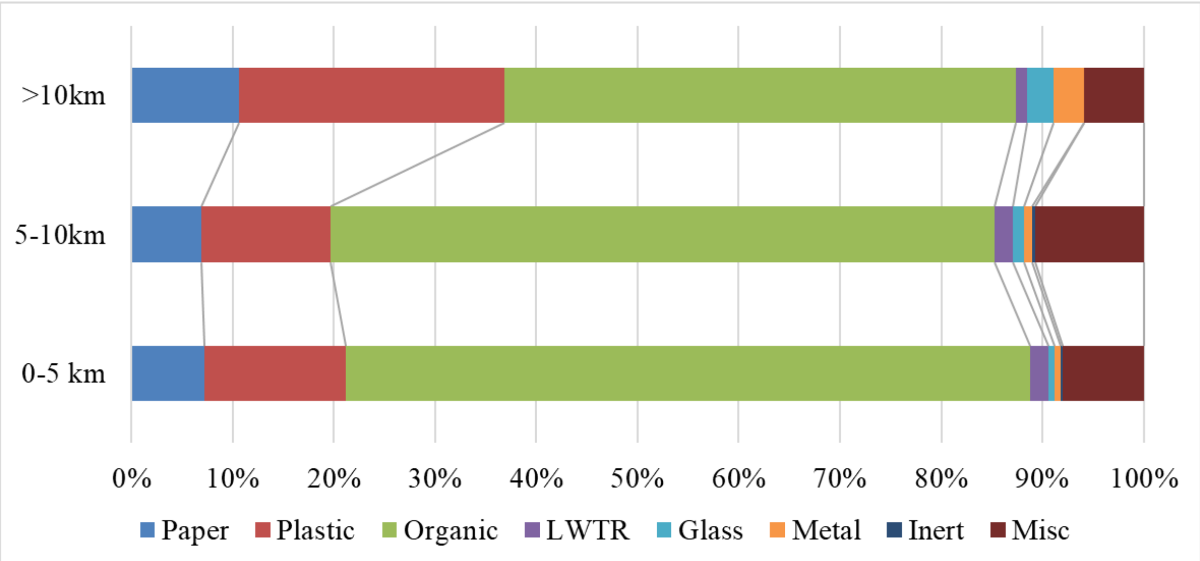

Figure 3.5 Comparison of household waste composition in different locations

Economic activities, commercial activities, business, government centers, education, and industry in each sub-district are the main factors that influence the resultant HW generation and its compositions. The other factor affecting waste generation is the family lifestyle, such as the time they spend at home or eating outside (Hoang, Fujiwara, & Phu, 2017).

Table 3.7 Waste composition from different location

Composition	0-5 km	5-10km	>10km
Magazine	0.06	0.45	0.22
Newspaper	0.64	1.16	0.66
Book	1.15	1.74	0.99
Packaging paper	4.11	2.57	7.11
Cardboard	1.21	0.95	1.66
PETE	0.96	1.88	4.98
HDPE	4.92	3.89	3.57
PVC	0.24	0.22	0.00
LDPE	6.12	5.45	14.44
PP	1.04	0.70	2.98
PS	0.24	0.29	0.00
Other	0.43	0.35	0.28
Food waste	63.66	61.96	46.34
Yard waste	2.75	1.77	0.34
Leaves	1.27	1.87	3.86
Leather	0.01	0.04	0.00
Wood	0.23	0.27	0.15
Textiles	1.30	1.27	0.87
Rubber	0.24	0.21	0.00
Glass	0.67	1.15	2.62
Metals	0.31	0.54	3.05
Aluminum	0.26	0.29	0.01
Stone	0.11	0.04	0.00
Ground	0.06	0.05	0.01
Construction	0.01	0.12	0.00
Demolition waste	0.02	0.01	0.00
Misc.	7.99	10.74	5.86

3.3.3 Effect of income level on waste generation

Based on the income level of the population, the average waste generation of high-income (HI), middle-income (MI), and low-income (LI) residents has almost the same value across the range. Average domestic waste generation for HI was 0.202 ± 0.132 kg/person/day, for MI 0.219 ± 0.180 kg/person/day, and LI 0.247 ± 0.222 kg/person/day (Figure 3.6). The result of the waste generation rate in different income level is shown in Table 3.8.

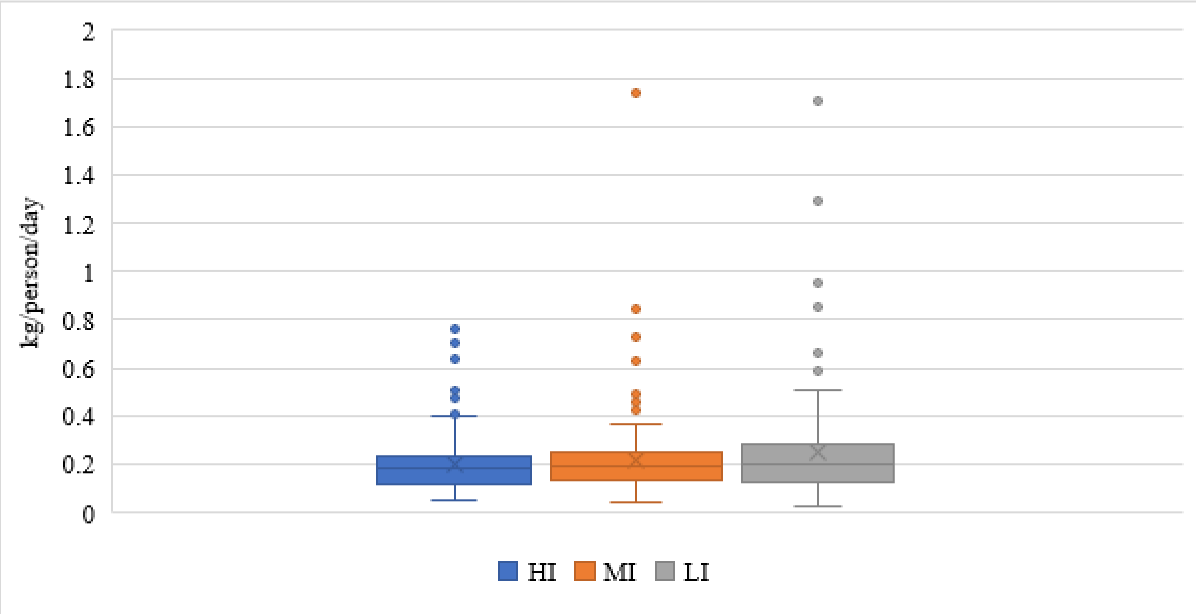

Figure 3.6 Box-Whiskers plot of household waste generation in different income levels

Other studies on several cities in Indonesia show that higher the standard of living and income level, the higher is the generation of waste (Table 3.9). However, this is not the case in the city of Medan. The difference of the findings might be caused by the difference of waste generation definition and the use of methodology. Although the income level is expected to be impact related to the level of consumption, the amount of waste generated per day is almost identical for all economic levels, as can be seen in Table 3.10. This study found no significant difference in waste generation rate within the different income level. The result of the statistical analysis of HW generation in different strata is described in Table 3.5.

Table 3.8 Result of waste generation rate in different income levels and sub-districts

Sub-district	Population	High- income (kg/person/day)	Middle-income (kg/person/day)	Low- income (kg/person/day)	All income classes (kg/person/day)
Medan Polonia	55949	0.261	0.351	0.403	0.353
Medan Area	98992	0.386	0.259	0.482	0.388
Medan Selayang	106150	0.176	0.182	0.185	0.182
Medan Helvetia	150721	0.129	0.171	0.143	0.149
Medan Tembung	137178	0.136	0.137	0.118	0.128
Medan Johor	132012	0.195	0.296	0.208	0.229
Medan Tuntungan	85613	0.213	0.223	0.331	0.267
Medan Labuhan	117472	0.206	0.238	0.251	0.235
All data Average		0.202	0.219	0.247	0.222
Standard deviation		0.132	0.180	0.222	0.191
Max		0.763	1.736	1.706	1.736
Min		0.053	0.045	0.027	0.027

Table 3.9 Waste generation of HI, MI, and LI groups in several cities in Indonesia

City	HI (kg/person/day)	MI (kg/person/day)	LI (kg/person/day)	Sources
Medan	0.202	0.219	0.247	This survey
Jakarta	0.300	0.230	0.260	1
Kendari	0.487	0.439	0.436	2

[1](Dinas Lingkungan Hidup Jakarta, 2016)

[2](Chaerul, Dirgantara, & Akib, 2016)

Table 3.10 Waste generation from different income level during eight days' survey

Strata	Day (kg/person/day)							
	1	2	3	4	5	6	7	8
HI	0.197	0.208	0.182	0.190	0.188	0.175	0.184	0.190
SD	0.113	0.153	0.136	0.116	0.120	0.114	0.104	0.135
MI	0.186	0.175	0.185	0.195	0.193	0.196	0.188	0.187
SD	0.095	0.111	0.108	0.105	0.094	0.123	0.096	0.088
LI	0.210	0.199	0.228	0.208	0.197	0.194	0.209	0.211
SD	0.133	0.127	0.192	0.135	0.126	0.131	0.124	0.151

SD, standard deviation

The waste generation levels were slightly lower than the national average standard SNI 19-3983-1995. This standard is used to predict the waste generation in Indonesia if there is no primary data available for the targeted city. According to the SNI, the range of waste generation is HI 0.35 – 0.4 kg/person/day, MI 0.3 – 0.35 kg/person/day, and LI 0.25 – 3 kg/person/day (Badan Standarisasi Nasional, 1995). Still referring to the SNI, although Medan city is categorized as a big city, the waste generation rate puts it in the category of a small city.

The variation in the composition of the HW with income level seems at the same. The composition is still dominated by paper, plastic, and organic for all locations. The organic fraction is still the main fraction. This organic waste commonly comes from food waste. Paper and plastic fractions originate from the packaging of fast food and other products. The detail composition result can be seen in Table 3.11. A large number of street food stalls in the city contributes to paper and plastic waste generated. Figure 3.7 shows the comparison of HW composition at different income levels.

Table 3.11 Waste composition from different income levels

Composition	HI (%)	MI (%)	LI (%)
Magazine	0.40	0.15	0.24
Newspaper	1.21	0.74	0.69
Book	1.42	1.18	1.33
Packaging paper	5.13	4.08	4.56
Cardboard	0.89	1.40	1.37
PETE	2.29	2.40	2.91
HDPE	3.99	3.67	4.50
PVC	0.07	0.10	0.24
LDPE	8.45	8.12	9.03
PP	1.69	1.30	1.66
PS	0.17	0.19	0.18
Other	0.44	0.34	0.31
Food waste	54.04	57.34	59.29
Yard waste	0.96	2.85	1.09
Leaves	2.73	2.48	2.01
Leather	0.00	0.02	0.03
Wood	0.16	0.19	0.26
Textiles	0.78	0.73	1.66
Rubber	0.10	0.09	0.22
Glass	1.95	1.43	1.25
Metals	1.84	1.29	0.98
Aluminum	0.25	0.13	0.20
Stone	0.01	0.07	0.06
Ground	0.08	0.01	0.05
Construction	0.05	0.04	0.05
Demolition waste	0.00	0.01	0.01
Misc.	10.91	9.64	5.83

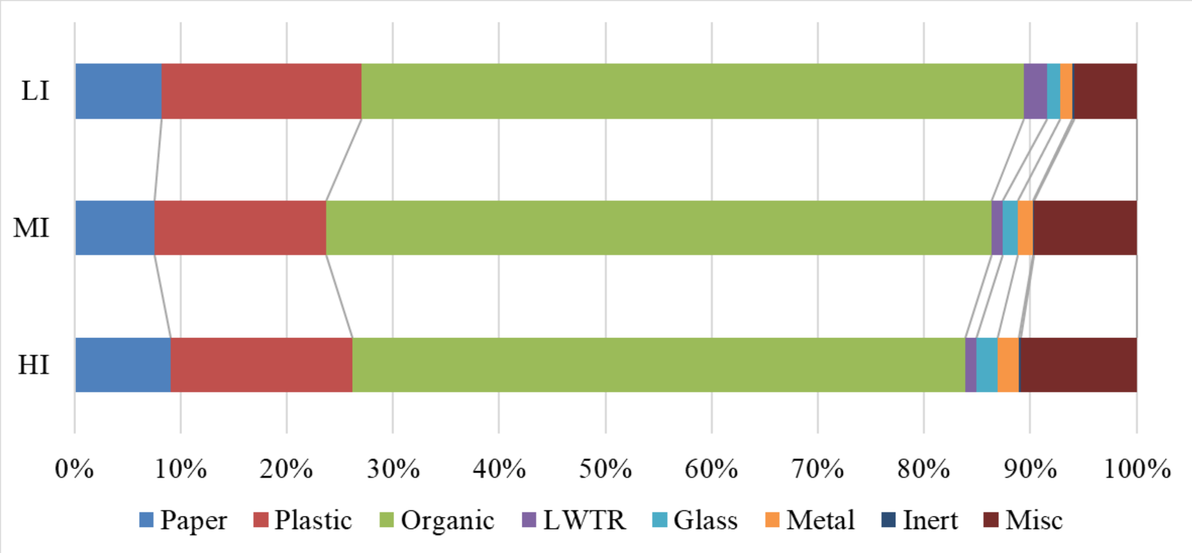

Figure 3.7 Comparison of household waste composition at different income levels

3.3.4 Opportunity for recycling

Medan City is still facing environmental issues related to waste management. At an average household generation rate of 0.222 kg/person/day, an estimated 490 tons/day of mixed waste from households are dumped into the landfill every day. This figure does not include waste from commercial activities, offices, educational institutions, and industries. The figure indicates that household waste amounts to 24.5% of the total waste delivered to Terjun landfill every day. With the economic growth of Medan City, waste generation level may also increase every year. As a result, the landfill will be filled up faster. The government will have problems with the limitations of the existing landfill and the difficulties of finding space for a new landfill. Thus, it will demand the right effort to overcome this problem.

The Indonesian government has tried to reduce the volume of waste entering the landfill. Various policies of waste management have been issued. Indonesia introduced Law No. 18/2008 concerning solid waste management. One of the points of the law is to increase the value of waste recycling so that the amount of waste disposed to landfill could be reduced. Indonesia also has the concept of "Reduce, Reuse and Recycle" (3R); one of its programs is through a waste bank (WB), in which people can dispose of their valuable waste and obtain money in return. Several types of valuable waste are worth selling in the waste bank. The price of each type of waste also varies in each WB, depending on the length of the supply chain from the WB to the recycling industry. Another effort to reduce the amount of waste that goes into the landfill is the composting program. Based on this study, Table 3.12 describes the composition of the solid waste in Medan, and the significant recyclable and compostable items that are commonly accepted in the WBs and other treatments that can be used.

Table 3.12 Solid waste recycling potential in Medan city

Composition	%	A	B	C	D	E
Magazines	0.25	●	●			
Newspaper	0.83	●	●			
Books	1.31	●	●			
Packaging paper	4.54	●	●			
Cardboard	1.26	●	●			
PET	2.60	●	●			
HDPE	4.11	●	●			
PVC	0.15	●	●			
LDPE	8.60	●	●			
PP	1.55	●	●			
PS	0.18	●	●			
Other plastic	0.35	●	●			
Food waste	57.40	●			●	
Yard waste	1.62	●			●	
Leaves	2.33	●			●	
Leather	0.02			●		
Wood	0.22			●		
Textiles	1.15			●		
Rubber	0.15			●		
Glass	1.48	●	●			
Metals	1.29	●	●			
Aluminum	0.19	●	●			
Stone	0.05			●		
Ground waste	0.04					●
Construction waste	0.05			●		
Demolition waste	0.01			●		
Miscellaneous	8.27					●

A: Types of waste accepted at the waste bank
B: Recyclables waste accepted at the waste bank
C: Recyclables excluded from the waste bank
D: Compostable waste
E: Non-recycled waste

Applying the waste recycling potential rating in Table 3.12, it is seen that up to 91.69% of the waste generated from Medan City could be recycled or composted. Among the entry points to waste recycling is the waste bank. The waste components that are potentially recyclable through the waste banks are paper, plastic, glass, metal, and aluminum waste, while rubber, textile, and wood waste are also recyclable but not through the WB. The organic wastes can be processed into compost at the WB or the composting center. This study found that 90.05% of waste generation in Medan City could be processed through the WBs.

Until now, in Medan as in many other cities in Indonesia, the WBs have not been integrated as a formal sector into the waste management system. The WBs are managed by the community independently. Until 2017, there were 97 WBs in Medan; but only 13 WBs were fit for a "good" rating, and the rest were below average (Dinas Lingkungan Hidup Kota Medan, 2017). One of the most prominent and active waste banks in Medan is the Sicanang Waste Bank. This WB receives various types of waste such as paper, plastic bottles, glass, cans, etc. The Sicanang Waste Bank has 813 active members and processes an average 4,858 kg/month of recyclable waste. This waste bank also receives compostable waste, using Takakura composting method with an average of 5 tons of compostable waste processed every month (Bank Sampah Sicanang, 2017). To increase community participation, the Sicanang Waste Bank offers free pick-up services from Monday to Saturday during working hours. However, not all waste banks have compost facilities, since processing compost requires capital, infrastructure facilities, technology, and human resources.

The households have to reduce waste generation at its source. The municipality guides the people how to sort their waste at the household level. The WBs system should be integrated as a formal sector into local municipal solid waste management; this will increase people's participation in the separation, collection, and recycling of waste (Raharjo, Matsumoto, Ihsan, Rachman, & Gustin, 2017), so that each sub-district has a recycling center driven by the WB system.

Another means of reducing waste generation is to use the excellent potential for composting of organic waste, which could treat 61.35% of waste generated (Table 3.12). Medan City predicts that the Terjun landfill will be full within two years (Naipospos, 2017b). If the city and communities succeed in running the WB, around 90.05% of the HW could be handled without being disposed to the landfill, thereby increasing its lifespan. The central government wants all valuable waste to go to the waste bank, and organic waste to be processed into compost fertilizer (Jong, 2016). However, this outlook may be far from reality if there is no good relationship between the government and society, and an urge to consciously manage the waste properly.

The WB is one of the policies of the Indonesian government in an effort to reduce the volume of waste discharged into landfills, by intensifying the recovery of the valuable fraction of waste. The 3R-transfer station, TPS-3R in the Indonesian terminology, that should be organized by communities, is another way driven by the Indonesian government. The result of this research shows that the WB has recycling potential in Medan based on its composition. It means that this potency is not only applicable for WB but also be potential for applying the 3R-transfer station as well as other informal recycling sectors. Combining the application of WB and 3R-transfer station is not only increasing recovery valuable material but also good for the environment especially in reducing greenhouse gas emission (Raharjo, Junaidi, et al., 2017).

Furthermore, sustainable waste management should be implemented. The pattern of management of municipal waste should be planned well, covering both the technical and non-technical aspects. People should be encouraged to sort the waste at source, and the government must provide containers and other infrastructure facilities to handle it. The government can also strengthen waste recycling activities by issuing the right policies. The commitment to these policies will be driven by effective communication, performance incentives, sustainable technology, and feedback. Collaborative research work is also on-going toward a zero-waste management objective and Waste-Free Indonesia 2020.

3.4 Conclusions

The estimated daily household waste of Medan generates an average of 0.222 kg/person/day. Organic waste is the most significant fraction, forming 61.35% of total weight, followed by plastic waste at 17.55%, paper 8.20%, and other materials like LWTR, glasses, and metals making up the balance. The HW generation in each location was statically different, but it has no significant difference within different income level. Based on the data obtained, HWs are contributed to one-third of the amount of waste disposed of the landfill every day. Most of the waste from households in Medan City is a compostable waste, as much as 61.35%, followed by 28.70% recyclable waste. The result of the waste composition shows a good prospect for WB activities. In order to improve solid waste management systems, the government should formulate the right strategies. The government has to ensure the WBs sustainability and also provide technical and non-technical assistance. The level of public awareness must be increased; the people should be taught to reduce and sort the waste from their homes.

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Chapter 4 Material flow analysis of waste bank activities

4.1 Introduction

Waste management has a complex problem to be resolved and requires a long process, especially in Indonesia. Indonesia's Law 18/2008 on Waste Management stated the need for a fundamental paradigm change in waste management. Changes in the paradigm of collect – transport - dispose of processing that relies on reducing waste and handling the waste. All levels of society, both government, business and the wider community, carry out activities to reduce the waste generation, recycle and reuse the waste or known as Reduce, Reuse and Recycle (3R) (KLH, 2013). The government has set a target in the form of a National Strategy Policy on Waste Management, which sets 30% through reduction and 70% handling activities in 2025 (KLHK, 2018). In 2017, the achievement of reducing household waste had only reached 2.12 percent. This figure is far below 15 percent in Presidential Regulation number 97/2017 concerning National Policies and Strategies for Household Waste Management and Household Waste (Susanto & Adi, 2018).

The waste bank is a concept of waste management in Indonesia that the handling of recyclable waste and enables people to earn money in the form of savings by depositing their recyclable wastes in the waste bank. The waste bank also encourages people to participate in management their surround environment actively. The operation of waste banks usually relies on the participation of the community where the waste bank is located and on the cooperation of the recycling sector (Priyo, Sulami, Murayama, & Nishikizawa, 2018). The waste bank activity is believed to be able to solve the environmental issue as a part of waste management and reduce the amount of waste dumped into landfills and provide economic benefits to the community (Wijayanti & Suryani, 2015). When the amount of waste to landfill is reduced, the operational costs of waste management can be cut. Waste bank activity is not only benefiting from the economic side, the empowerment of the local economy but also in terms of environmental and social issues (Wulandari, Hadi Utomo, & Narmaditya, 2017).

Indonesia issued a regulation specifically regulating waste banks activity, which is in the Ministry of Environment Regulation No. 13 in 2012 to implement of the reduce, reuse, and recycle (3R) concept through waste banks. By 2012, there were approximately 886 waste banks in Indonesia (KLH, 2013). The number of the waste bank increased to 1172 in 2015 (Putri, 2018). In 2018, the number of waste banks grew significantly to 5,244 units that spread across 34 provinces and 219 regencies/cities in Indonesia. The waste bank contributes 1.7% of the national waste reduction (1,389,522 tons/year) from the national waste generation and generates an average income of Rp. 1,484,669,825 per year (KLHK, 2018).

Medan is the capital city of North Sumatra province with more than 2.3 million inhabitants. The city has an area of about 265.1 sq.km. Located near the equator, the northern part of Sumatra Island, Indonesia, Medan has an entirely tropical climate with two major seasons; dry season (February–July) and the rainy season (August–January) (Statistic of Medan Municipality, 2017).

Medan generates household wastes (HWs) an average of 0.222 kg/person/day. This amount contributes to one-third of the amount of waste disposed to the landfill every day. Most of them are compostable wastes, as much as 61.35%, followed by 28.70% recyclable waste (Khair, Rachman, & Matsumoto, 2019). The sanitation agency in 2016 estimated that as many as 1600 tonnes of waste from various sources were disposed into the landfill every day, while in 2017 the number waste dumped to landfill increased to 2000 tonne/day (Naipospos, 2017).

Formally, there is no sorting at the source or the communal container. The mixed waste is directly disposed to the landfill. Informal parties such as scavengers (waste picker) try to find items of economic value that are then sold to collectors. Waste in Medan City is disposed to the Terjun landfill, which is managed by the municipality, and located in Medan Marelan sub-district, approximately 15 km from the city center. At Terjun landfill, there is also no waste processing; the waste is just dumped without treatment. Scavengers are involved in the collection of recyclable items here.

Material flow analysis (MFA) already found to be an attractive decision-support tool in resource management, waste management, and environmental management. MFA is a valuable tool in substance management because it can cost-efficiently determine the elemental composition of waste precisely. Some experts who have experience with MFA suggest that waste management should be replaced by materials and resource management (Brunner & Rechberger, 2016). Using MFA could contribute a better sight of waste flow in waste bank

activities and identify the process and flow that have the highest potential for improvement and also more efficient.
The research objective of this study is investigating the material flow of waste bank activities in Medan, Indonesia, in order to support the decision making the process of waste management stakeholders.

4.2 Materials and methods

4.2.1 Overview of waste bank

Medan as in many other cities in Indonesia, the waste bank activities have not been integrated as a formal sector into the waste management system. Most of the waste banks in Medan City are managed by the community, organizations, and individuals. They provide services for exchanging recyclable items into money in a savings system that adopts a simple version of the bank's formal system and uses temporary places owned by individuals or organizations. In general, recyclable items received from the community are weighed and recorded in the savings book, and the amount of equivalent money of the item will be paid once every three months or more.

According a record from Dinas Lingkungan Hidup Kota Medan shows there were 97 active of 142 registered waste banks in Medan (Dinas Lingkungan Hidup Kota Medan, 2017). Based on 97 units of active waste banks, only 13 waste banks were fit for a "good" rating, and the rest were below until 2017 (Dinas Lingkungan Hidup Kota Medan, 2017).

4.2.2 Methodology and data collection

The study of waste bank activities was conducted in Medan city. The stages of this study include the collection of secondary data and primary data. Secondary data collected is a general description of the study area, number, status, and location of the waste bank. Primary data in this study were interviews and field research on selected waste banks. The survey and data collection were conducted in December 2017 until April 2018. Since this study used data report of waste bank activity, we cannot consider the accuracy of the data.

A semi-structured interview approach was conducted to cover the following points:

- Background information and waste bank profile
- Information related to necessary activities and processes
- Type of waste that accepted by the waste banks
- The use of materials and substances
- Input and output through the waste bank processes

Waste banks were sorted according to their rating for each group. Waste banks with the best rating were chosen as the selected waste bank. They consist of one representative from the institution entity, one representative from a school entity and one representative from a community entity.

The selected waste bank representing the group is the Sicanang as a representative of the institutional waste bank, PAUD Fitri representing the school waste bank and Membawa Berkah representing the community waste bank. Table 4.1 presents the list of the name of the selected waste bank.

Table 4.1 List of waste bank representatives

No	Type	Name of waste bank	Status	Active members
1	Institution	Sicanang	Active	813
2	School	PAUD Fitri	Active	80
3	Community	Membawa Berkah	Active	90

This study took case of 3 types of waste banks, the central waste bank Sicanang, PAUD Fitri, and Membawa Berkah. This study found that PAUD Fitri and Membawa Berkah include as a partner of the central waste bank. Figure 4.1 presents the collaboration of waste banks in Medan.

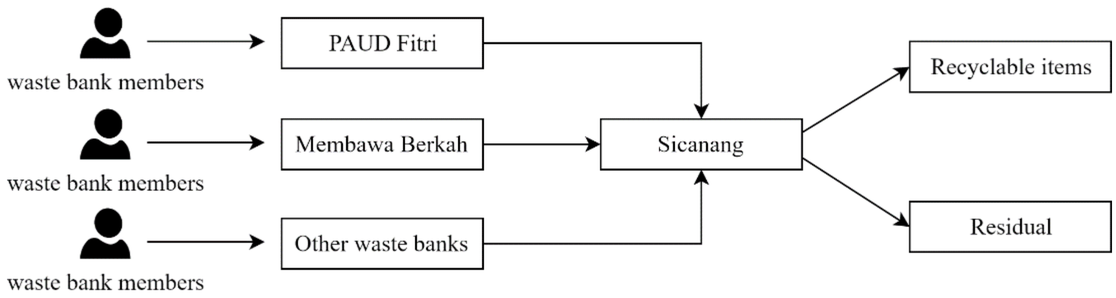

Figure 4.1 Waste bank networks in Medan

This study used MFA methodology that consists of the following steps (Brunner & Rechberger, 2016):

- Defining the object and goal of the study.
- Determining relevant substance and system boundaries, processes and goods
- Defining flows of good and substance
- Balancing the inputs, outputs, and stock through the processes
- Providing schematic and interpretation results

The number of studies used MFA as a tool in on waste management, throughout the quantification of waste flows and waste substance. MFA assesses the flows and stocks of materials in a system defined on a spatial and temporal scale (Brunner & Rechberger, 2016). According to the mass balance principle, the mass of all input a process equals the mass of all outputs of this process plus storage. Technically, this can be illustrated through Equation 4.1 (Brunner & Rechberger, 2016).

$$\sum_{k_1} \dot{m}_{input} = \sum_{k_0} \dot{m}_{output} + \dot{m}_{storage} \tag{4.1}$$

Where k_1 and k_0 represent input and output flows respectively and $\dot{m}$ represents the flow or flux. The MFA was started by receiving waste from the waste bank, and it ends at output material from waste bank activities as shown in Figure 4.2. The MFA was calculated and modeled using STAN software based on waste bank data in the period of October – December 2017.

Figure 4.2 Boundary of study

4.3 Results and discussion

4.3.1 PAUD Fitri waste bank

PAUD Fitri waste bank is a Fitri School of Early Childhood Education and Development (PAUD), located on Jalan Lingkungan IV, Lorong Mesjid, Bagan Deli Village, Medan Belawan District, Medan. It serves payment of school fees with recyclable waste. This goal is to help low-income families in fishing settlements who want their children to go to school. This waste bank was established in 2013, the presence of this waste bank encourages its member (parents of students) collect recyclable waste every day, then bring the waste to school as a substitute for their children's school fees. Besides that, it helps to maintain environmental cleanliness in Kelurahan Bagan Deli and reduces waste disposal in the landfill.

Figure 4.3 Storage of PAUD Fitri waste bank

PAUD Fitri members bring the recyclable waste to the waste bank; a staff will weigh the waste and record it. The collected waste from the members will be sorted manually before being transported and sold to Sicanang waste bank. The flow of PAUD Fitri activities is shown in Figure 4.4.

Figure 4.4 Waste bank activities flow

The types of waste received by PAUD Fitri are plastic, paper, glass, and metal waste. PAUD Fitri received an average 658.2 kg recyclable waste every month from its customer. A staff of PAUD Fitri is responsible for sorting the waste in once a week.

Figure 4.5 shows the analysis of the material flows of PAUD Fitri waste bank. It can be described that there is no significant difference between the input and output. PAUD Fitri generates an average of 7 kg residual per month. This residual comes from cleaning and sorting process of plastic waste. The dominant plastic waste is PET bottle, PAUD Fitri remove the PET bottle label and caps in order to increase the price. 200 kg of water was used to wash the plastic waste every month.

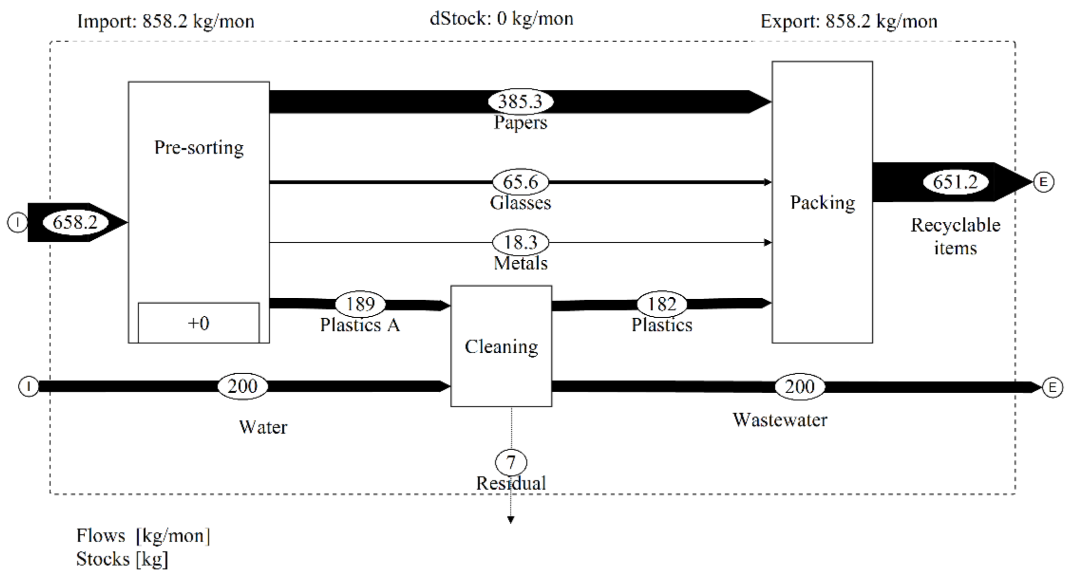

Figure 4.5 Material flow analysis of PAUD Fitri waste bank

4.3.2 Membawa Berkah waste bank

Membawa Berkah waste bank was established in 2016. The establishment of this waste bank aims to educate the people to not littering the waste; a clean-living environment makes children play comfortably. In 2017, Membawa Berkah waste bank won the award as one of the ten best waste banks in the Gold category in Medan. This waste bank operates once a week, during 2017 Membawa Berkah succeed to collect ± 20 tonnes recyclable waste.

Figure 4.6 Membawa Berkah's staff is weighting the recyclable waste

Membawa Berkah obtains the recyclable waste from the community who deposited their waste. The waste is sorted and cleaned before being picked up by the third party, currently Sicanang waste bank. The flow of Membawa Berkah waste bank is similar to PAUD Fitri waste bank, as shown in Figure 4.4.

Membawa Berkah accepts four types of waste; plastics, papers, glasses, and metals. The average amount of recyclable waste received by Membawa Berkah reached 786.52 kg per month. Two workers are responsible for sorting and cleaning the waste with working hours of 12 hours in a month. Membawa Berkah requires 280 kg of water per month to clean the waste and discharges 280 kg of wastewater. From its process, Membawa Berkah waste bank generates 2.73 kg of residue per month originated of cleaning the plastic waste in the form of PET bottle labels. Figure 4.7 shows the MFA of Membawa Berkah waste bank.

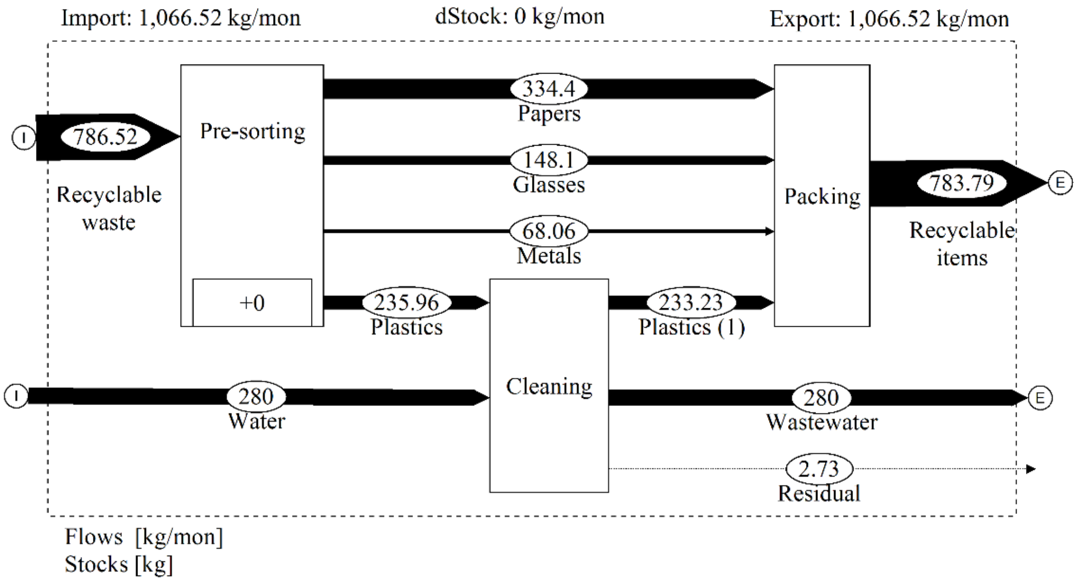

Figure 4.7 Material flow analysis of Membawa Berkah waste bank

4.3.3 Sicanang waste bank

Sicanang waste bank inaugurated by the Mayor of Medan on December 8, 2014. This waste bank aims to carry out waste management activities around the city of Medan as a pilot project for efficient waste management by involving the participation of the community and the City Government. The goal of this collaboration is to reduce the generation of waste disposed to the landfill.

Sicanang waste bank serves pickup and purchase of recyclable waste from other waste banks around Medan City. They will pick the waste up every day from Monday to Saturday. Currently, as many as 60 waste banks have become a partner at the Sicanang waste bank. They deposited the recyclable waste regularly. At this central waste bank, advanced sorting is needed to classify the type of waste into more specific to increase the selling price.

Sicanang waste bank receives four types of waste and export 19 types of waste. Four types of waste received are papers, plastics, metals, and glasses. In advanced sorting, the papers waste will be sorted into HVS, Duplex, Cardboard, Book, Newspaper, and other papers. Plastic wastes are sorted into HDPE, LDPE, PP, PP (plastic), PET bottle, PET (other) and PS. Metals are sorted into copper, brass, aluminum, cans and other metal.

Figure 4.8 Removing the label of mineral water cups

Figure 4.9 presents the analysis of the material flow of Sicanang waste bank. An example process from Sicanang is plastic wastes. The most of plastic waste is a plastic bag, the waste bank sorts the plastic bags based on its color, size and cuts it into the sheets. The next step is to clean the plastic from polluter by washing and to dry it. Sicanang waste bank does the waste sorting every day; four workers are responsible for the work. Of the four workers, a person was responsible for sorting paper, a person for sorting metal and two people for sorting plastic. Although Sicanang receives waste sorted recyclable waste from their partners, residues are still found. The sorting activities, such as on paper and plastic type, remain the residues that to be disposed of in landfills. On average in one month, Sicanang waste bank received an average 8898.03 kg of sorted recyclable wastes. Especially for plastic sorting, Sicanang requires and discharges as much as 800 kg of water per month. For the entire process, the waste bank generates 14.5 kg of residue per month.

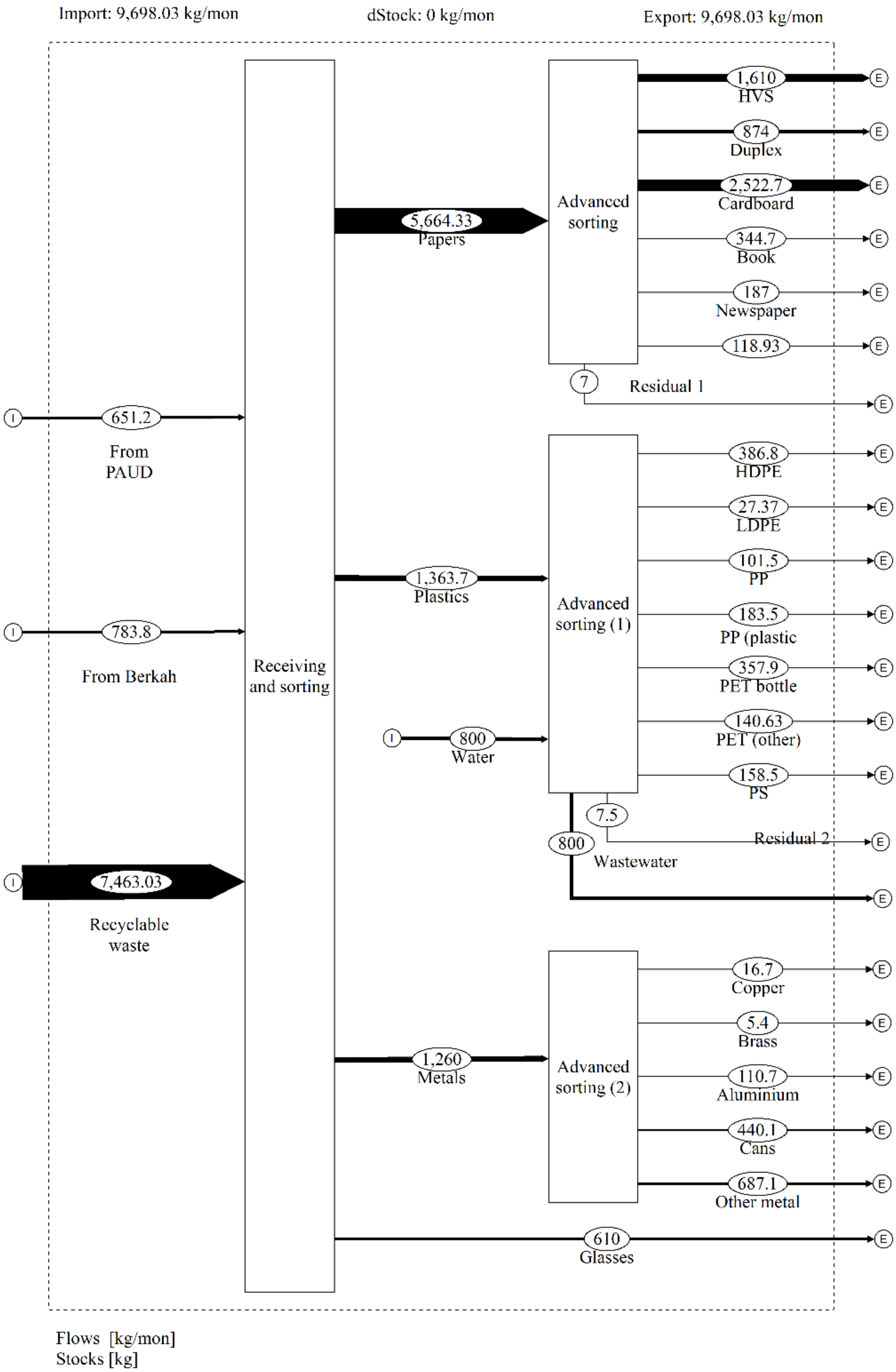

Figure 4.9 Material flow analysis of Sicanang waste bank

4.4 Discussions

Figure 4.10 presents the Sankey diagram of the flow recyclable wastes at waste bank activities. On the left of the diagram shows the input of recyclable wastes. Several single flow arrows present the type of waste and material as a result of sorting activity. The single waste flows end in recyclable items as the result of waste bank activities. The sum flow arrows indicate the amount of the collected and sorted recyclable wastes at the waste bank.

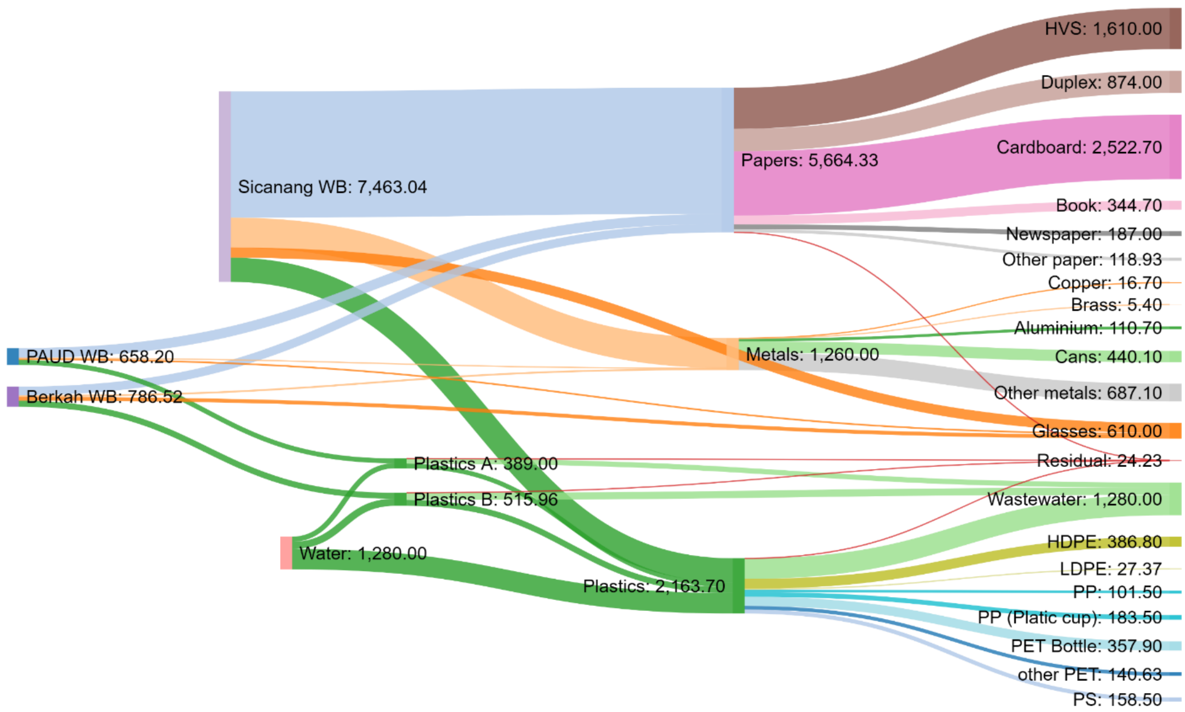

Figure 4.10 Sankey diagram of waste bank activities in kg/month

In total, around 58% of the collected recyclable waste is paper, 22% of the total is plastic, 13% is metal, and 6% the remaining recyclable waste is glass. This percentage shows that waste banks process more paper waste compared to other types of waste, such as paper, metal, and glass. This result is similar to a study conducted in Yogyakarta (Purnama Putra, Damanhuri, & Sembiring, 2018). A study of the composition of household waste in the city of Medan, as shown in Table 4.2, found that plastic waste was the second position after organic or the highest in the category of inorganic waste which was 17.6%. However, this situation is slightly different compared to the percentage of plastic managed by waste banks. Logically, plastic is the most type of waste collected at waste banks.

The presence of the scavengers is predicted to reduce the amount of plastic waste reaching the waste banks. Physically, plastic waste is relatively easy to find in the surrounding environment and is resistant to weather condition. Plastic wastes are often coming from outdoor applications — different conditions with paper waste, where paper wastes are often used from the indoor application. Waste producers will store their paper wastes indoor to keep it dry and not exposed to rain. This condition causes the scavengers relatively challenging to find it.

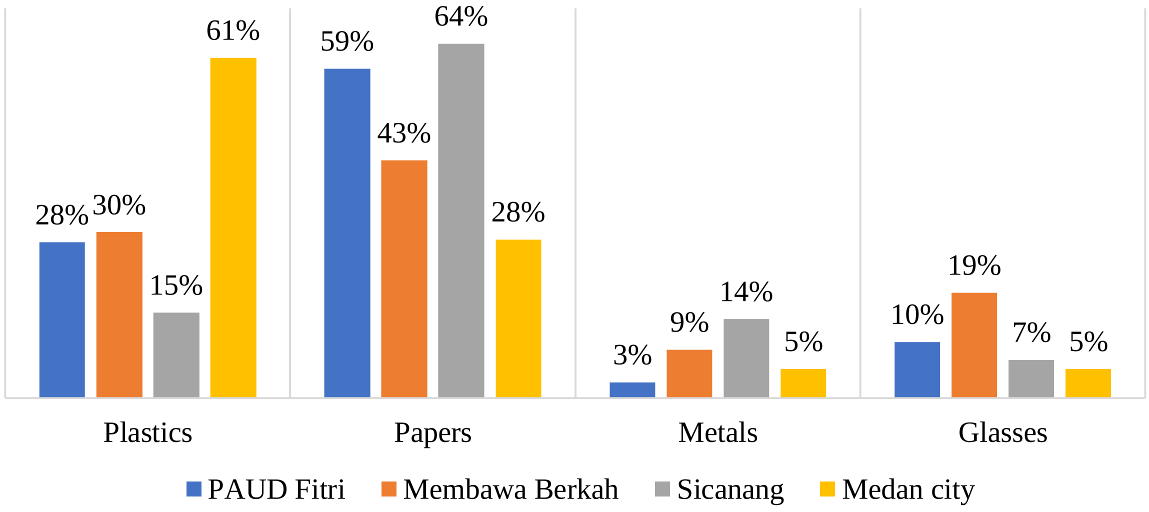

Figure 4.11 Composition of output material

Waste banks are one part of the informal sector in waste management in Indonesia. In addition to waste banks, there are also scavengers that target recyclable waste. It is estimated that there are around 3000 scavengers in the city of Medan (Sibuea, 2019). They start searching covering many areas: transfer waste station, roadsides, residential areas, commercial areas, and area that has the potential to find recyclable waste. They sell the waste not to waste banks, but to junkman or *lapak*. In Indonesia, there are stakeholders (formal and informal) who play an essential role in collecting recycled wastes scavengers: waste collector crews, junkmen (waste traders), intermediates (lapak), dealers (bandar) and brokers (Damanhuri & Padmi, 2012).

The author estimates that there is still much plastic waste that has not been managed; maybe this is the makes Indonesia into the top three countries mismanaged plastic waste in the World (Jambeck et al., 2015). This data also indicates that the potential for plastic waste is still significant to be managed at waste banks.

Table 4.2 HW composition of Medan City

Composition	%
Organics	61.4
Plastic	17.6
Paper	8.2
LWTR	1.5
Glass	1.5
Metal	1.5
Inert	0.2
Misc.	8.3

Figure 4.12 presents the percentage of input and output material for waste bank activities. Recyclable wastes account for 87.4% of the total amount of the input material, and 12.6% is water. The waste bank activities generate 87.2% recyclable items, 12.6% wastewater dan 0.2% residues. The use of water for cleaning activities is still high; this indicates that the quality of recyclable wastes is still many polluters, which have been discarded. In this case, waste banks need to educate their members to be able to improve the quality of the recyclable waste. Method of how to handle waste at home and policies of waste banks need to be improved.

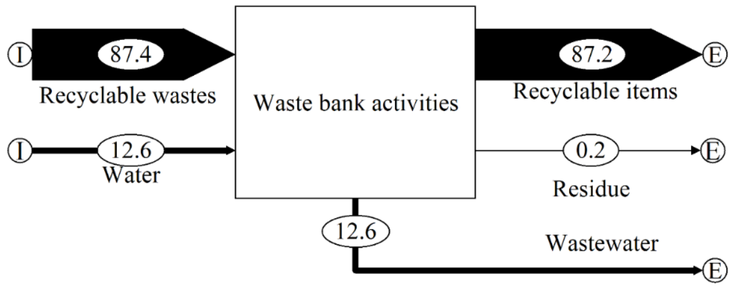

Figure 4.12 Percentage of input and output material for waste bank activities

The community should be able to change the habit of handling waste, starting from its source. As much as possible separate recyclable wastes from polluters starting from homes, it is like not mixing it with wet garbage or rotting garbage. The management may consider issuing exclamations such as always remove cap (cover), rinse with water, clean it, and put it in a container such as a basket (Tachikawa City, 2013) (Ota City, 2017) or not accept unclean items that have sludge or grease (Nakano City, 2019).

4.5 Conclusions

As one part of waste management, waste banks must continue to innovate and make improvements. In addition to the community, the government plays a significant role in supporting the future of waste banks. The government plays a role in providing management support training, regulation, guidelines, systems or funding as mandated in Indonesia's Law 18/2008 on Waste Management

This study found that the activities of waste banks are still traditional, which is lack of technology adoption. In the future, the waste bank should be more efficient and able to manage large amounts of wastes, because the potential for recyclable wastes is still available and abundant.

The findings of this study are essential to the development of useful instruments and policies for improving the waste bank activity in support of waste management. The MFA of waste bank activities give an understanding of the use of resources. In the future, it is necessary to conduct further research that covers recyclable waste from "*cradle to grave*" in a city or regional scale.

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Chapter 5 Environmental and economical assessment of waste bank activity

5.1 Introduction

Indonesia is likely to be responsible for about 3.2 million tonnes of mismanaged plastic waste every year. This amount makes Indonesia into the top three countries mismanaged plastic waste in the World. The amount of plastic waste may double by 2025 (Jambeck et al., 2015). This amount of waste potentially ends up in rivers and oceans due to poor waste management awareness. Plastic waste is one example of different types of waste that has not been well managed. Highlighting the issue, the Indonesian government says the country is now facing a waste management crisis (Rebecca Henschke, 2016). The government has committed to maximizing its efforts to resolve the country's waste issue. In 2014, Indonesia initiated "Waste-free Indonesia 2020" campaign (The Jakarta Post, 2014) and yet three years later it revised the target. The Indonesian government sets to have a 70% decreasing in waste by 2025 (Ratri, 2017).

Waste bank (WB) is one of the municipal solid waste management initiatives that have been implemented in Indonesia following the Law No. 18 of 2008 on Waste Management and the Indonesian Government Regulation No 81 of 2012 on Household Waste Management. The regulation has mandated the need for a fundamental paradigm shift in waste management, from a paradigm of collect-transport-dispose into a paradigm of processing that relies on waste reduction and handling (Kementerian Lingkungan Hidup, 2012). The WB is also known as a social innovation to educate people to sort waste and raise public awareness of the processing of recyclable waste. The growth of waste banks in urban and rural areas showed a positive trend on the level of public interest concerning the waste (Kementerian Lingkungan Hidup, 2012).

Life cycle assessment (LCA) has been used for a long time as a tool for analyzing potential environmental impacts in many different sectors, including municipal solid waste management (Klöpffer & Grahl, 2014). LCA provides a mature and ISO standardized methodology to assess a full set of environmental impacts (Dong et al., 2018). The LCA studies have been used in various waste management system scenarios, but their coverage has mostly been limited to very few Asia countries (Yadav & Samadder, 2018). Researchers recommend stakeholders in solid waste management to consider LCA as a tool, which, by its ability to capture the local specific conditions in the modeling of environmental impacts and benefits (Laurent et al., 2014). It is important to consider economic indicator when evaluating, so then it can improve waste recycling activity. It requires an excellent tool to measure its economic performance. Cost-benefit analysis (CBA) is one of those tools. CBA can recognize the alternative that could accomplish a specific goal with the lowest cost. Although environmental assessment can predict the impact, that does not come at no cost, hence the argument for the use of CBA to weigh costs against benefits (Moosa, 2016). The CBA also allows for the inclusion of external environmental impacts and the associated social benefits or costs upon a valuation to inform the sustainable waste management (Lam et al., 2018).

Scholars have widely discussed the application of LCA and CBA to different kind of services in the field of solid waste management. However, still a few studies of the environmental impacts and economic performance of waste bank could be found in the literature. The combination of environmental and economic information drives towards the most sustainable choice in term of waste management planning. The objective of this study is to evaluate the environment and the economy of waste bank activities as a part of municipal solid waste management in Indonesia. The study analyses the effectiveness of waste bank management to become environmentally and economically. This study is expected to provide relevant information for WB manager and decision-maker in deciding how to improve waste bank and also municipal solid waste management in Indonesia.

5.2 Materials and methodology

5.2.1 Case Study

Medan city is a capital city of North Sumatra province and is considered to be one of the big cities in Indonesia and also as a hub city in Sumatra Island. Medan has approximately 2.2 million inhabitants (Statistic of Medan Municipality, 2017a). The city government recorded as many as 1595 tonnes of waste dumped into the landfills every day (Statistic of Medan Municipality, 2017b). Table 5.1 describes the municipal solid waste composition condition in Medan City. A recent study shows that about 28.70% of this waste is recyclable and could potentially be processed at WBs. Further, around 61.35% of this waste is compostable.

Table 5.1 Household waste composition in Medan city

Composition	Average (%)[a]	Type of waste
Paper	8.20	Recyclable
Plastic	17.55	Recyclable
Organic	61.35	Compostable
Leather, wood, textiles, and rubber	1.53	-
Glass	1.48	Recyclable
Metal	1.48	Recyclable
Inert material	0.15	-
Other	8.27	-

In order to reduce the volume of waste going to landfill, communities in Medan city had the initiative to build the waste bank program. Through this activity, the community can participate in waste recycling. Besides reducing the amount of waste disposed to landfill, people can earn money as a benefit.

Waste banks are one aspect of waste management in Medan, but have not been integrated into the municipal waste management system. The WB accepts recyclable waste, sorts, and sends it to recycling companies where it can be converted into raw material for industries.

Waste banks were first established in Medan in 2011; however, after the creation of a central WB (CWB) in 2013, their numbers increased to 83. According to the Environmental Agency of Medan city, 97 of the 142 registered WBs were active in 2017. These WBs collect approximately 63,050 kg of recyclable waste every month (IGES, 2019).

Until now, there was only one CWB in Medan, which carries out waste management activities around Medan city and has implemented a pilot project for efficient waste management with the participation from the community and City government.

This study assessed the environmental and the economics performance of the CWB in Medan. The sample selected is representative of a well-performing and active WB in Medan. The CWB could be a model for other WBs in Medan or other cities in Indonesia. Currently, as many as 61 of 97 WBs are in partnership with the CWB and deposit their recyclable waste regularly.

Non-partnership WBs handle their recyclable wastes themselves and can sell the waste to the CWB or other parties. Figure 5.1 shows the flowchart of WB activity in Medan. This WB is the biggest and the most active in Medan. On average, the recyclable waste collected by this WB is about 70 tonnes a year. The CWB collects the sorted recyclable waste from its partners and groups it into more specific types.

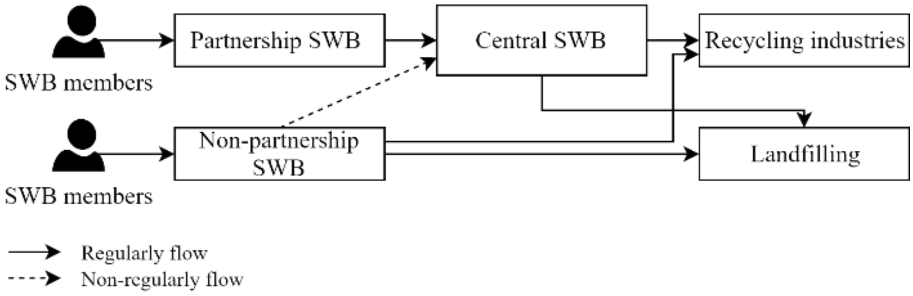

Figure 5.1 Flowchart of waste bank activities in Medan

5.2.2 Life Cycle Assessment (LCA)

According to ISO 14040:1997/2006, there are four phases of LCA: goal and scope definition, life-cycle inventory (LCI), life-cycle impact assessment (LCIA) and interpretation (ISO & others, 2006).

5.2.3 Goal and Scope Definition

This LCA study aims to estimate greenhouse gas (GHG) in carbon dioxide (CO_2) equivalent of existing waste bank activity. The result of the study would be useful for the central and local government of Indonesia. The WB activities consist of transporting, collecting, sorting and cleaning, packaging, and transporting to recycling industries or landfilling.

Figure 5.2 shows a definition of the boundaries—what is included in the LCA. The LCA starts from transporting the sorted recyclable waste from the WB partners and ends at the recycling facilities or landfill.

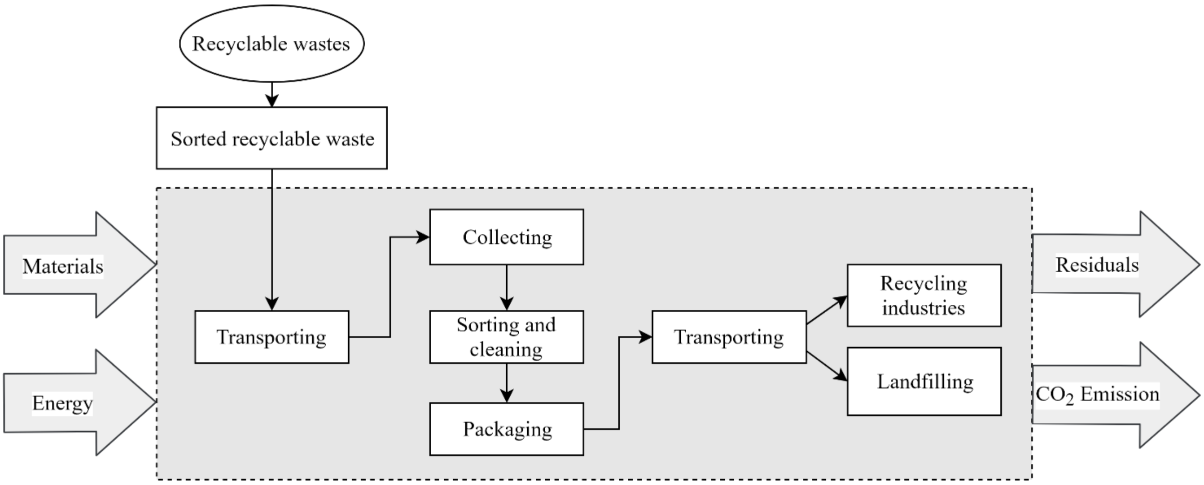

Figure 5.2 The boundary of the study

5.2.4 Life Cycle Inventory

Preliminary data were obtained from the government to map the WB activity and their status. To achieve the objective, data in this study were collected from interviews at waste bank sites, reviewing their monthly report, management plan, invoices, and quantities bill. These data were collected in 2017 and 2018. Other data were gathered from the literature, in particular, related to emission factors. The LCA was calculated based on the CWB data for October – December 2017.

(i) Transporting

Transporting includes picking up waste from the WB partners all over Medan and transport of recyclable items to recycling industries and the residue to the landfill. The WB has a truck and a light truck that pick-up waste from Monday to Saturday. Figure 5.3 shows the distribution of the WB partners and recycling industries.

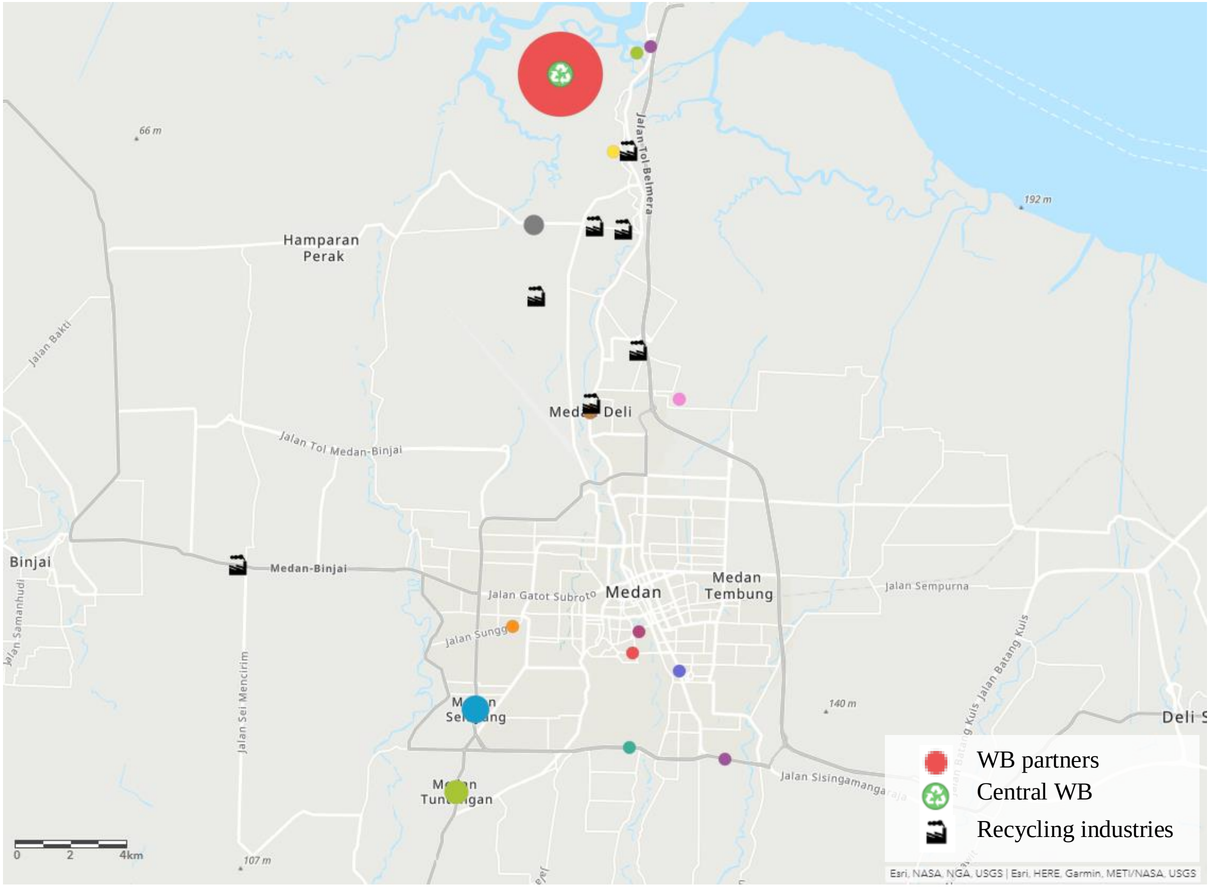

Figure 5.3 The distribution of the WB partners and recycling industries

(ii) Collecting

CWB obtained recycling waste from its partners. The CWB staff weigh and record the sorted recyclable waste received from the WB partners.

(iii) Sorting and cleaning

The CWB receives four types of waste: paper, plastic, metal, and glass. This waste is sorted into 19 categories: paper waste into HVS, duplex, cardboard, book, newspaper, and other papers; plastic waste into HDPE, LDPE, PP, PP (plastic), PET bottle, PET (other), and PS; and metals into copper, brass, aluminum, cans, and other metal. Sorting increases the value of the wastes. For example, when the WB receives a plastic bottle of mineral water, it separates the bottle and cap, labels, and then sorts by bottle color. The WB washes the plastic waste if needed and then dewaters them. This requires water and electricity. The sorting and cleaning stage produce waste residue and wastewater. The residue material is disposed in the landfill while the wastewater is discharged into the drainage.

(iv) Packaging

The output material obtained from the sorting and cleaning process are packed here. The 19 categories of waste are sold to recycling companies, while the residue is sent to the landfill.

(v) Recycling industries

The sorted recyclable wastes are sold to recycling industries to be used as raw material. This study assumes that the recyclable material from the WB can substitute virgin material. For example, plastic material could be processed into plastic pellets to replace virgin raw materials. The amount of waste recycled per month and transport distance to the recycling industry is shown in Table 5.2.

Table 5.2 Total recycling rates per month and transport distance for selling recyclable waste

Type	Category	Weight (kg/month)	Transport distance (km)
Plastic	HDPE, PP	672	10
	LDPE, PET (all)	526	35
	PS	156	15
Paper	Cardboard	2523	6
	Duplex, Book, Newspaper, Other paper	3135	15
Metal	All category	1260	15
Glass	All category	610	15

(vi) Landfilling

All residues from the WB are diverted for landfilling. This study considers the existing landfills as the site for open dumping.

5.2.5 Life Cycle Impact Assessment

The result of the inventory data was categorized, investigated, and classified to the green potential, which accounts for the emission of greenhouse gases from waste bank activity. The emission comes from CO_2, CH_4, CO, and N_2O. Avoided landfilling and avoided virgin material was calculated by WARM, which is also adopting LCA methodologies (US EPA, OSWER, 2018).

The estimation of transportation emissions was obtained by calculating the use of fuel and the distance from the waste bank site to recycling industries and landfill site. The general equation to estimate the emissions could be expressed as:

$$E = \sum Fuel \times EF$$ [a] (5.1)

E = emission (kg), Fuel = TJ, EF = kg/TJ

[a](IPCC, 2006)

$$E = VKT \times EF \times 10^{-6}$$ [b] (5.2)

E = emission (tonne year^{-1}), VKT = vehicle kilometers traveled (km year^{-1}), EF = emission factor (g km^{-1})

[b](The Minister of the Environment, 2010)

This study used the emission factors from the Intergovernmental Panel on Climate Change (IPCC) model, as presented in Table 5.3. The primary pollutants such as CO_2, CH_4 and N_2O are included in the calculation.

Table 5.3 The emission factors of fuel vehicle

Emission factors	unit	amount
CO_2 for diesel fuel	kg/TJ	74100
CH_4 for light duty-diesel	mg/km	9
N_2O for light duty-diesel	mg/km	4
CH_4 for truck-diesel	mg/km	23
N_2O for truck duty-diesel	mg/km	30

Source: (IPCC, 2006)

This study also considers the indirect emissions from the electricity consumption of the WB activities. Emission factor for electricity was based on data issued by the Indonesian government. Table 5.4 shows the inputs for the LCIA of the WB activities.

Table 5.4 Material inputs for estimation LCIA

Description	Unit	Amount
Residue to landfill	tonne/year	0.3
Electricity consumption	kwh/month	136.3
Wastewater	m^3/month	1000.0
Electricity emission factor[1]	kg CO_2/kwh	0.877

[1](Ministry of Energy and Mineral Resources, 2015)

5.2.6 Cost benefit analysis

To assess the economic performance of waste bank activity, the internal and external cost will be evaluated and compared. The total cost and the total benefit of waste bank activities are defined in two components, as shown in Equation 5.3 and Equation 5.4 (Hylton, 2016).

$$Total\ cost = C_{internal} + C_{external} \tag{5.3}$$

$$Total\ benefit = B_{internal} + B_{external} \tag{5.4}$$

$C_{internal}$ represents an internal cost, $C_{external}$ is external cost, $B_{internal}$ is an internal benefit, and $B_{external}$ is an external benefit. The cost analysis was conducted according to the same study boundary as LCA.

5.2.6.1 Internal costs and benefits

The internal costs and benefits include all the costs/benefits paid or received by the firm (Squires, 2012). The internal costs determined included the capital, operation and maintenance, transportation, and disposal facilities costs. The capital costs were the amount of money for buying waste from waste bank partners. The operation and maintenance costs consist of collection, sorting and cleaning, and packaging costs. The transportation costs were estimated based on the traveling distance, fuel consumption, and fuel price. While the benefit was calculated based on the amount of money that earned from waste sales to the recycling industry. This study groups the internal costs and benefits into collecting, sorting and cleaning, packaging, transporting, landfilling, and selling to recycling industries.

5.2.6.2 External costs and benefits

The external costs or benefits could be environmental costs paid by society or government at large through ill-health of those people exposed to emission or a subsequent knock-on benefits of an improved environment (Squires, 2012). The external cost was conducted by converting the environmental emission to monetary values from WB activities. The external cost was obtained by calculating the treatment of residual material at the landfill site and converting environmental emission to monetary values from waste bank activity. The avoided emission from recovery material and avoided virgin material were also considered as the external benefits. This study used the social cost of carbon (SCC) to monetize the CO_2. The SCC monetizes the damages associated with an incremental increase in carbon dioxide emissions in a given year. It is also meant to be a comprehensive estimate of climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs (US EPA, OA,OP, 2018). The external cost and benefit are calculated at the SCC value of 26.3 US dollar/tonne CO_2 at a discount rate of 3 percent (Working Group on Social Cost of Carbon & States Government, 2009).

5.2.7 Functional unit

The functional unit for environmental assessment is carbon dioxide equivalent (CO_2 eq.) per tonne of waste managed. The cost analyses are the costs and benefits involved per tonne of waste managed.

5.3 Results and discussions

5.3.1 Environmental assessment

In general, the contribution of CO_2 comes from the use of energy, such as fuel and electricity. There are five parts for calculating CO_2 emissions: collection, sorting and cleaning, packaging, transportation, and landfilling. The collection activities do not produce CO_2 emissions. It is caused that the collection is an administration stage where the WB's staff weight and record the waste. Sorting and cleaning activities require electricity for water pumps and also produce wastewater, especially for recyclable plastic. These electricity and wastewater used contribute to CO_2 emission. The next part is packing; this activity does not produce emissions to the environment. WB workers manually pack material recovery without the help of any machine. The transportation sector is the largest sector in emitting CO_2 into the environment. This transportation sector includes waste transport activities from the WB partners, WB to the recycling industry and landfills. Distance to the industrial location affect the results of CO_2. The landfilling sector contributes to CO_2 from the amount of residue discharged to the landfill. Open dumping landfill also emits CO_2 emission.

Figure 5.4 shows the emission of carbon dioxide equivalent for every tonne of managed waste in the waste bank. As a result, there are no carbon emissions in the collection and packaging part. Sorting and cleaning emitted 0.20 tonnes of CO_2 eq. per year for a tonne of managed waste. As for transportation activities emit carbon as much as 3.01 tonnes CO_2 eq. per year. This amount comes from transporting the sorted recyclable waste from WB partners, 2.29 tonnes CO_2 eq. per year, transport to recycling industries 0.66 tonnes CO_2 eq. per year and the transport to the landfill 0.06 tonnes CO_2 eq. per year. Residue material dumped into a landfill emits carbon as much as 0.01 tonnes CO_2 eq. per year. The total carbon emissions generated from WB activities are as much as 3.21 tonnes per year for each tonne of processed waste.

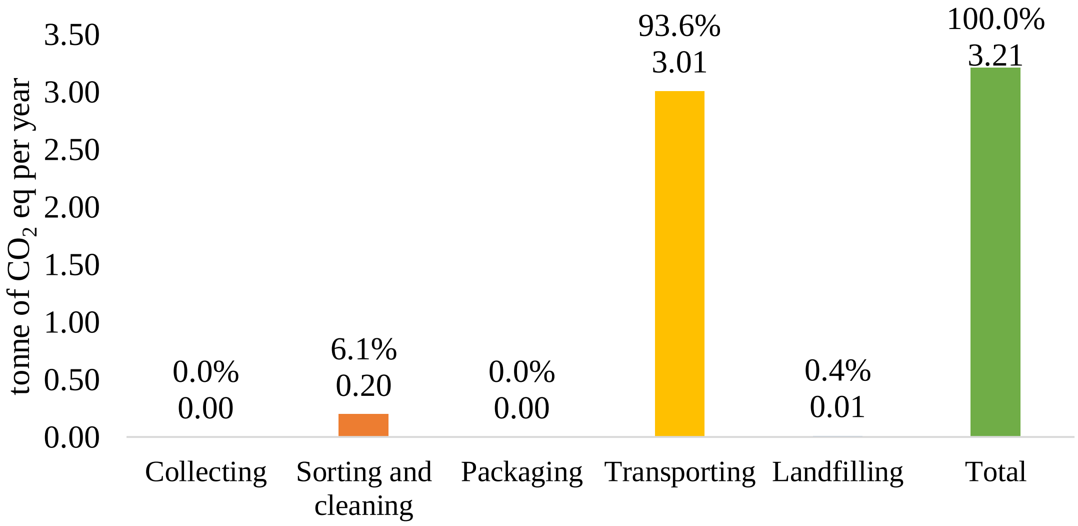

Figure 5.4 Emission of carbon dioxide equivalent for every tonne of managed waste in the waste bank

The percentage results illustrate that the transportation sector contributed 93.6% of the CO_2 emissions eq. of WB activities. Following the sorting and cleaning activities contributed 6.1%. The third rank is landfilling, contributing 0.4% of CO_2 eq. emissions. The collection and packaging sectors are 0% each.

The study also estimates the amount of carbon savings from the result of waste bank activities. The carbon savings are derived from avoided of virgin material and avoided from landfilling. The recyclable items from the WB substitute virgin material input in the manufacturing process, rather than being disposed as waste and can be used in identical products or as new products.

The recyclable items yield carbon savings by offsetting a portion of CO_2 emitted in raw material acquisition, manufacture, and transport of virgin inputs and materials. WB also has an impact on reducing the amount of waste that goes to landfills. Avoided emissions are by diverting recyclable waste dumped to landfill through a recycling waste activity.

Table 5.5 shows the result of the amount of carbon savings from the waste bank activities. The negative value indicates the savings from the waste bank activities. Negative value also shows that WB can reduce environmental effects from waste management activities. The WB activities could save as much 37.73 tonnes CO_2 eq. per year for every tonne of managed waste.

Table 5.5 Carbon emission and carbon saving from WB

Activity	tonne CO_2 eq. per year
Waste bank activity	3.21
Avoided from landfill	-4.49
Avoided of virgin resources	-36.46
Total (carbon saving)	-37.73

5.3.2 Cost analysis

As a member of WB, they can sell their recyclable waste to the WB. The money they get is converted into savings. The saving money can be withdrawn by the members later. On the other hand, as a manager, the WB buys recyclable waste from its members. The waste will be purchased according to classification and quality. The waste in the WB will be resold to the recycling companies at varying prices, which also depends on the condition and quality. Consequently, WB is trying to increase the selling value of the recyclable waste; one of its efforts is by cleaning them. To run these activities, WB requires resources such as employees, equipment, and transportation. WB is a community-based activity that manages finances independently and develops its business model.

The WB attempt to run its activities without any financial disturbance. The cost analysis results of WB are summarized in Table 5.6. During collection, the WB needs on average 17.7 million rupiahs per year to purchase the recyclable waste. Sorting and cleaning are the second largest cost activity at the WB. This cost includes the cost of labor and material including operations cost, electricity, water, tax, etc. The transport cost includes the cost of fuel for transporting the recyclable waste to the WB. The landfill tipping charges paid by the WB for dumping the residual material in the landfill comes to approximately 487,073 rupiahs per year per tonne of waste. The WB's primary income comes from selling waste to the recycling companies: about 32.9 million rupiahs per year per tonne of waste.

Table 5.6 Cost analysis results

	Activity	Cost Rupiah $year^{-1}$ $tonne^{-1}$	Benefit Rupiah $year^{-1}$ $tonne^{-1}$
Internal	Collecting	17,763,059	
	Sorting and cleaning	15,006,483	
	Packaging	904,564	
	Transporting	5,566,547	
	Landfilling	487,073	
	Selling Rec. items		32,894,554
External	Environmental	1,183,081	15,076,435
Total		40,910,807	47,970,989

The WB also accrues environmental costs and benefits. The CO_2 emissions cost the environment around 1.1 million rupiahs per year, while the carbon savings are worth about 15 million rupiahs per year per ton of managed waste.

The final results indicate a benefit of 7 million rupiahs per year per tonne of waste managed by the WB. The cost analysis results show that the total internal cost is 6.8 million rupiahs per year greater than the benefits (Figure 5.5). This indicates that the WB needs third-party financial assistance to cover the costs whereas, the monetization of potential carbon savings could bring in as much as 13.9 million rupiahs per year.

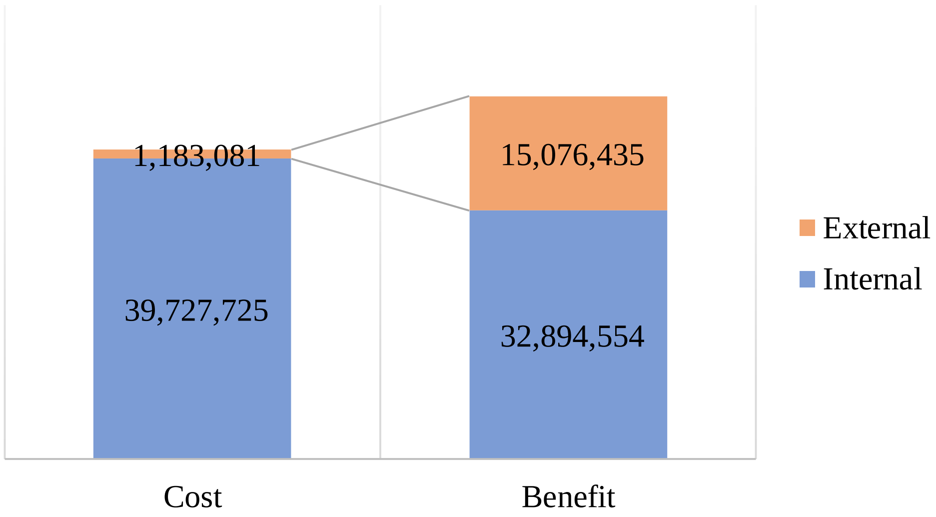

Figure 5.5 Cost and benefit of the waste bank (Rupiah)

5.3.3 Discussions

In developing countries like Indonesia, open dumping landfills still exist, which contributes to the increased emissions and cost in managing the environment. WB presents to address those problems. WB has an excellent opportunity regarding the environment and economy. This study showed that the WB is promising to handle recyclable waste to reduce environmental burden.

The CO_2 emissions from cleaning activity are relatively high; this indicates that the quality of the discarded wastes is still many polluters. The WB partners and members should improve the quality of the recyclable waste. Waste handling at the household level and the policies of waste banks need improvement. The management should implement strict instructions such as the caps (covers) to be removed, rinsed with water, and put in a separate container (Tachikawa City, 2013) (Ota City, 2017) or not accepting items with sludge or grease (Nakano City, 2019).

The community needs to be educated about WB. They also need guidance on how to sort and determine the types of recyclable waste. Good waste quality will increase the value of waste and reduce environmental burdens. Waste bank management also needs to find another creative policy to attract the attention of the community to participate in 3R actions.

The WB also has the potential to reduce CO_2 emissions from recyclable items. The cost analysis shows that WB has a deficit in its internal benefits. However, it has a surplus in its external or social benefits. Therefore, the government should provide incentives or subsidies in operations. The price of recyclable waste also needs to have particular policies, a particular policy on the price of recyclable waste needs to be formulated so that WB has enough profit to be able to cover operating costs. This study also demonstrates the need for good cooperation among stakeholders for sustainable waste management.

Transport activity is the biggest CO_2 emitter. The government should encourage setting up another central waste bank to reduce the distance from the partner WB to the CWB.

The WB needs professional mentoring to be more environmentally and more economical. A preventive approach needs to be taken by the government. The government allocates more funds for preventive activities than end-of-pipe control if the support to WB increases, the amount of waste, and the cost of waste processing in an expensive landfill can be reduced so that it will create a clean environment and a healthy society.

5.4 Improvement scenarios

Based on the results of the research above, there are several opportunities for improvement in WB activities. This increase is presented in several scenarios of waste bank activity and compares it with the base scenario. Some scenarios of improvement that can be implemented are:

1. Scenario S1; adding more central waste bank
2. Scenario S2; tax incentive program
3. Scenario S3; combining S1 and S2

5.4.1 Scenario S1

Scenario S1 considers adding more CWB to reduce cost and emission from transporting sector. Based on the distribution area, the WB partners can be grouped into 3 or 4 clusters. Each cluster is considered to have one CWB. Thus, Scenario S1 is divided into S1a and S1b. Scenario S1a consists of 3 CWBs and S1b has 4 CWBs, it has shown in Figure 5.6.

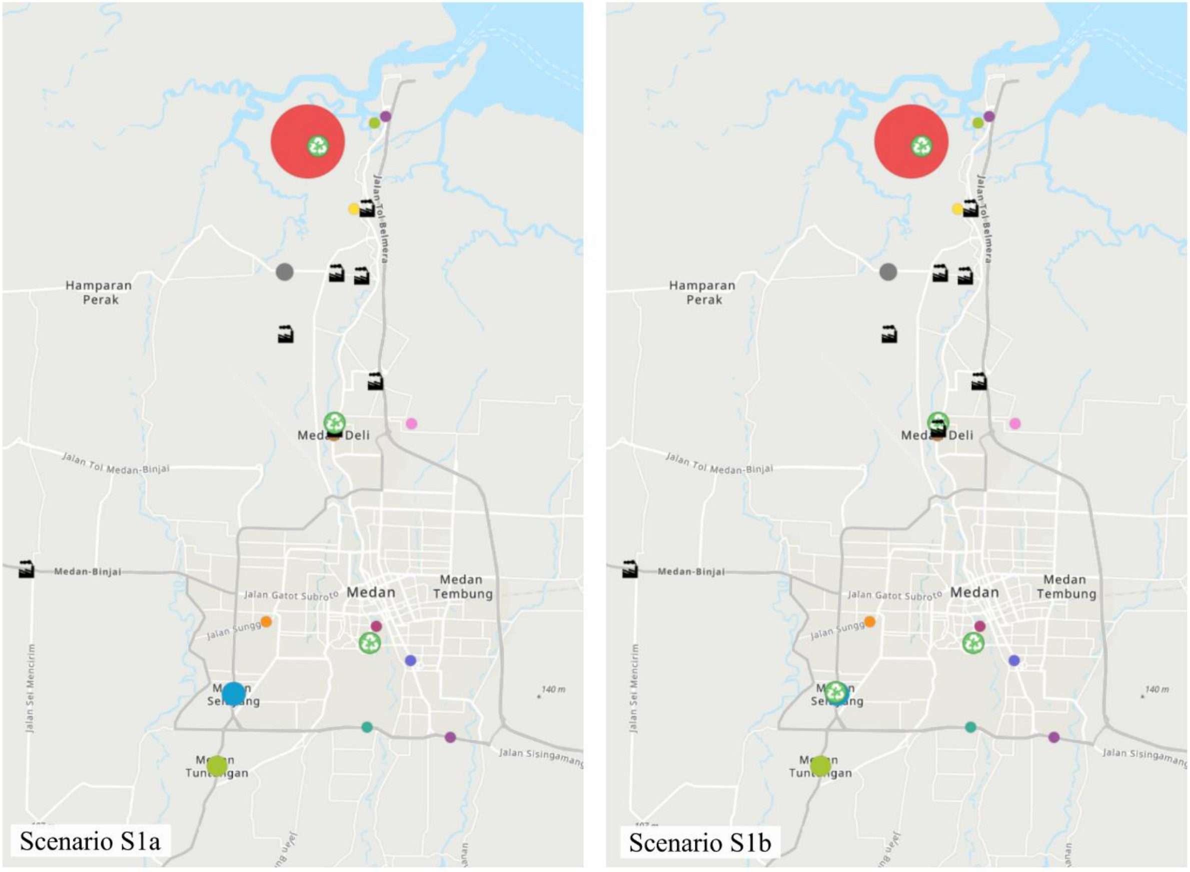

Figure 5.6 Scenario S1

The additional scenario is to upgrade one of the existing waste banks to become a central waste bank. Scenario S1 affects the change in travel distance, both in picking up waste from partners and selling it to the recycling industry. By using the same methodology with the baseline, the result scenario S1 can be seen in Figure 5.7 and Table 5.7.

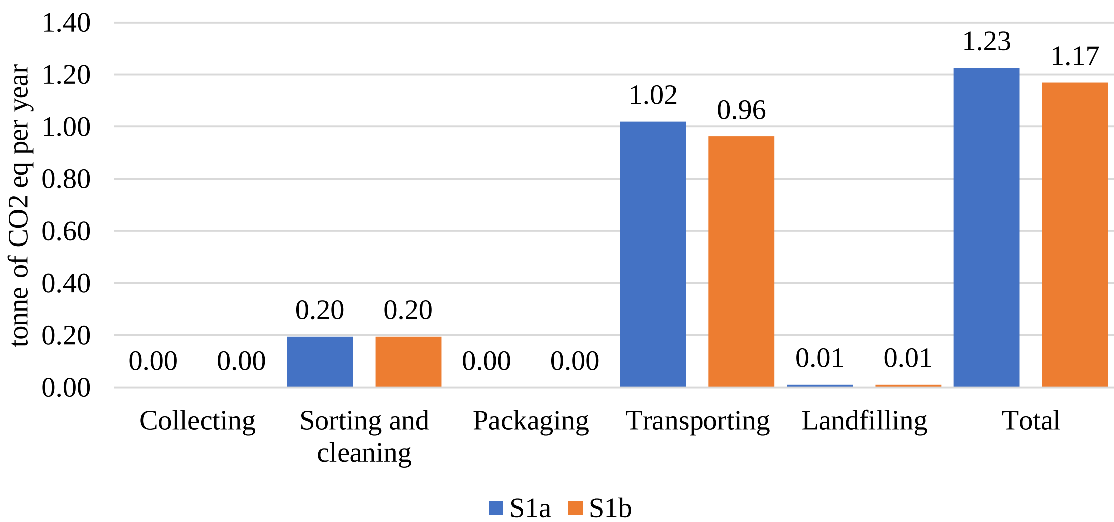

Figure 5.7 Emission of CO_2 equivalent of scenario S1

Table 5.7 Cost analysis results of scenario S1

	Activity	Cost Rupiah $year^{-1}$ $tonne^{-1}$		Benefit Rupiah $year^{-1}$ $tonne^{-1}$	
		S1a	S1b	S1a	S1b
Internal	Collecting	17,763,059	17,763,059		
	Sorting and cleaning	15,006,483	15,006,483		
	Packaging	904,564	904,564		
	Transporting	1,914,153	1,776,328		
	Landfilling	487,073	487,073		
	Selling Rec. items			32,894,554	32,894,554
External	Environmental	430,528	430,528	15,076,435	15,076,435
Total		36,505,860	36,368,035	47,970,989	47,970,989

Comparing scenario S1a and S1b, S1b shows a slightly better result than S1a. The result of the environmental assessment reveals that S1a is able to reduce CO_2 emissions by about 62% while S1b was able to reduce 64% of CO_2 emissions. Cost analysis shows that S1a can reduce internal costs by 9% and S1b by 10%.

5.4.2 Scenario S2

In scenario S2, the city could give a tax incentive to waste management stakeholders to boost recycling. In this scenario, the tax incentive is implemented to waste bank program in the form of vehicle tax and road permit exemption. This program affects the sorting and cleaning cost. The tax incentive may reduce the internal cost of waste banks. About 3% of the internal cost could be reduced from applying this incentive policy. The results of the S2 scenario can be seen in Table 5.8.

Table 5.8 Cost analysis results of scenario S2

	Activity	Cost Rupiah $year^{-1}$ $tonne^{-1}$	Benefit Rupiah $year^{-1}$ $tonne^{-1}$
Internal	Collecting	17,763,059	
	Sorting and cleaning	13,916,367	
	Packaging	904,564	
	Transporting	5,566,547	
	Landfilling	487,073	
	Selling Rec. items		32,894,554
External	Environmental	1,183,081	15,076,435
Total		39,820,691	47,970,989

Scenario 2 does not affect environmental performance, so the environmental performance result is the same as the baseline.

5.4.3 Scenario S3

Scenario S3 is to combine all possible of S1 and S2. This scenario aims to optimize the performance of waste bank activity. A comparison for each scenario is presented in Figure 5.8 and Figure 5.9.

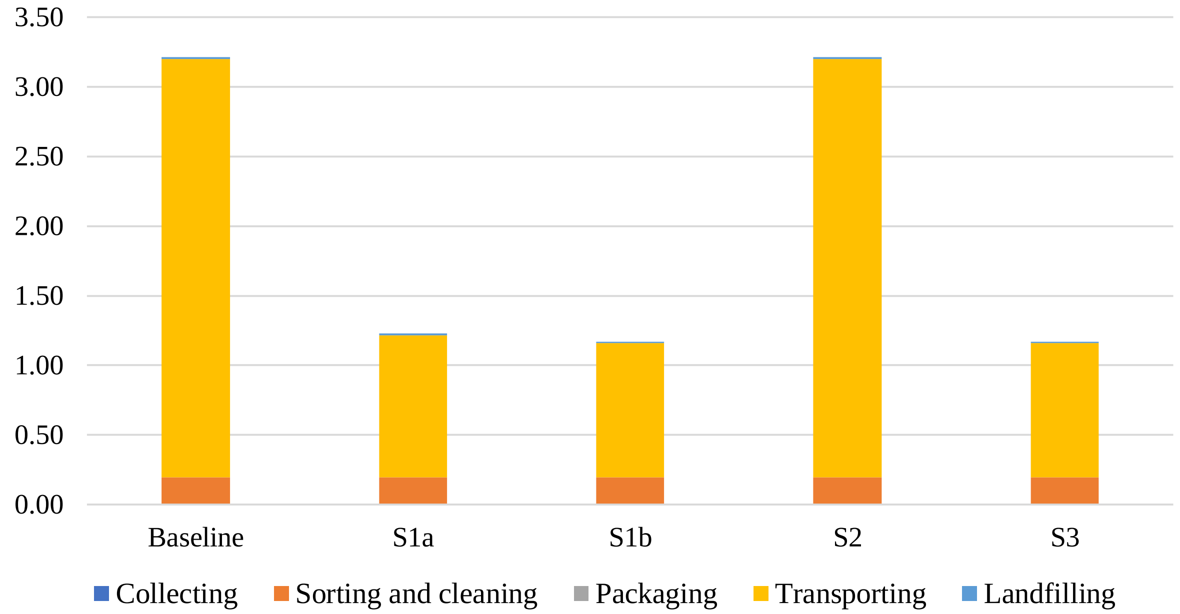

Figure 5.8 CO_2 emission comparison between the scenarios

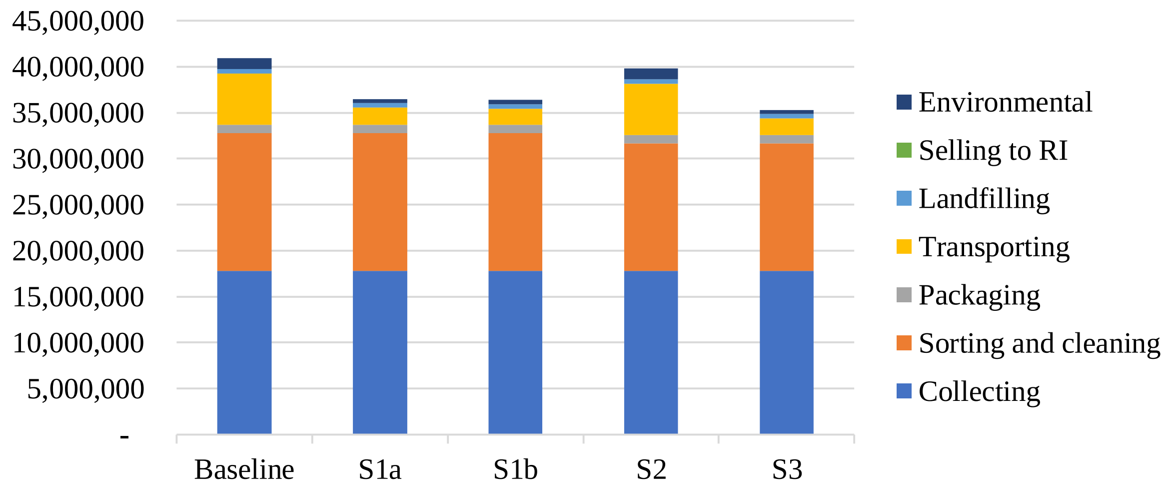

Figure 5.9 A comparison of cost analysis between the scenarios

Scenario S1b is selected to represent S1, which is then combined with scenario S2. Figure 5.10 and Table 5.9 present the results of the analysis.

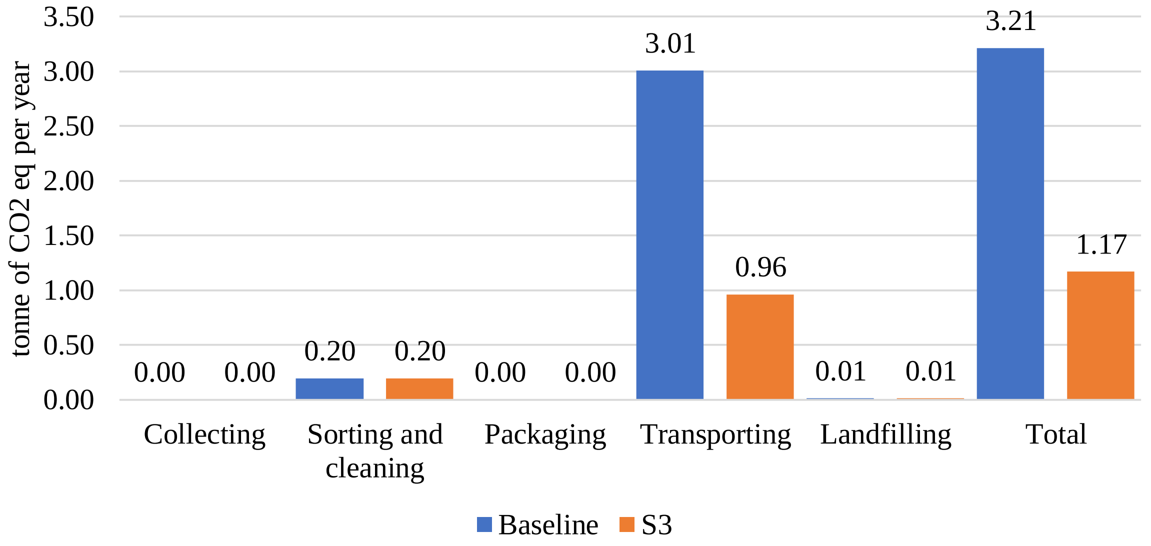

Figure 5.10 A comparison of CO_2 equivalent between baseline and S3

Table 5.9 Cost analysis result of scenario S3

Activity		Cost Rupiah year^{-1} tonne^{-1} Baseline	Cost Rupiah year^{-1} tonne^{-1} S3	Benefit Rupiah year^{-1} tonne^{-1} Baseline	Benefit Rupiah year^{-1} tonne^{-1} S3
Internal	Collecting	17,763,059	17,763,059		
	Sorting and cleaning	15,006,483	13,916,367		
	Packaging	904,564	904,564		
	Transporting	5,566,547	1,776,328		
	Landfilling	487,073	487,073		
	Selling Rec. items			32,894,554	32,894,554
External	Environmental	1,183,081	430,528	15,076,435	15,076,435
Total		40,910,807	35,277,919	47,970,989	47,970,989

Scenario S3 emits less CO_2 about 64% of reduction and provides 14% cost reduction. Internal cost is an essential component in the operation of a waste bank. Comparison of internal costs and internal benefit in Figure 5.11 shows that the cost is still higher than the benefits. These findings suggest that waste bank still needs financial assistance to be able to operate normally.

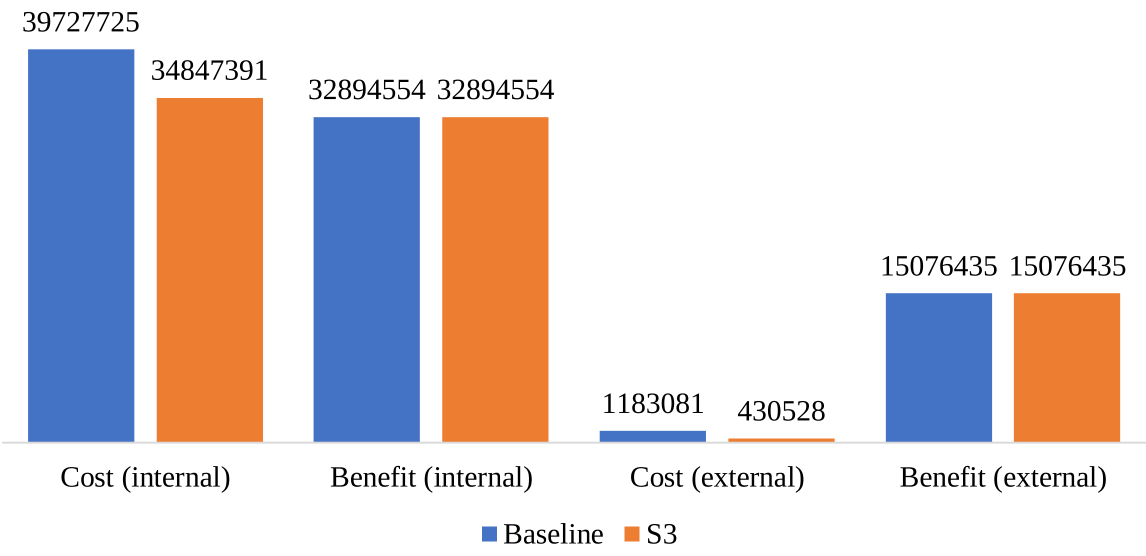

Figure 5.11 Improved cost and benefit comparison of the waste bank (rupiah)

5.5 Conclusions

This study revealed that a solid waste bank is an environmentally friendly alternative for waste management that can reduce waste and provide carbon savings. This study found that the WB emits 3.21 tonne CO_2 eq. per year for a tonne of waste managed and provides carbon savings of 37.73 CO_2 eq. per year per tonne of waste managed. Furthermore, the cost analysis shows that the WB provides benefits equal to 7 million per year per tonne of waste managed.

The WB activity could be long-term sustainability to reduce environmental burdens and to ensure economic viability in municipal waste management in Indonesia. However, it still needs further improvement. Improvement scenarios show that WB activity can be optimized to be more efficient. To achieve it, WB needs support and cooperation from stakeholders, such as government, communities, and the private sectors.

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Chapter 6 Summary and conclusions

6.1 Summary

Indonesia's Law 18/2008 on Waste Management mandated the need for a paradigm change in waste management. Changes in the paradigm of collect – transport - disposed to processing that based on reduction and handling the waste. All levels of society, government, business, and the wider community, are together to implement "Reduce, Reuse and Recycle program." The waste bank is one of the municipal solid waste management initiatives that have been implemented in Indonesia following the Law 18/2008. This initiative is believed to overcome environmental issues, especially related to waste management. The waste bank is one of community-based waste management in Indonesia that encourages the community to sort their waste and enables them to earn money in the form of savings by depositing their recyclable wastes. The result of this activity could reduce the amount of waste into landfill and increases the recycling rate.

In the context of the sustainability of waste management, it requires balancing social, economic, and environmental perspectives. Several researchers have conducted studies and proposed strategies to increase community participation. This research was conducted to study waste bank activities a part of municipal solid waste management in Medan City; this research aims at:

- Providing the current situation of municipal solid waste management in Medan, its generation and the composition of HW
- Investigating the waste bank activities and its material flows
- Evaluating the environment and the economy of waste bank activities

The current condition of municipal solid waste management in Medan shows some essential points:

- Even though it has been more than ten years since it was issued, the implementation of the mandate of Indonesia Law 18/2008 is still not well achieved. Several targets are still challenging to achieve, including the target of reducing waste and upgrading open dumping landfill to sanitary landfill

- If there is no reduction in waste, it looks like Medan will continue to lack the number of trucks and landfill needs. However, considering building bulky waste facilities, and recycling could overcome the issues
- There is still not finding the budget for surveys and research in waste services
- Medan could improve their waste management services, such as encouraging people to sort their waste and bulky waste services
- The informal sector plays a leading role in waste management activities, especially in 3R activities

Municipality/stakeholder needs the quantity and composition of the solid waste data in planning municipal solid waste strategies and to improve its service. This study found that the generation rate of HW in Medan City is 0.222 ± 0.191 kg/person/day. Organic waste was found to form the most significant fraction at 61.35%, followed by plastic 17.55% and paper 8.20%. This study revealed that up to 91.69% of the waste generated from Medan City could be recycled or composted. Among them could be accepted in the waste bank.

Material flow analysis could give a better sight of waste flow in waste bank activities and identify the process and flow that have the highest potential for improvement and more efficient. Around 58% of the collected recyclable waste in the waste bank is paper, 22% of the total is plastic, 13% is metal, and 6% the remaining recyclable waste is glass. The percentage shows that paper is the highest and the second is plastic. It seems different compared to the composition of HW in Medan, plastic is the highest and followed by papers in the category of inorganic waste. The percentage of input and output material for waste bank activities shows that the recyclable wastes account for 87.4% of the total amount of the input material, and 12.6% is water. The waste bank activities generate 87.2% recyclable items, 12.6% wastewater dan 0.2% residues.

The environmental and economic assessment was conducted to analyze the potential environmental impacts, especially CO_2 and to measure the economic performance of waste bank activity. This study adopted the LCA methodology to assess the environmental impact. The cost-benefit analysis was used to assess economic performance. Waste bank shows an excellent prospect regarding the environment and economy, handling recyclable wastes to reduce environmental burden. Waste bank emits as much as 3.21 tonnes per year for each tonne of processed waste and could save as much 37.73 tonnes CO_2 eq. per year for every tonne of managed waste. The economic performance indicates that waste bank activities could give a benefit of 7 million rupiahs per year per tonne of waste managed. This benefit mainly comes from the external, the monetization of potential carbon savings from the waste bank activities. Improvement scenarios show the possibility of optimizing the WB activity. Based on the scenario, the WB activity could achieve 64% less CO_2 emission and 14% cost reduction.

6.2 Conclusions and remaining study tasks

This research leads to the following conclusions:

- Medan City has to make improvements in all waste management sector towards sustainable development
- Waste generation and composition shows a good outlook for the future of waste bank activities
- Waste banks activities are still outdated, which is the absence of technology adoption. In the future, the waste bank should be more efficient and able to manage large amounts of wastes
- Waste bank activity proved to reduce environmental burdens and to ensure economic viability in municipal solid waste management.
- Improvement scenario revealed that WB activity could be more environmentally friendly, which emits less CO2, but it still requires another strategy to cover financial deficits.

The limitation of this research leaves some remaining tasks to be addressed in the future. The following are a few areas of remaining tasks.

- Investigating community behavior related to their needs, participation and environmental awareness
- Developing some waste bank models as a part of waste management
- Developing scenarios of integration waste bank into the municipal solid waste management system