WASTE AS A RESOURCE

ASSESSING THE FEASIBILITY OF SUSTAINABLE (ORGANIC) WASTE MANAGEMENT SYSTEMS IN LAKE TOBA, INDONESIA

ACT project report

LAKE TOBA CONSULTANCY

TEAM 2789
Gijs Tubben
Isten Sweno Tamba
Jingyi Fang
Martijn Oosting
Somtochukwu Okonkwo
Fleur de Thouars

AFVALZORG

waste4change

December 2021

Executive summary

BSF cultivation as an organic waste management strategy is a feasible option for the Lake Toba region. The vast majority of waste generated in the Lake Toba area is organic waste, produced by households, restaurants, hotels, markets, and aquaculture companies. However, there are several political, economic and sociocultural obstacles that can inhibit the successful implementation of the project. Firstly, the current waste management systems and regulations in the area are insufficient and poorly implemented. Waste separation at source is not a common practice in the area for households and small enterprises. Sufficient expertise on improving the current system is lacking in the area. Furthermore, the budget for waste management is not ample for improving infrastructures and regulation enforcement. Besides insufficient budget, there has also been a certain extent of lack of political will to improve waste management. Moreover, important sociocultural obstacles to improving waste management in the area include a lack of education and awareness on the importance of sustainable waste management. It is recommended to work together with the local (sub-district or district level) government and NGOs to establish local regulations, heighten awareness amongst locals and provide better waste infrastructures. For this, additional budget is necessary that can be sourced from private companies and local inhabitants.

List of abbreviations

3R	reduce-reuse-recycle
AD	Anaerobic digestion
BPODT	Badan Pengelola Otorita Danau Toba: Lake Toba Tourism Authority
BSF	Black Soldier Fly
CSR	Corporate Social Responsibility
LCA	Life cycle analysisinter
TPS	Tempat Pembuangan Sementara: Temporary waste storage
TPA	Tempat Pemrosesan Akhir: Final processing site
YPDT	Yayasan Pencinta Danau Toba: Lake Toba Heritage Foundation

Table of contents

Introduction

Tourism is one of the major sources of foreign income for Indonesia. Ever since the occupation of Bali by Dutch colonists, Bali has been promoted as paradise on Earth. This made Indonesia gain a reputation for beauty and luxury (Adams, 2018). After gaining independence in 1945, the focus on tourism started to expand beyond Bali and after the 1966 coup, tourism became the nation's primary focus. Political instability, however, led to a decline of tourism in the 1990's and early 2000's (Adams, 2018). Since then, efforts have been made to re-establish Indonesia as a tourist destination. The current president of Indonesia, Joko Widodo, in 2015 urged his cabinet to focus on the development of tourism in ten regions, with a specific focus on Borobudur, Mandalika, and Lake Toba.

Lake Toba is a volcanic lake resulting from an eruption of the mega-volcano some 74.000 years ago (Smithsonian, 2021). The lake is central to life and culture in this region. Fishery and tourism are two of the main sources of income in the region (World Bank, 2016). The Lake Toba area is home to the native Batak culture. The center of this culture is the Samosir island which houses many tourist attractions. Naturally, in recent years the focus of tourism in this region has been on this sub-region (World Bank, 2016).

Efforts to encourage the development of sustainable tourism around the Lake Toba region should take the problem of over-tourism into account. Given the negative experience of over-tourism in tourist destinations like Bali, the fear of over-tourism still exists (CELTH, 2020). Over-tourism can be defined as *"the impact of tourism on a destination, or parts thereof, that excessively influences perceived quality of life of citizens and/or of the visitors in a negative way"* (CELTH, 2020 p.4). This happens when available local infrastructure cannot handle the extra impact made by both domestic and foreign visitors (CELTH, 2020). The development vision of the Lake Toba region should focus on maintaining the natural beauty and tranquility of the region (World Bank 2016; CELTH, 2021). This can be achieved by providing support systems and infrastructures by regional governments and local initiatives to ensure sustainable tourism. One of these support systems is the sustainable management of (organic) waste, which currently is mostly dumped on roadsides or in the lake, or openly burnt or buried (Khair et al., 2021). The resulting effect of the poor management of this waste includes an unhealthy environment, air pollution, ecological degradation and water pollution. This is a major issue, given that the lake is a major source of water for households within the area. Moreover, trash scattered around the environment makes the region less appealing for tourists. It is therefore of significant importance to improve waste management systems to encourage the development of tourism as a source of income for the area.

In some sub-districts, such as Merek sub-district (one of the most populous areas surrounding Lake Toba), organic waste is taken to the field and then piled up, and inorganic waste is burned or thrown in the municipal landfills without being separated or treated (Khair et al., 2021). Such improper ways of handling waste encourage overexploitation of resources, erosion, extreme climate changes, disease carrying pest and soil degradation. A collaboration between Afvalzorg, a Dutch landfill and waste management company; and Waste4Change, an Indonesian waste management company; is aiming to re-use solid (organic) waste in several processes. Some of their solutions include landfill gas extraction (Afvalzorg, 2021), and Black Soldier Fly cultivation (Kim et al., 2018; Rahmi et al, 2019). Insects are promising sources of protein and fat supplements for a variety of food production due to their high protein and fat content, as well as their biology and digestibility and could prove valuable to the local economic system (Lee et al., 2019). They however need a constant and sizeable stream of organic waste to be fed. These systems are already in use in some areas in Indonesia like Java (Bahraini, 2021, August 11) and other countries like Tanzania (Ministerie van Landbouw, 2019, May 9). Implementation of waste management solutions by Afvalzorg and Waste4change will not only help in reducing, reusing

and recycling waste in the region but help to provide a more economic viable, cleaner, healthier and greener environment in the Lake Toba region (Brunner et al., 2015).

1. Problem statement

The commissioning companies, Afvalzorg and Waste4Change, want to assess the feasibility of sustainable waste management systems in the Lake Toba region to reduce negative impact on the environment and to encourage the development of sustainable tourism. Evidently, the companies already have extensive knowledge on (organic) waste management. However, the companies have little information yet on waste management in the Lake Toba region. Due to the different economic, political, and sociocultural circumstances in the Lake Toba region compared to Java, it is uncertain whether their existing projects can be implemented in the Lake Toba region as well. Thus, to achieve an insight into the feasibility of a sustainable waste management system in the Lake Toba region, additional information and knowledge is needed on the generation, collection, and treatment of waste in the Lake Toba region (Khair et al., 2021; Suryati et al., 2021). Moreover, insight is needed into the potential context related obstacles that the companies might encounter when opening business in the Lake Toba region. Sociocultural, political and economic circumstances specific to the Lake Toba region may impact the potential success of the project. Sociocultural obstacles are important to consider since these impact the behaviour of residents towards waste management (Ikhwan et al., 2021). Political obstacles are important because waste management is a governmental responsibility in Indonesia (Presidential regulation of Indonesia No 97/2017). Finally, economic obstacles can determine the influence that (lack of) available resources may have on the potential success of the project (Kurniawan et al., 2021). Subsequently, these needs can be translated into the following problem statement:

Although the commissioning companies already have extensive knowledge on sustainable waste management, for setting up a sustainable waste management system in the Lake Toba region there is still a lack of insight into how much (organic) waste is generated, collected, and treated in the Lake Toba region, and what obstacles may influence the implementation of sustainable (organic) waste management systems in this region.

The purpose of the project is to provide an assessment of the possibilities for implementing a sustainable organic waste management system in the Lake Toba region, based on an overview of the amount of organic waste that is generated, collected, treated and the obstacles that inhibit the implementation of a sustainable organic waste management system in the Lake Toba region. The conceptual framework in Figure 1 shows an overview of the influences on the feasibility of sustainable waste management systems and serves as an illustration on how they relate to each other.

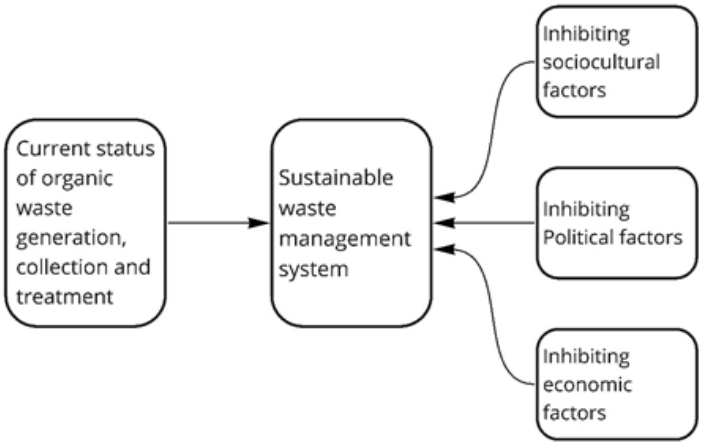

Figure 1: Conceptual framework: influences on the feasibility of sustainable waste management systems in the Lake Toba region, Indonesia

The main research question therefore is: What are the possibilities for implementing a sustainable (organic) waste management system in the Lake Toba region?

To answer this main research question of the project, the following sub-questions are formulated:

- What is the quantity of (organic) waste generated, collected, and treated in the Lake Toba region?
- What are the existing systems and value chains on (organic) waste separation, collection and treatment in the Lake Toba region?
- What are the sociocultural factors that inhibit sustainable waste management in the Lake Toba region?
- What are the political factors that inhibit sustainable waste management in the Lake Toba region?
- What are the economic factors that inhibit sustainable waste management in the Lake Toba region?

Ethical considerations

While the project has many positive implications, there are ethical considerations attached to setting up a sustainable waste management system in the area. Firstly, there are ethical concerns to a Dutch university and company being involved in a development intervention in Indonesia. International development projects between developed and developing countries have been under critique from postcolonial thinkers for reproducing colonial inequalities, instead of helping to diminish them (Kornprobst et al., 2020). Since this project involves a Dutch organisation collaborating to set up a project in the previously colonized nation of Indonesia, this can be subject to postcolonial critique. Moreover, a Dutch university and company working on a development project in Indonesia may result in biases and incorrect contextual assessment. Dutch norms and values may differ from Indonesian, specifically Batak, norms and values. This should be taken into consideration when starting a project in the Lake Toba area. Furthermore, insufficient contextual understanding may result in a project that impacts local livelihoods in a way that is not foreseen. Finally, from a development ethics point of view, development projects such as the implementation of a sustainable waste management system in the Lake Toba area should qualitatively enrich the lives of human beings and move away from a singular focus on economic growth (Astroulakis, 2011). Therefore, an ethical implication of the project is a lack of insight into how this project will better the lives of human beings in several aspects besides economic.

Structure

In the next chapter, the methods used to find data will be discussed. Furthermore, important concepts will be operationalised. Following this, the findings in the literature research are discussed in chapter 3. The chapter is divided up into the topics: Current waste generation, collection, and treatment; Current and future waste management systems; and Obstacles to improving waste management systems. Chapter 4 will analyse findings in the interviews. This analysis will follow the same structure as the literature research. In Chapter 5 the results from both literature and interviews will be discussed. Chapter 6 will consist of a conclusion on the data found, practical recommendations and recommendations for future research.

2. Methods and operationalisation

The research activities consisted of literature research and interviews with stakeholders. The literature research was done first, because the interviews would build on academic literature research (Boeije, 2009). The interviews were built on the basis of academic literature research (Boeije, 2009). The interviews were used to gain more information from different stakeholders to estimate the feasibility of the practices that may be useful to improve the waste management system. Finally, through integrating all the information obtained from these two channels, conclusions were drawn, and practical and feasible recommendations given. Triangulation of information collection methods was ensured, by obtaining information from multiple channels, including literature research and interviews with different stakeholders (De Vaus, 2001).

Literature research

The literature research method was based on the research topic, assessing the feasibility for a sustainable waste management system in the Lake Toba region. This main research question was divided into multiple subtopics. The method of academic literature research allowed the research topic to be understood, and a basic inventory of knowledge to be constructed. In the process of literature research, the final direction and scope of the research was established. The literature that was reviewed focused on the different sub-topics:

- Quantity of waste generated, collected, and treated
- Current waste management systems
- Future plans for waste management systems
- Possible alternatives for waste management systems
- Political, socio-cultural and economic obstacles to sustainable waste management

Firstly, a wide scope of academic research papers and databases were read, aiming to get a comprehensive understanding of the whole topic. After this, the collected information was sorted to make the large amount of information systematic. The most interesting and relevant information was selected for in-depth follow-up research. After collecting a large amount of valuable information through literature research, key information, missing information or unclear information was identified. Furthermore, the subtopics relevant to the project were selected for further in-depth research. These subtopics formed the basis for the creation of interview guides. In addition, some official local data on current waste generation, waste collection and waste treatments and budget were obtained from interviews with representatives of local governments. Those data were analysed and integrated in the literature review.

Interviews

The interviews were used to gather insights from key stakeholders, including local governments and NGOs. Purposive sampling was used to identify stakeholders to interview. The representative of the relevant stakeholder was contacted by the manager with the assistance of Nuffic, as part of the ACT cooperation and the Lake Toba Living Lab project. After getting the representative's response and their consent for the interview, a list of questions for each interviewee was prepared. On the agreed upon date and time, the interview was conducted. Next, the transcription of interview content, coding work and information collation were done.

The stakeholders identified to be interviewed were two different local governments; Simalungun and Samosir, as well as two NGOs; YPDT and Toba Clean Movement. The two governments are two representative districts of Lake Toba. Simalungun was identified as it is the local administrative, industrial and agricultural centre with the largest number of inhabitants. Samosir was selected as it is the tourism centre of the Lake Toba region. YPDT is the Lake Toba Heritage Foundation, who work on

cases concerning the environmental issues of Lake Toba. Toba Clean Movement is a non-profit environmental organization who focuses on sustainable development based on the blue economy principles of environmental protection, social justice, respecting nature and local wisdom. They are in collaboration with the BPODT for waste management in Lake Toba region, which gives them interesting insights into higher level governmental decision-making processes as well.

The interviews with the representatives of two governments were used to answer the sub-research questions on what the existing waste management systems are, what the inhibiting political factors for sustainable waste management systems are, and what the inhibiting economic factors are. furthermore, official data on waste sources, waste collection, waste treatment and budget for waste management in the area were requested during the interviews. The interviews with representatives from the NGOs YPDT and Toba Clean Movement aimed to find out current local efforts concerning waste management and plans for future waste management systems. Besides this, insights into political and socio-cultural factors that may influence waste management were also obtained. After confirming the meetings with the representatives, question lists for the interview were prepared. A systematic method was used to create separate interview guides per stakeholder. First, we created interview blueprints. On the basis of these blueprints, we created main questions and identified a list of follow-up questions. The interview guides can be found in appendix 1A, 1B, and 1C. To prepare for the interviews with stakeholders, trial presentations were done within the group setting.

During the interviews, a duo from the ACT team led the conversation, and other team members observed and took notes. At the beginning of an interview, the duo introduced themselves and the purpose of the interview and asked for permission to record the session. An oral consent form was read. After receiving full consent, the interviewer started with the prepared interview guide. The structure of the interviews was semi-structured, meaning that the interview guide did not fully determine the structure of the interview. After asking a main question, the interviewer listened attentively to the answer, aiming to ask a suitable follow-up question. This allowed for a deeper understanding of the interviewee's view of the subject. To close off the interview, the interviewee was thanked for their time, and asked if they had any more information they would like to add. They were also invited to join the final presentation on 17 December 2021.

After the interviews, the contents of interviews were transcribed in edited verbatim. The transcribed texts were analysed by assigning codes to different subjects in the program MAXQDA. Codes were established beforehand (See the coding tree in Figure 2), to make each code correspond to a sub-topic. Each team member participated in the coding of two different interviews. This resulted in each interview being coded four separate times. This system increased the reliability of the final coded information, as four different perspectives were included. All the different coded information was then placed into one file, ordered per code topic. After this information was sorted and critically reviewed, the relevant contents were analysed. All team members participated in the making of the interview guide and the analysis of the interview. This reduced bias and enhanced the reliability and validity of the information as this was a form of analyst triangulation (Boeije, 2009). Furthermore, having multiple interviewees meant there was also triangulation of information sources.

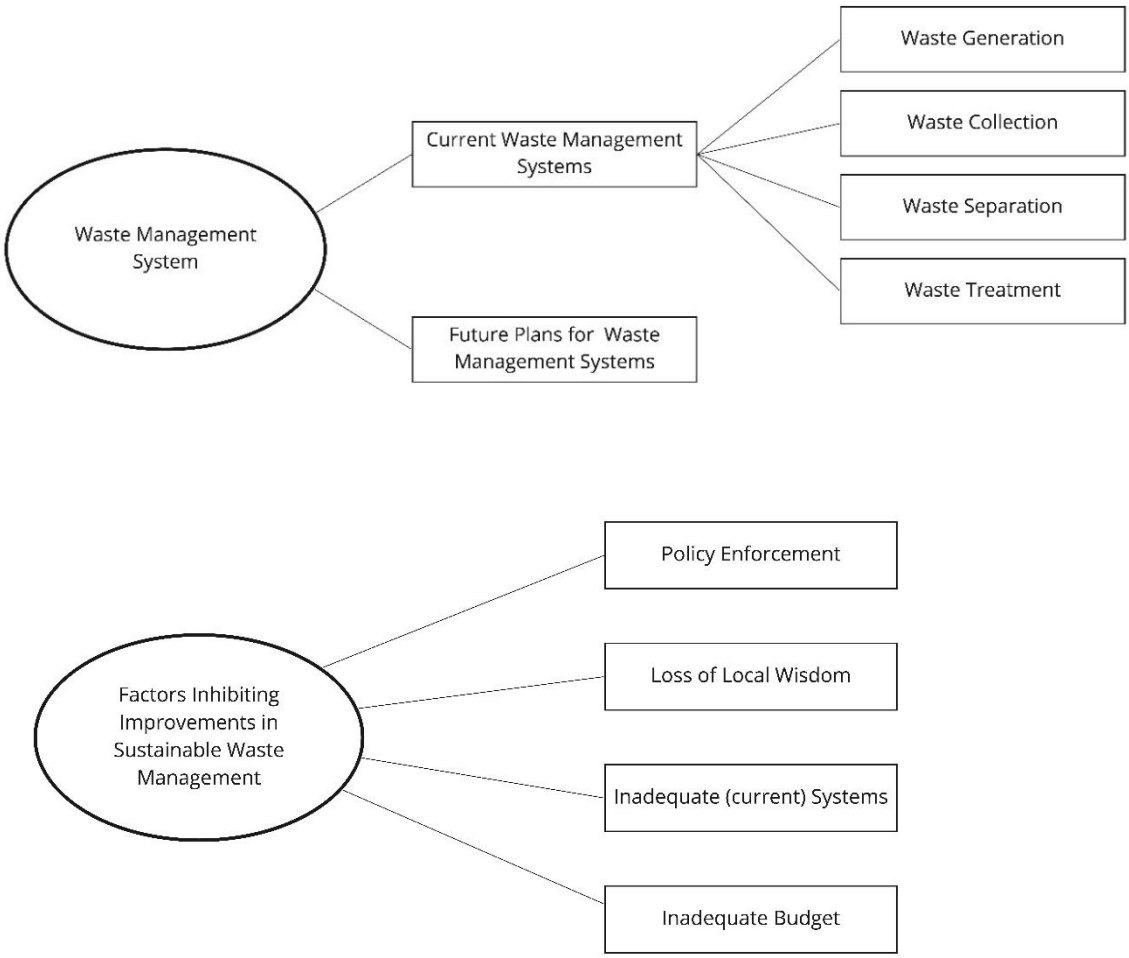

Figure 2: The Coding trees for Waste Management Systems and Inhibiting Factors for Sustainable Waste Management

Operationalisation of key concepts

Waste: Waste as used in this context refers to solid waste. This includes inorganic waste (paper, plastic, bottles and metal) and organic waste (food, plant, vegetable, and other biodegradable waste) excluding sewage and agricultural wastewater.

Waste management systems: Waste management systems are all required activities and resources that are used to manage waste throughout its entire life cycle, from generation to final treatment. It includes all processes of separating, collecting, transporting, treating, and all regulatory, monitory and technical institutions needed to facilitate these processes (Waste-management, 2017).

Sociocultural factors: Within the scope of this research, sociocultural factors refer to human behaviour towards waste (Ikhwan, 2021). Human behaviour is a dependent variable impacted by the wider paradigm in which people live, including values, beliefs and awareness (Elwell, 2013). People's behaviour can be investigated through observing current behaviour towards waste management (e.g. littering, separating, recycling etc.), and people's willingness to change this behaviour.

Political factors: Within this project, political is defined according to the definition by Heywood (2019). Political aspects are regulations or interventions by government departments, cabinet rooms and

legislative chambers that have influence on the waste management in the Lake Toba region. Civil society is therefore excluded from the definition. The levels of government ranges from sub-districts leaders to national leaders.

Economic factors: Economic factors include land, labour, capital and infrastructures. The land refers to land required for the building of recycling facilities, and landfills. Capital and infrastrucres covers all tangible goods required for sustainable waste management, e.g. containers, transporting trucks, machineries and technologies for landfilling and incinerations, composting, and waste treatment.

3. Findings: Literature research

Quantity of waste generated, collected, and treated

Waste generation and collection

The Lake Toba region is divided into eight districts, three of those districts make up the vast majority of the Lake Toba shoreline. They are called the Simalungun, Samosir and Toba Samosir districts (Figure 3).

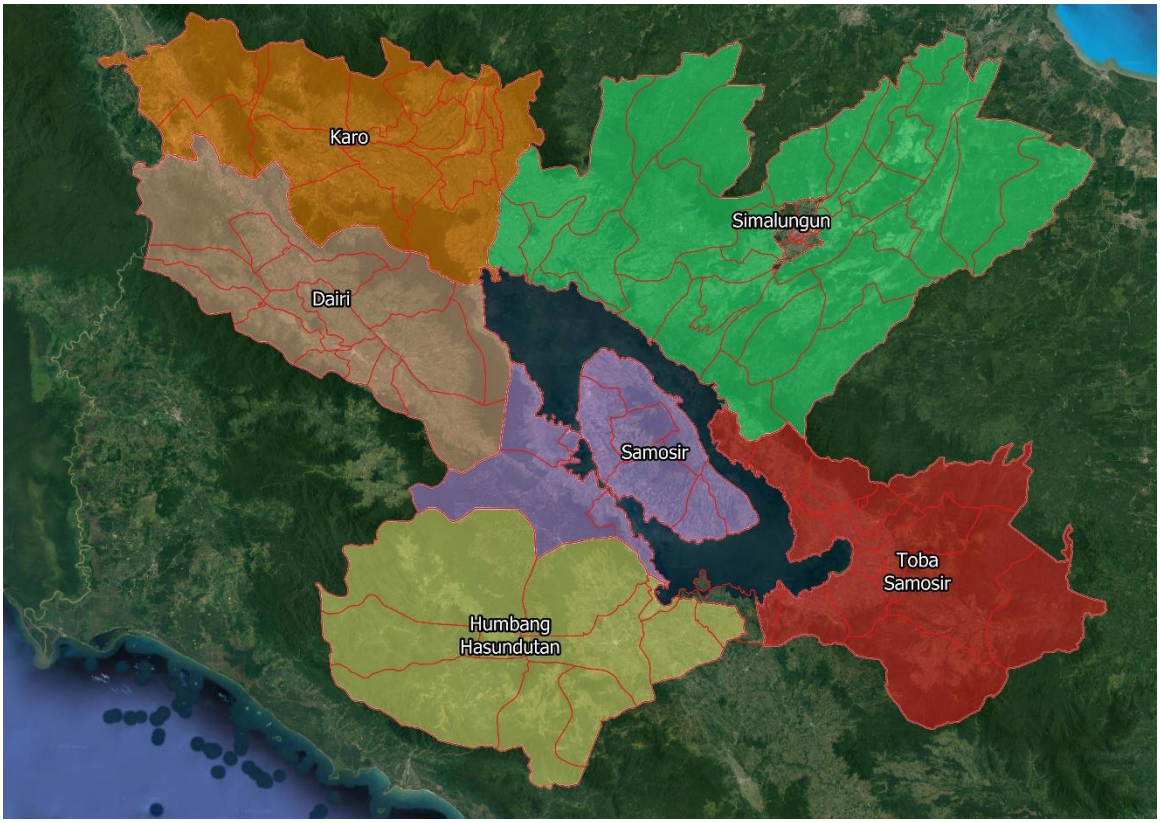

Figure 3: Lake Toba districts

Simalungun has the highest population with 871,678 in 2020 compared to 126,710 in Samosir and 184,493 in Toba (Statistics of North Sumatra, 2020). This difference in inhabitants inevitably lead to differences in waste produced and collected. Tatsuno et al. (2021) estimate that out of the total solid waste that is generated in Simalungun, only an estimated 18.3% is collected. In Samosir an estimate 47.1% of the total solid waste that is generated is collected, though data on hindsight suggests it is around 34% instead (Ministry of Environment and Foresty, 2021). In Toba, 37.1% of the total waste that is generated in that region is collected (Tatsuno et al., 2021). This means that the amount of waste that is collected differs a lot between areas but is generally low. The total amount of waste generated can be seen in Table 1 and Figure 4.

The estimated amount of organic waste produced is 116,629 t/year for Simalungun, 23,440 t/year for Samosir and 12,205 t/year for Toba Samosir (Tatsuno et al., 2021). The difference between the values of Samosir in Table 1 and Tatsuno et al. (2021) can be explained due to the fact that Tatsuno et al. (2021) estimated the of waste streams, and Table 1 describes the realized data in 2020 according to the Ministery of Environment and Forestry.

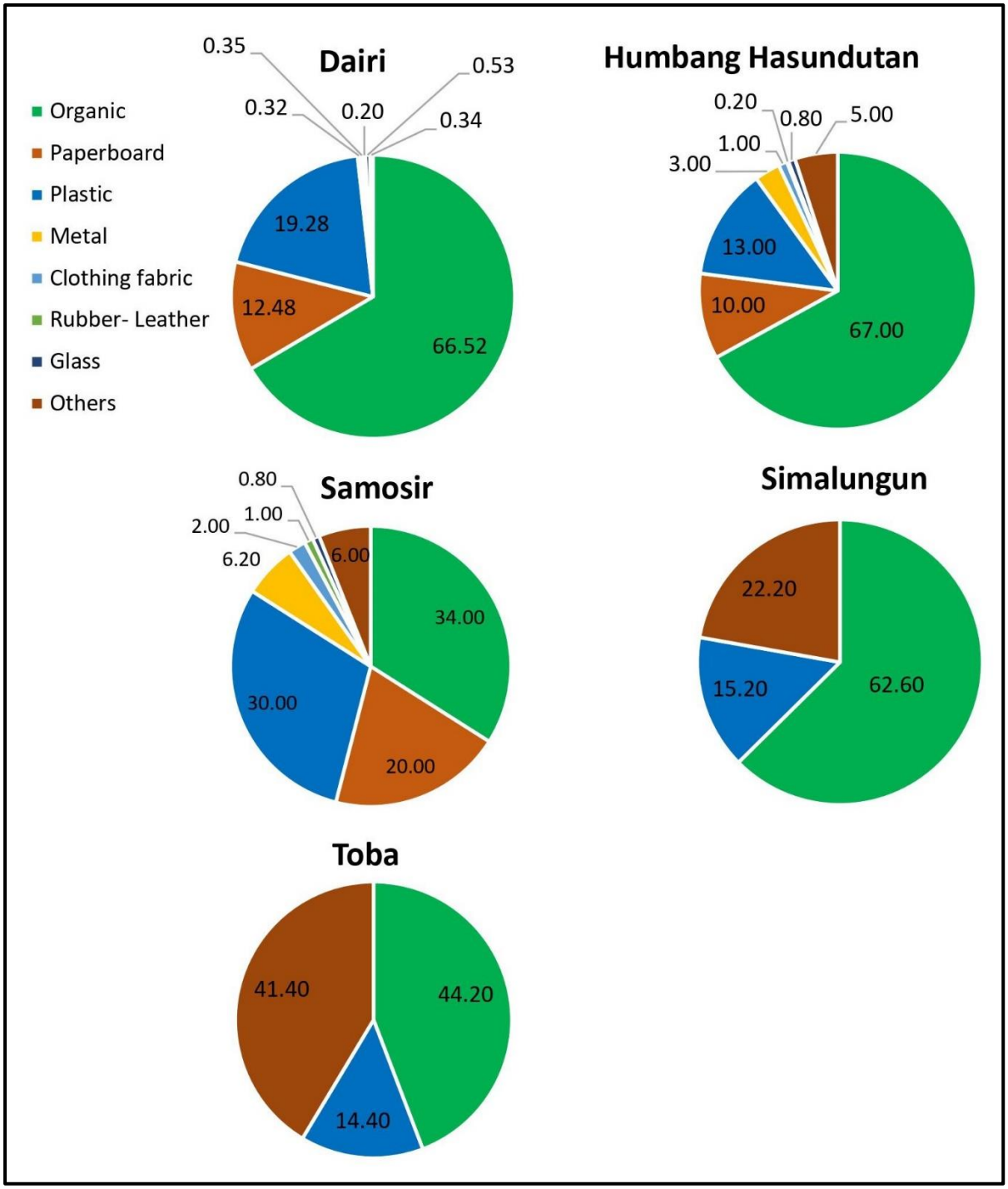

Figure 4: Waste composition in percentage of total waste. Source: Ministery of Environment and Forestry, 2021 for Dairi, Humbang Hasundutan, Samosir and Tatsuna et al (2021) for Simalungun and Toba Samosir

District	Annual Waste Generation (tonnes/year) (A)	Annual Waste Management (tonnes/year) (B)	%Waste Handling (B/A)
Dairi	41,508.38	10,318.55	24.86
Humbang Hasundutan	20,825.37	11,348.23	54.49
Samosir	32,370.63	10,402.50	32.14
Simalungun	187,506	3,431.36	18.3
Toba Samosir	27,614	1,024.50	37.1

Table 1: Annual waste generation and collection in several districts, Lake Toba region. Data from Ministry of Environment and Forestry (2021) and Tatsuno et al (2021).

Other studies, like Suryati et al. (2021) researched the amount of waste in the subdistricts of Girsang Sipangan Bolon, located in the Simalungun district, and Merek, located in the Karo district. The Girsang Sipangan Bolon subdistrict waste turned out to be 65% organic. Merek's waste was 69% organic (Figure 5). Though there is some disunity between results, it can be concluded from these studies that residential waste streams convincingly organic. This percentage ranges between 40% to up to 70% of the total waste stream.

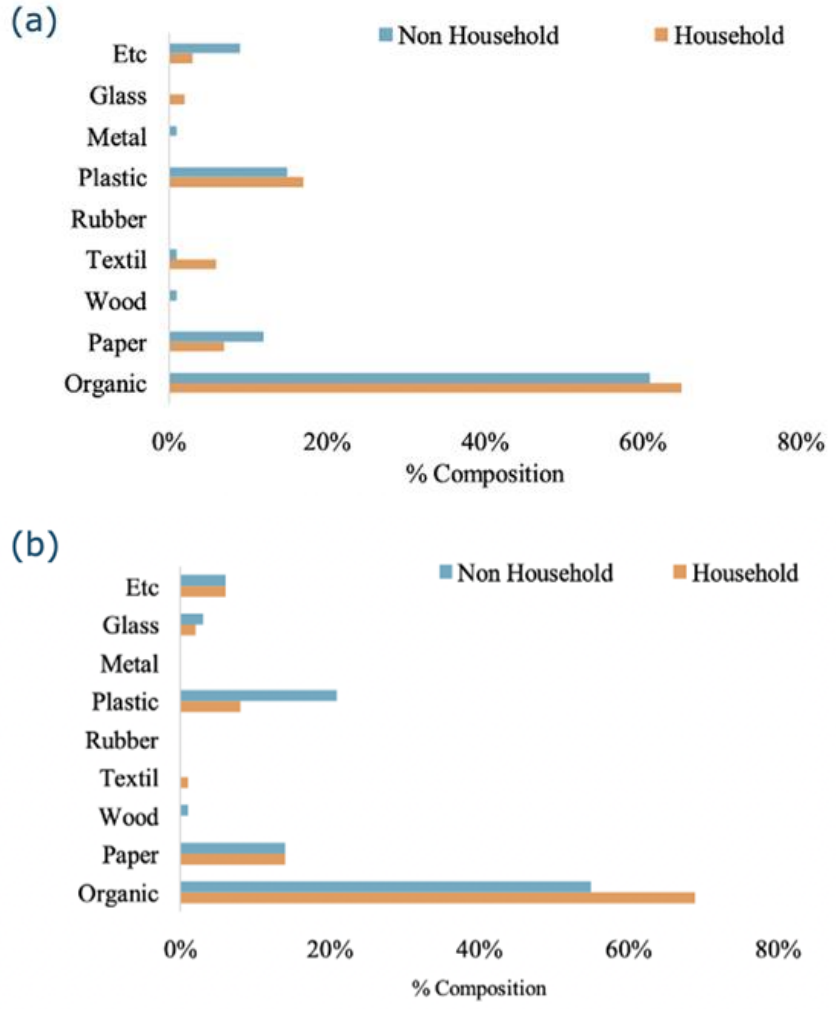

Figure 5: (a) composition of household and non-household waste in the Girsang Sipangan Bolon sub-district; (b) composition of household and non-household waste in the Merek Sub-district. (KLHK, 2019, as cited in Suryati et al., 2021).

Residential waste in the region is thus responsible for a sizeable waste stream which for a large part consists of organic waste, supported by evidence from previous studies and seen in Table 2 and 3. Other large waste generators in the area are shops, restaurants, and markets as seen in Table 2 and 3. While this information is insightful, it must be noted that some data on large waste generators is lacking. Waste generated by industry and tourist attractions, and the composition of the waste from different generators are interesting factors which need further research.

No	Source	Weight (kg)	Volume (l)	Unit
1	Household	0.414	3.02	Person / day
2	Shops	1.727	24.19	Officer / day
3	Restaurants	1.404	11.39	Officer / day
4	Hotels	0.190	3.37	Room / day
5	Schools	0.006	0.05	Student / day
6	Markets	0.106	0.13	m^2 / day
7	Ports	0.011	0.47	m^2 / day
8	Tourism areas	-	-	m^2 / day
9	Banks	0.026	4.44	Employee / day
10	Roads	0.010	0.29	m / day
11	Other offices	0.175	7.20	Employee / day

Table 2: Waste generation of the Girsang Sipangan Bolon sub-district, Simalungun District (Suryati et al., 2021)

Years	**District**	**Source of waste**						
		House hold (tons)	**Office (tons)**	**Market (tons)**	**Commerce (tons)**	**Public Facilities (tons)**	**Area (tons)**	**Other (tons)**
2020	Dairi	2.26	0.12	2.64		0.55	0.36	
2020	Humbang Hasundutan	10.00	0.50	1.00		1.45		2.50
2020	Samosir	12.00	2.00	5.00	5.00	1.00	3.00	1.00

Table 3: Source of Waste in Dairi, Humbang Hasundutan, and Samosir (Source: Ministery of Environment and Forestry, 2021.)

In addition to the waste producers in these residential areas, it is worth noting that the aquaculture industry is also an important local waste producer. Within an area of 1130 square kilometres, Lake Toba produces about 76,000 metric tons of aquatic products each year, the producers of which include large aquatic companies and small aquaculture farmers (Danaparamita, 2016). Haranggaol, a subdistrict of Simalungun is the second largest producer of farmed fish in Lake Toba, and 80% of the population in this area is dependent on fish farming (Danaparamita, 2016). There are large amounts of floating net cages for fish agriculture in several places in the area (Figure 6). Major aquatic product producing companies include PT Suri Tani Pemuka (a subsidiary of Japfa Group, Singapore) and PT Aquafarm Nusantara (a subsidiary of Regal Springs Group, Singapore). They operate tilapia hatching,

farming and food processing in Simalungun. Both firms' aquatic products are exported to many countries in Europe and the United States (Danaparamita, 2016).

Over-farming is a common phenomenon in the aquaculture industry (Alongi et al., 2009; Halide et al., 2009). In recent years, the rapid growth of fish cage aquaculture in Indonesia led to environmental problems due to inappropriate waste management by these aquaculture producers (Syandri et al., 2020). The organic wastes of aquaculture mainly include excessive feed, dead fish and shrimps, and faeces (Miller & Semmens, 2002). Unfortunately, data on the amounts of waste generated from aquaculture in the Lake Toba region is not available. However, judging from multiple news reports, improving waste management is urgent in this industry (Sianturi & Siniwi, 2016; Danaparamita, 2016).

Figure 6: Densely packed floating net cages in Haranggaol (Danaparamita, 2016)

Waste treatment

Meidiana and Gamse have expanded on the different percentages for household waste treatment in Indonesia in their 2010 study (see table 4). Collection of waste at the landfill is the main waste treatment that accounts for 69% of total household waste. Only 7.15% household waste is used for composting[1]. Burying without any sanitary treatment, open burning and disposing in rivers accounts for 9.6%, 4.8% and 2.9% of total treatment methods respectively. These three treatments are non-environmentally friendly practices which can directly cause soil, air and water pollution. In a different study focussed on a sub-district in Simalungun, similar results to the Indonesia-wide study by Meidiana and Gamse were found on the different waste treatment techniques (Khair et al., 2021).

[1] Composting is a sustainable waste management treatment that reuses organic waste and transforms it into valuable fertilizer for agricultural soil as a source of plant nutrients, and improves soil structure and water holding capacity of farmland.

Method	Amount(Million ton/year)	Percentage (% of total method)
Transported to landfill	11.6	69
Buried	1.6	9.6
Composted	1.2	7.15
Burnt	0.8	4.8
Disposed in river	0.5	2.9
Others	1.1	6.55
Total	**16.8**	**100**

Table 4: household waste treatment methods of Indonesia in 2006. (MOE, 2008 as cited in Meidiana & Gamse, 2010)

The three large aquaculture firms in the Lake Toba area all have different approaches to waste management. PT Suri Tani Pemuka has a cleaning system imported from Norway for cleaning waste and dead fish at the bottom of floating net cages, as well as broadcaster machines that can control the amount of feed and feeding speed to reduce feed waste (Danaparamita, 2016). Furthermore, PT Aquafarm Nusantara's general manager Juan Carlos Martinez stated that their waste management is very strict, and the dead fish are collected daily from the farms and then converted into fertilizer or animal feed, or distributed to local residents (Gunawan, 2019). However, the company was sued by YPDT and condemned by the provincial government's Environmental Agency because of its poor waste management (Gunawan, 2019). Government officials and YPDT members have seen the company dump sacks full of fish carcasses into the lake (Gunawan, 2019). These large farms thus seem conscious of their impact on the lake but have made only limited progress in improving their processes. Besides the large aquaculture companies, for small local farmers realizing (organic) waste management is difficult because they cannot afford expensive waste treatment technology, such as cleaning equipment (Danaparamita, 2016). Moreover, because of a lack of experience and knowledge, they throw away many fish carcasses in the lake and nearby hillsides, and neglect to clean up the waste in floating net cages (Budiono., 2021). Thus, even though there is some degree of willingness to treat waste properly, there is still much room for improvement.

Waste management systems

Current waste management systems

Based on presidential regulation of Indonesia No 97/2017 provincial, district, and local levels of government are responsible for providing land, facilities and infrastructure for waste management. Currently, local governments are deemed responsible for collection of the waste though they only have limited capacity to carry out their task, as we see by the low rates of waste collection (Tatsuno et al, 2021). Part of the funding is supposed to come from the national central government (Bebassari, 2020; IGES & CCAC-MSWI, 2019). Further funding should come from waste collection tariffs collected from the local inhabitants (Khair et al., 2019). The collection of waste is done by a combination of systems, such as direct individual door-to-door collection with trucks or motorcycles, and communal container collection. Both options are provided by the local government (Khair et al., 2021). Non-collected waste is dumped in rivers or burned in the open (Khair et al, 2021). The non-separated waste that is collected, is transported and dumped on a landfill. There are only two official operating landfills in the Lake Toba region which have been commissioned in 2020 (Tatsuno et al., 2021), and one of these is still an open-dumping system in which open incineration occasionally occurs (Khair et al, 2021).

There are however more sustainable alternatives available and active already. A government-supported community initiative which is used to improve waste management system sustainability called Waste Banks is currently popping up in communities around Lake Toba (Tatsuno et al., 2021). These private initiatives collect, separate, (temporarily) store, and capitalize on non-organic waste streams such as glass, paper, metal, and plastics (Wulandari et al., 2017). Besides separating waste streams themselves, Waste Banks also aim to increase the involvement of locals in collecting,

separating and reducing waste on a household scale (Trimurni & Dayana, 2018). It is intended as an economically sustainable initiative which can invest money back in the community they operate in (Wulandari et al., 2017). Different waste banks of varied sizes have been commissioned at different governmental levels. On top of that, a recycling centre for valuable resources has been created in every of the districts supported by the United Nations Environment Programme, and the Ministry of Environment of Japan (CCET, 2020).

The addition of Waste Banks systematically changes the way waste is collected and treated. According to Governor Regulation of North Sumatera No 03 / 2020, waste should first be collected temporarily in intermediate collection points (TPS) in every local community, in the form of communal waste containers. After that, waste is transported to an Integrated Waste Processing Site (TPST), or waste banks. Such a system has been visualised in Figure 7.

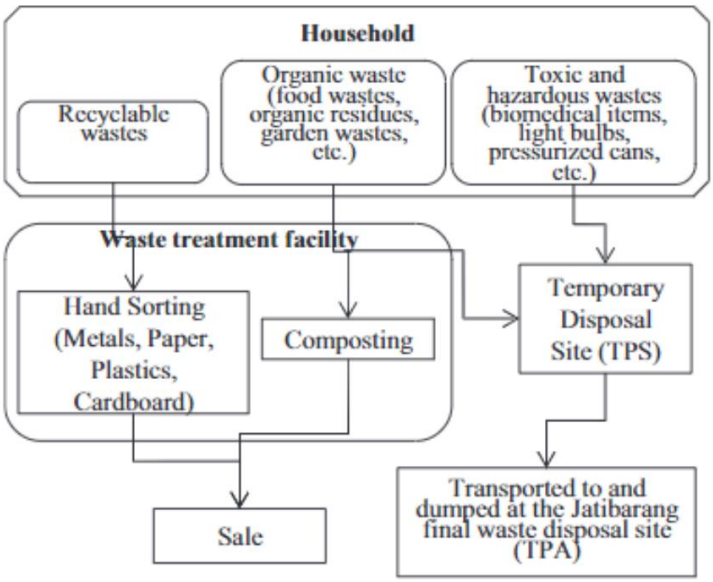

Figure 7: Waste bank as part of value chain (Sekito et al., 2013)

Based on this regulation, the location of temporary disposal site (TPS) for each district is in Merek for Karo district Girsang Sipangan Bolon for Simalungun district, Ajibata, Lumban Julu, Balige, Tampahan for Toba Samosir district, Muara for Tapanuli Utara district, Sidikalang for Dairi district and Sianjur Mula-Mula, Simanindo, Onan Runggu and Pangururan for Samosir district. At these sites, waste is separated and treated. Only unmanageable waste will finally be brought to the final processing site (TPA). The location of these final processing sites is Silimakuta in Simalungun district, Laguboti in Toba Samosir district, Siborong-borong in Tapanuli Utara district, and Lintong Nihuta in Humbang Hasundutan district. The location of these TPS and TPA can be seen in Figure 8. However, data published by Ministry of Forest and Environment of Indonesia year 2020 shows that there are only three TPA in Lake Toba regions; Dairi, Humbang Hasundutan and Samosir districts. Other recent literature even states that there are only two official landfills (Tatsuno et al., 2021). These contradicting findings show that there is a lot of ambiguity and unclarity with regards to waste management systems present in the region.

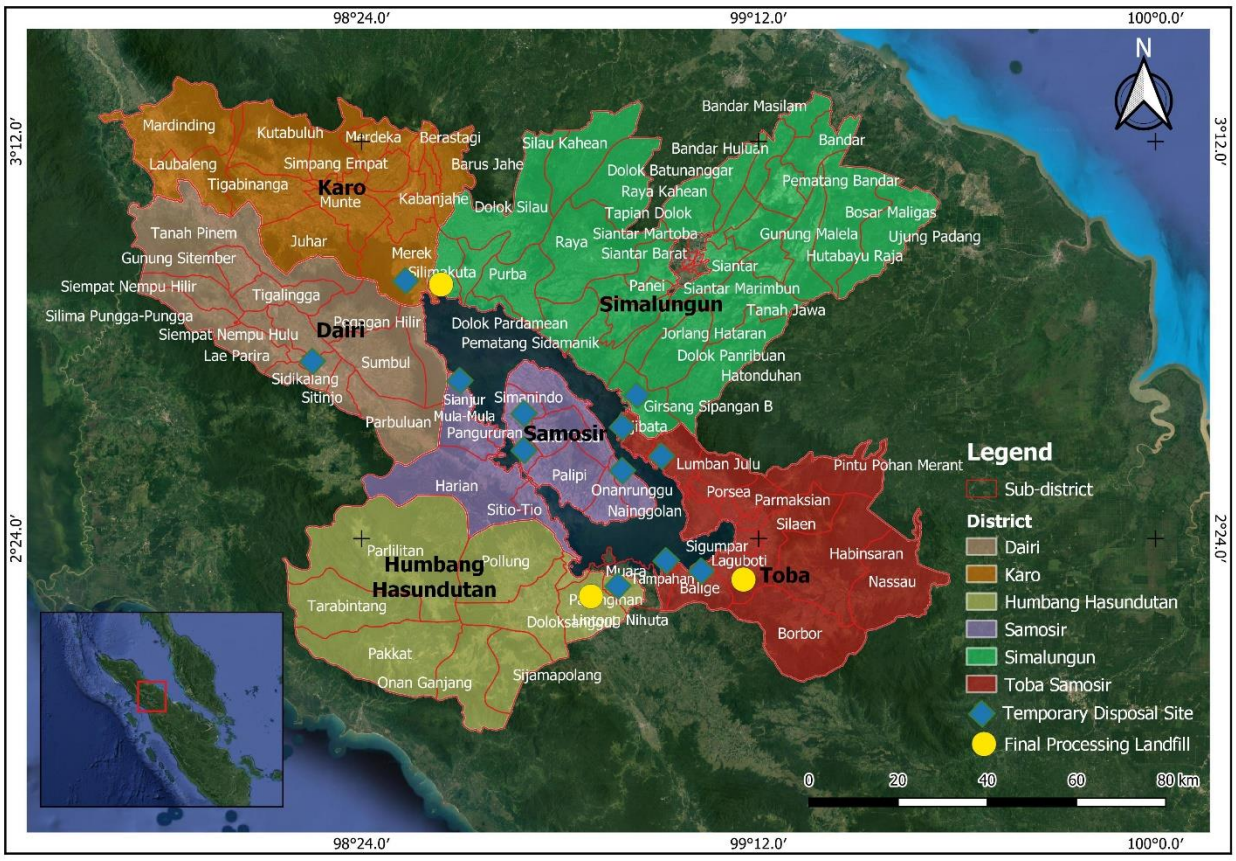

Figure 8: The locations of temporary disposal site and final processing sites based on Governor Regulation of North Sumatera No 03 / 2020

Future waste management systems

Recently the Indonesian national government has envisioned ambitious plans to reduce waste production by 30% and sustainably collect and treat at least 70% of the generated waste by 2025 (Tatsuno et al., 2021). This shift in paradigm is currently being promoted by the Indonesian Central Government, with a heavy focus on Reduce - Reuse – Recycle; better known as the 3R's (Trimurni & Dayana, 2018). The expected result of the 3R is to handle waste more effectively at source. Communication and education play an important role in the success of this new campaign (Trimurni & Dayana, 2018). Results in other areas in Indonesia show that community involvement and training can have a sharp increasing effect on waste separation and collection (Sekito et al., 2013).

Goals were set in 2021, to create 6 main waste banks for the whole Sumatra Utara province, 9 sectoral waste banks in sub-districts and 40 small local community focussed waste bank units in villages in accordance with Governor Regulation No. 03/2020 (CCET, 2020). Toba Samosir has already agreed on pilot cooperation projects in which Waste Banks play a central role and waste itself is handled in a more sustainable way (Tatsuno et al. 2021). As with the Waste Bank in Medan, they still have but limited impact. They seem to have a promising impact on their surrounding community though, through ever increasing promotion of separating waste streams (Trimurni & Dayan, 2018). Further investment in Waste Banks by the Indonesian government is expected due to the important role Waste Banks have in the strategy (Khair et al., 2019). It is expected that in time these Waste Banks will become economically autonomous, no longer needing government funding, relying instead on their own profit (Tatsuno et al., 2021). They are interesting as Corporate Social Responsibility projects for larger companies, like Coca-Cola Indonesia’s investment in green solutions in local communities (Waste4Change, 2020).

Possible alternatives for organic waste management systems

Besides the systems that are present in the area, or for which plans are being made, other options for waste management exist as well. In this subchapter, we will elaborate on a few different possible alternatives for (organic) waste management in the Lake Toba region.

Firstly, breeding Black Soldier Fly (BSF) larvae is considered as a method to treat organic waste, not only because they are not a risk for spreading diseases and parasites, but also because they have a high organic waste consumption rate and can consume a variety of organic waste. In addition, their adults contain 20%-40% fat that can be directly used as poultry feed and can be used as protein and lipid raw materials to produce derivative products such as biodiesel (Raksasat et al., 2020). Besides this, an integrated, independent, and sustainable waste management system designed and operated by Universitas Negeri Semarang, Indonesia also used BSF to treat organic waste such as leaves and food (Fathoni et al., 2021). In addition, FORWARD and SPROUT are BSF waste treatment pilot projects that were funded and implemented in Indonesia by SECO, the Swiss State Secretariat for Economic Affairs and SLU (Swedish University of Agricultural Science) & Eawag (Swiss Federal Institute of Aquatic Science and Technology), respectively (Zurbrügg et al., 2018).

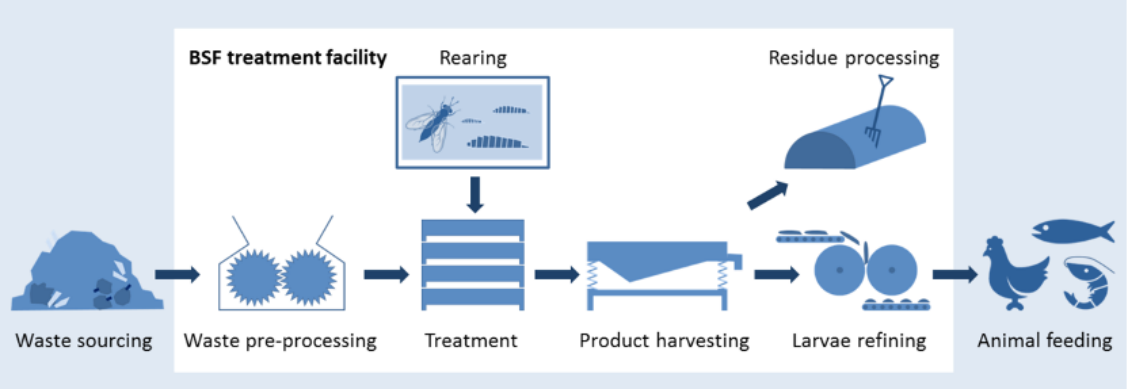

Figure 9: BSF waste treatment system (Zurbrügg et al., 2018)

In addition to BSF, earthworms can also be considered for organic waste management. Earthworms are an important decomposer in nature, and they also play an important role in the natural degradation of waste (Rakkini et al., 2017). They can degrade 95%-100% of cellulose within 5-6 weeks, and other organic wastes such as hard nut shells and animal bones can also be degraded in a longer time (Bhat et al., 2018). They can secrete a variety of enzymes (protease, lipase, cellulase, etc.) to catalyse the rapid conversion of organic waste in the soil (Sinha et al., 2002). Because the body cavity fluid secreted by earthworms can kill pathogenic bacteria, this biodegradation process is very hygienic (Sinha et al., 2002). Londhe & Bhosale's (2015) research confirmed that the excrement of organic waste digested by earthworms does not pose any risk to the environment. Earthworm composting technology has also been applied to organic waste management in many areas (Rakkini et al., 2017). It not only converts organic waste into nutrients such as nitrogen, phosphorus and potassium to improve soil fertility, but also improves soil water retention capacity (Adhikary., 2012; Pathma & Sakthivel., 2012). In an earthworm composting practice in Malaysia, mixing tea dregs with soil proved that earthworm composting can reduce a lot of organic waste in soil within a short period (Shamini et al., 2011).

Transfer of organic waste from compost to anaerobic digestion (AD), and then recovering the biogas produced by AD for energy generation is currently a popular method in developed countries (Istrate et al., 2020). The implementation of such a biogas-to-energy system in developed countries relies on the separation of organic waste at the source, and a high recycling rate of waste (Istrate et al., 2020).The life cycle assessment (LCA) results affirmed the beneficial influence on the environment of the biogas-to-energy system (Istrate et al., 2020). In areas where organic waste is not or barely

recycled, like in the Lake Toba region, this is a promising alternative. For implementation of AD organic waste treatment in Lake Toba region, the separation of organic waste at the source or in the landfills is necessary. If this cannot be done, or the budget is not sufficient to buy biogas equipment, recovering landfill gas for utilization is also a feasible and economical way to create energy and alleviate air pollution, because the landfill gas also has a high methane content. This is because in developed countries, organic waste accounts for a higher proportion in total wastes compared to developing countries (Polprasert., 2007). Therefore, even if there are no additional measures to promote AD, the large amount of organic waste buried in the landfill automatically undergo AD to produce methane after consuming oxygen (Polprasert., 2007). Moreover, by this way methane as a greenhouse gas can be reused, instead of emitted into the atmosphere.

Political, socio-cultural and economic obstacles to sustainable waste management

The political, socio-cultural, and economic obstacles to sustainable waste management are discussed under different subtopics to include insufficient policy enforcement, inadequate current systems, insufficient budget/funding, loss of local wisdom, and lack of transparency and conflict of interest.

Policy enforcement

An important potential political obstacle for the implementation of sustainable waste management systems, is the lack of strong law and policy enforcement by the government (Williams, 2019). Since setting up a sustainable waste management system requires organic waste to be separated from synthetic waste, policies on separation of waste should be sufficiently regulated. While policies regarding waste management exist on the national and local level, enforcement of those waste management policies is still low in Indonesia (Gaevoy et al., 2010). Unclear decision-making structures play a role in this lack of enforcement (Trimurni & Dayana, 2016). According to the 2016 study by Trimurni and Dayana, a strong coordination system on waste management between the provincial, district and municipal level governments was lacking. As an example, is the case of Mebidangro, the Medan metropolitan area in the Lake Toba area, the provincial government oversees and coordinates delivering public services (Trimurni & Dayana, 2016). However, this contradicts with the autonomy that the district and municipal level governments have regarding waste management in the area (Trimurni & Dayana, 2016). Trimurni and Dayana identified these ambiguous decision-making structures in the area to result in a lack of initiative by district and municipal level governments (Trimurni & Dayana 2016). This lack of enforcement of national and local waste management policies may lead people to treat waste themselves in ways that are within their capacity, which may lead to the burning or burying of waste (Gaevoy et al., 2010; Khair et al., 2021).

Enforcement of waste management policies is of utmost importance to successfully achieve sustainable waste management in the Lake Toba region (Amir & Anto, 2018). Lack of waste management policy enforcement such as the 3R (reduce, reuse, recycle), encourages illegal dumping of waste in forests, swamps or rivers resulting in environmental damage. It also leads to lack of knowledge on the total amount of waste generated in a specific area (Wibisono et al., 2020), which may result in lack of basic insight on how to adequately tackle waste management. Lack of enforcing waste management policies also stimulates illegal behaviour such as generation of wrong type of waste, bribery, and other waste crimes (D'Amato et al., 2018).

Inadequate systems

In a recent study by Khair et al. (2021), it is stated that in the Girsang Sipangan Bolong subdistrict of Simalungun, waste management is still far from Indonesia's standard. As discussed above, in the Simalungun district an estimated 18.3% of all solid waste produced is collected. Even this small percentage of waste that is collected is not done so optimally, according to Khair et al. (2021). Currently, a functional waste management system is lacking. Firstly, the government does not provide

individual waste containers, only a limited number of communal ones (Khair et al., 2021). These communal containers are general containers, with no options to separate waste (Tatsuno et al., 2021). On top of that, the government in the Simalungun district only provides communal containers for waste collection in certain places, especially those locations often visited by tourists (Khair et al., 2021). On the contrary, large (organic) waste producing locations, such as the market in Kecamatan Raya, lack adequate containers (Khair et al., 2021). This disparity indicates an unequal focus on development projects by the government, prioritizing tourist locations over local hotspots. For an organic waste management system, collecting organic waste from marketplaces such as Kecamatan Raya would be essential to the success of the project proposed by the commissioning organizations. Therefore, this tourist-focussed approach can pose a serious obstacle to successful sustainable waste management.

Due to the lack of a government regulated waste collection and treatment facilities, the local inhabitants of the Simalungun district treat their waste independently, in ways that can destroy its potential use, for example through burning, composting, recycling and individually using organic waste for animal feed (Gaevoy et al., 2010; Khair et al., 2021). The locals that do wait for collection trucks to pick up their waste use baskets or trash bags that are often falling apart (Khair et al., 2021). This causes the waste to be scattered along roads, some of it unable to be collected by waste collection trucks (Figure 10) (Khair et al., 2021). Waste separation is not common in the Lake Toba region, since the infrastructures for separated waste are not provided (Tatsuno et al., 2021). Even informal ways of waste management which often are present in developing countries, such as scavenging, are absent in the Lake Toba region (Tatsuno et al., 2021). This is because there is no real market yet in the region for selling certain types of waste, which means there is no economic incentive for people to individually separate waste (Tatsuno et al., 2021).

Figure 10: Waste collection and transportation in Girsang Sipangan Bolon (Khair et al., 2021)

Besides the permanent inhabitants, the behaviour towards waste management by tourists should also be considered. Before Covid, in 2015, the Lake Toba area attracted 1.7 million visitors (World Bank, 2016). Majority of these visitors were domestic tourists, with only 4% of all tourists – around 60.000 people in total- being international (World Bank, 2016). This large number of visitors increases the amount of waste generated in the area. While tourism is an important source of income for the area, the large number of visitors can be problematic for waste management, since there is no strong waste management system in the area (Khair et al., 2021). Similar to the locals, tourists in the Simalungun area also do not separate their waste (Tatsuno et al., 2021; Khair et al., 2021). Waste from tourist places such as hotels and restaurants end up in the landfill, without being source separated (Khair et al., 2021).

To improve on the current situation, the Indonesian government aims at managing 70% of waste by 2025 (Presidential Regulation of Indonesia No 97/2017), using a 100% cost recovery system. This 100% cost recovery system will completely recover the money spent on the collection, transportation, and treatment of waste from citizens. There are several potential issues with this system, however. Firstly, since households need to economically contribute to this cost recovery system, this could be seen as

a burden on the households. The inability of the households to comply with the recovery system, especially those situated in remote areas (Tatsuno et al., 2021), may result in a lack of resources needed to sustainably manage waste in the Lake Toba area. Another issue would be lack of transparency on how and by whom (private business, local or national government) these recovery fees are collected, managed and spent (Khair et al., 2019). And finally, it might be difficult to correctly distribute waste management costs between commercial institutions (including restaurants, hotels, guest houses, shops, supermarkets and open markets), and the local household waste generation (Kurniawan et al., 2021).

Insufficient budget

Sustainable waste management requires adequate funding for variables such as labour, equipment, technologies, and infrastructures. This is because insufficiency of these variables will result in the inhibition of waste management systems in the Lake Toba area (Kurniawan et al., 2021). These variables can be broadly divided into two. First the start-up costs, and second the running or operating costs. The start-up costs include the costs of acquiring landfills, building waste treatment facilities and technologies, providing machines for transporting waste, as well as waste containers in streets and marketplaces, and cost of hiring and training employees. The running or operating costs are costs of managing waste on a daily basis (Dohogne, 2014) and include cost of collecting waste from households, markets, streets and other commercial business premises. It also includes salaries, or wages, maintenance and repair of plants and machineries, transportation cost, sundry and office cost. According to Kumar et al., (2020), one of the major limitations to sustainable waste management is a lack of finance to ensure adequate operation, technology, institutions and efficient administration of waste management.

According to available literature, in 2012, the budget for waste management in the district of Samosir was as low as +/- 0.62% of the total budget (Sianturi et al., 2018). The 2021 Samosir government budget showed that only 0.14% of the total budget was assigned for environmental agency (total budget £56,725,774.42, environmental agency budget £78,824.35) which includes more that waste management. Comparing the 2012 waste budget and 2021 waste budget in Samosir, it could be observed a decline in waste budget by 0.48%. This is striking compared to other developing countries like Ethiopia, in which 20% to 50% of district budget is spent on achieving sustainable waste management (World Bank, 2021). The inability of the government to provide adequate resources required for sustainable waste management in different regions poses a great threat to achieving sustainable waste management. According to (Kumar et al., 2020), the required money for starting-up and running waste management systems is substantial. An analysis will have to be made on costs and returns of separated solid waste stream collection and treatment.

Loss of local wisdom

Besides lacking intervention by the public and private sector in Lake Toba, loss of cultural and local wisdom towards waste management is another detrimental factor. Before the region became highly globalized, traditional beliefs guided the local population towards more sustainable handling of waste. Before going further into the local wisdom in the Lake Toba area however, it is important to note that the people living in the Lake Toba region are extremely diverse in sociocultural background. Lake Toba is home to the native Batak culture. Batak culture is a heterogeneous culture, with different subethnicities, including Simalungun, Tapanuli, Karo and Pakpak. All of these sub-clusters have many different traditions, and even languages and religions (Lumbaranja, 2012; Harahap, 2020). In addition to native inhabitants, which are the majority, a small percentage of the inhabitants around the lake are non-natives (Statistics of Sumatera, 2015).

Local wisdom refers to the traditions and beliefs of the local inhabitants, that have been passed down over generations. For instance, Batak local wisdom discourages people from throwing trash in the lake, because it was believed that this could cause the waves in the lake to become vicious, which will cause ships to sink (Harahap, 2020). Moreover, it would cause the harvest of agriculture to fail

(Harahap, 2020). Through these beliefs, environmentally conscious habits were promoted. However, at present the native population in the Lake Toba area no longer have strong beliefs around sustainable managing of waste. Even though many are dependent on the cleanliness of the Lake Toba area, Latifa et al. (2020) found that the native inhabitants do not seem to place high importance on keeping the area clean, when compared to non-natives. This mentality has detrimental effects on the environment of Lake Toba, as most of the people living around the lake are the native population (Statistics of Sumatera, 2015).

Besides the internal loss of local wisdom, powerful actors also demonstrate a lack of interest in and respect for local wisdom. In a 2001 study, Saragih and Sunito found that bottom-up development in the Lake Toba area was not stimulated by government actors. Local governments usually were found to have negative assumptions about the local communities they dealt with (Saragih & Sunito, 2001). A general lack of respect for local knowledge and institutions existed, seeing traditional institutions such as ancient property rights as an obstacle to development (Saragih & Sunito, 2001). This negative view on the culture of Lake Toba as an obstacle to development, caused the government to have a lack of trust in the local population for fostering change (Saragih & Sunito, 2001). Bottom-up change was therefore not stimulated, and locals had never been involved in development projects (Saragih & Sunito, 2001).

Lack of Transparency and Conflict of Interest

Indications exist for a lack of transparency in government spending (Transparency International, n.d.). For instance, in the Samosir 2021 budget, the budget for waste management for Simalungun local governments were included in the budget for environmental agency. What percentage of this budget goes into waste management is not specified. As a result, it could be difficult to keep track of what is actually spent on waste management. Due to lack of transparency through proper records, monthly or annual report publication, environmental officials in some cases are reluctant to report establishments that fail to comply with the environmental quality standard resulting to increase in environmental pollution and degradation (Husin & Tegnan, 2017). A study on waste management in Indonesia, Thailand and Malaysia showed that conflict of interests was also evident in waste fee collection processes where officials in charge of collection fees accept less fees from family members, and friends resulting in cost inefficiency (Willmott & Graci, 2012). Also in Indonesia, environmental officials have been reported to misuse budget. Moreover, a lack of political will to report is evident, establishments that do not comply with the environmental quality standards have remained unpenalized, resulting in an increase in environmental pollution and degradation (Husin & Tegnan, 2017).

To conclude from the different obstacles to sustainable waste management, the inefficient top-down decision-making structure combined with a lack of stimulation of bottom-up projects, correlates with the lack of action on waste management in the region until now (Trimurni & Dayana, 2016; Saragih & Sunito, 2001; Tatsuno et al., 2021).

4. Findings: Interview analysis

In the following chapter the interviews done with the governmental representatives of Simalungun and Samosir, and the representatives from the NGOs YPDT and Toba Clean Movement will be analysed. The information is structured according to the research questions identified in the problem statement.

Current Waste Management Systems

Waste Generation

From the interviews, we can deduce that there is a lack of data on the quantity of waste collected in the Lake Toba region. The Samosir government representative estimated that the average amount of waste collected in Samosir is around 7500 tons per year.

With regards to the composition of waste, there are some ambiguities. The Simalungun local government representative was not sure of the ratio of solid to organic waste collected in the region. The interviewee from the YPDT thought that more plastic waste is generated, while the interviewee from the Samosir local government said that more of organic waste is generated in the Lake Toba region, according to the research by the ministry of environment.

"The composition of the waste produced both at the district level is still dominated by wet waste or organic waste. Based on research from the Ministry of the environment." -Samosir government representative

The Simalungun representative states that the major generators of waste besides households are the tourist hotspots, restaurants, hotels and traditional markets. The amount of waste generated also differs between festive and non-festive periods.

"Waste transportation during the festival has also increased due to the large number of visitors" - Simalungun government representative

"If there is a request, we can provide trash containers during festivities and later we will transport the garbage." - Samosir government representative

Waste Collection

Waste collection is coordinated in Samosir by the district and in Simalungun by the sub-district, according to the interviews with representatives from both governments. Both have minimal waste collection systems. From the interview, it was found that that most of these districts do not have waste collection trucks and have to share with other districts in rotation. Some districts have an average of three trucks to collect all the waste generated in the whole district.

The sub-districts have not yet received even one truck per sub-district. Some, one truck for two sub-districts. And 1 district is very large. - Simalungun local government representative

"For example, some districts have only 3 trucks to collect all the waste generated in the whole region and this poses a great problem because 90% of waste generated in these areas don't get to be collected" - Toba Clean Movement representative

Aside from household waste, other large waste producers exist, one of those are the local markets. According to the interviewee with the YPDT, the waste of these large markets is often collected and managed well.

"In large markets, the waste has been well managed by the local environmental agency" - YPDT

In Simalungun, the government is not the only one that works on waste management, some of the work is outsourced. According to the Simalungun local government, there is a third party with as many as 60 people in the Girsang Sipangan Bolon District. This third party is focused around the touristic Parapat. The interviewee also stated that more waste containers are placed in touristic areas. Both the Simalungung and Samosir government interviewees emphasised a focus on touristic areas.

"There is a priority for tourist areas" - Simalungun government

"Not all areas are served yet. Besides Pangururan and Simanindo cities as key tourism areas, we also serve national roads such as Tele, Tomok and Onan Runggu Harbor." - Samosir government representative

Several organisations exist that assist with waste management in Simalungun. Some of these are the waste banks and companies like Suri Tani Pemuka This is one of the aquacultural farm companies. They provide help through their corporate social responsibility (CSR) programme, in collaboration and coordination with the government:

"Sometimes we make a request as well as yesterday we made a request to PT. Suri Tani Pemuka. They provide composter as well as trash cans. Then it is divided among places that need it." – Simalungun government representative

It is interesting to note that the company, PT. Suri Tani Pemuka, was mentioned as well by the representative of the YPDT as a company that polluted the environment with their aquacultural practices, and they tried to have their permits cancelled:

"YPDT sued the permit of the company in Lake Toba, especially the one that works with fish cages, 2 years we fight injustice for the environment, especially the regulation, the permit of the company is opposite to the environment. The big companies are PT Aquafarm Nusantara, as a foreign company and also PT. Suri Tani Pemuka."

Currently, there are no private waste companies or third parties in charge of waste management within Samosir. The Samosir representative agreed that the government is 100% in charge of waste collection in Samosir. According to the Clean Toba Movement representative, food vendors and restaurants have a better waste collection system compared to other sectors and households, because private businesses collect their organic waste to produce organic animal feeds (BSF), and liquid organic fertilizers.

In Samosir, some hotels for example Samosir Cottages and other hotels in Tuk-Tuk have tried to separate their waste. They worked together with the government for collection of non-organic waste. The YPDT representative also stated that restaurants need to use waste containers in order to get their waste collected.

"There are several hotels that have already sorted it out, we just need to take solid waste" - Samosir government representative

"Restaurants supposed to follow the local regulations. Every restaurant must have their own waste container for the government to collect their waste from their container. This has been applied in big restaurants." - YPDT representative

Waste Separation

All the interviewees agreed that in the Lake Toba region, waste is not being separated from the source. The Toba Clean Movement representative said that the government always talked about waste separation but have not yet taken action to separate waste at the source. In waste banks, waste is collected (not separated from the source), cleaned and sorted by some waste management companies in need of the waste, like Toba Clean Movement who is working on producing Black Soldier Flies and organic liquid fertilizers.

"Usually, the government talks about separation of the waste. But, for many years, only talk. If the people separated the waste, after that, nobody knew what to do!" - Toba Clean Movement representative

Waste Treatment

There are different waste treatment systems present in the Lake Toba area. Dumping the waste in landfills is the most common way of waste treatment in Samosir, some of the waste gets composted.

"There is compost house is in Palipi, so the raw materials we deliver there are water hyacinth which our officers collect along the Pangururan beach. That is what is brought to our compost house and processed into compost." - Samosir government

In the Girsang Sipanganbolon district, the waste is brought to the temporary landfill site first, after that it is brough to a landfill in the Panambean Pane sub-district, according to the Simalungun representative.

The Toba Clean Movement representative stated that they collect organic waste from food vendors and waste banks in Sianipar Sihailhail. This NGO has successfully treated these organic wastes to get liquid organic fertilizers and black soldier flies which are organic animal feeds for chicken, fish and pigs in Sangkar Nihuta and Tambunan. The NGO also hopes to replicate this in other subistricts in the Lake Toba region. A waste bank was established in Tiga Ras, Simalungun which is managed by the village head instead of the sub-district. This strategy has been implemented in multiple villages. The Toba Clean Movement interviewee that works together closely with the BPODT was in favour of the waste banks, as it is has been implemented before and has proven to work.

"Organic waste is collected from food vendors and waste banks in Sianipar Sihailhail, and is used for producing Black Soldier Flies in Sangkar Nihuta and organic liquid fertilizer in Tambunan." - Toba Clean Movement representative

The palm oil producers in the Simalungun district compost their waste and use that as fertilizers, according to the Simalungun government representative. In Tiga Ras, collected waste is sorted in the waste bank. In both Simalugun and Samosir, according to the interviewees from these governments, the sorted organic waste is composted while the plastic waste is sold. The remaining waste after sorting is buried in the TPA. Most households and farmers, especially rice farmers, do not know how to treat their waste and thus engage in open burning of waste.

"The garbage is piled up there Stacked and covered as much as we can with soil." – Simalungun government

Other waste treatments were attempted by local governments in the Lake Toba region, but without success. The Simalungun government tried treating organic waste to produce Black Soldier Flies but failed. Moreover, in 2019 the government provided a factory to recycle plastic and garbage in the Humbang Hasundutan district. However, the recycling facility failed because local governments were not committed to its management.

According to interviewees from the Samosir government, the waste treatment in Samosir is taken to a temporary landfill in Batu Napal, Harian District and piled there. The organic waste that can be used as compost is sorted, recycled and composting in Palipi. Other non-recyclable waste was buried at the end of the year because the Samosir government does not yet have heavy equipment for waste disposal but has been renting or borrowing from third-party agencies.

"We took waste to a temporary landfill in Batu Napal, in Harian District. But it is still a Temporary TPA because there is no permanent TPA yet. We pile it up there, then we bury it at the end of the year. But we still don't have our own heavy equipment but borrow from other agencies or rent from third parties."- Samosir government

"Later waste will be sorted and compositing, so the waste that can no longer be used is buried." - Samosir government

"The compost house is in Palipi" - Samosir government

The Sianipar Sihailhail area does a good job in the treatment of organic waste, which almost realizes the 100% recycling and reuse of organic waste. Their organic waste is collected in the waste bank and used to feed BSF in Sangkar nihuta, or used as organic liquid fertilizer in Tambunan, which are green treatments.

"Organic wastes are collected from food vendors and waste banks (bank sampah) in Sianipar Sihailhail, and are used for producing Black soldier flies in Sangkar nihuta and organic liquid fertilizer in Tambunan." - Toba Clean Movement representative

Future Plans for Waste Management

More trash bins

The lack of trash containers is also a common problem in the Lake Toba Region. Fortunately, there will be more sorting trash containers in use through efforts of governments in the future. The interviewees of the two local governments stated that they will try to provide sorting waste containers locally. They recognised that it would help to realise the sorting of waste from the source.

"If we can, we will add facilities and infrastructure as well as separate trash bins."- Simalungun Government representative

"Indeed, the long term must be to have separated trash bins."- Samosir Government representative

This would answer the need mentioned by the interviewee of YPDT, who said more waste containers are needed in Lake Toba region.

"Almost in all districts, the waste bins are not available yet. We expect there to be a waste bin at least every 10 meters. And in Bali this is done better."- YPDT representative

Waste banks

The establishment of waste bank is a beneficial plan for improving waste management in the future, which was a consensus reached by all interviewees. Waste bank is a trend system that mentioned by all stakeholders.

The interviewee of YPDT believed that waste bank can not only reduce recyclable waste such as plastic waste as to reduce the workload of government on waste collection, but also provide income for local people. However, the problem was that government did not support the waste banks by providing a place to build the waste bank – which should be done on government owned land. Besides, constructing waste banks in villages could help farmers to get more organic compost and reduce the dumped organic waste.

"The availability of waste banks, besides reducing the plastic waste, can also provide more income for the locals. So the government does not need to put more effort in the waste management, instead the locals automatically collect their waste. "- YPDT representative

"The problem is, we started to make waste banks in one location in Lake Toba, the locals were very enthusiastic because they could make money from waste, but the problem is that they did not have enough support from the government to find a place to build the waste bank." - YPDT representative

"Also, if the waste banks are available in every village, it will help them to get organic compost for their land." - YPDT representative

The interviewee of the Simalungun government also agreed that if the waste bank is expected to be built and put into use in the future, the recycled plastic waste can be weighed in the waste bank and the amount calculated as a remuneration for the residents to recycle the waste.

"If they have done the sorting and they make a waste bank. Well, the results of the waste can be a source of income for them. Examples of plastic waste that have been sorted are weighed and the amount of money is calculated. So they can earn from it. "- Simalungun Government representative

The interviewee of the Samosir Government also stated that if the budget is available, they would like to establish a waste bank and manage it by themselves in the future.

"If there is a budget available, one approach to processing waste is a waste bank. What we work on first are schools and offices. At the end of the new year, we will pay after we sell this, later all the waste, which has economic value, will go to the field as much as possible." - Samosir government representative

The Toba Clean Movement interviewee who works in collaboration with BPODT indicated that a proposal was currently made to BPODT to build a waste bank. The TCM had contacted the Ministry of Maritime and Investment Affairs, who has established a waste bank in Bandung which is doing very well. The interviewee believed that the establishment of a waste bank should not only rely on the government, but NGOs are also key stakeholders. A good example of this is a waste bank in Humbang that was already set up by NGOs. The Toba Clean Movement representative stressed the necessity of linking every stakeholder in the future for building and running waste banks.

"Waste banks are for every kind of waste. The concept of waste bank is economic motivation to provide economic benefits to the lowest cluster, people with no money." - Toba Clean Movement representative

"*There are non-governmental movement to build a Waste Bank in Humbang although it is still in the planning phase.*"- Toba Clean Movement representative

Waste separation at landfills

The Simalungun government is planning on separating waste at landfills like in Panambean Pane, through employ contract workers. Then plastic waste will be sold to waste houses, the income from the sale will be used in waste bank management. Organic waste will be made into compos, and they are training employees and experimenting with better composting methods, such as mixing with EM4. In the future, there will be a complete and efficient waste management system for sorting waste in landfills, selling plastic waste, composting organic waste, as well as running waste bank in this area.

"The plan is to be sorted. Like in Panambean Pane there is already a sorting because there are several honorary workers. So there is also sorting." -Simalungun Government representative

Future plans for BSF treatment

The main treatment of organic waste is composting, but there are alternatives that are being implemented. There has been training for cultivation of BSF in Simalungun, but this organic waste treatment method has not been successful yet in that area. They hope to get external support, perhaps from a third-party waste management organization, to obtain BSF larvae to successfully use organic waste to breed BSF in the future.

"We have participated in BSF training. We've made the place, the nets, but it's not working. This is expected to deplete organic waste but has not worked."- Simalungun Government representative

"During the training, the larvae were given, now we want to make our own. But the larvae haven't arrived yet. So now trying to find more larvae for that." - Simalungun Government representative

The representative of the Toba Clean Movement, mostly active in Toba, has had a more positive experience implementing this method as a waste treatment strategy, although the project is still very new. They plan to expand more BSF projects in other villages.

"We have started already with a project for the maggot. Right now, in the second phase. Now we will also start in another village" - Toba Clean Movement representative

In Samosir, the only way of treating organic waste separately is composting, no attempts of using BSF has been made yet. There are future plans for more waste separation, which could open up possibilities for BSF.

Regulations and Policy Enforcement

From the interviews, unclarity arose on the regulation that exist surrounding waste management in the Lake Toba region. When inquiring about the fines for littering for example, the Simalungun and Samosir government representatives stated that there were no sanctions or regulations in existence yet.

"For now, there is no sanction and there is no regulation on the height of the penalty." - Simalungun government

"There are no sanctions for non-compliance yet, because there are no local regulations. There are future plans to construct regulations and sanctions. For now, we refer to the national regulations." - Samosir government representative

On the other hand, the YPDT representative stated that there were national regulations on littering, but enforcement of these rules was lacking. According to him, the national regulations that exist should be applied at the local level. However, this is not the case as the national regulations cannot pass the middle government level (province and district). This leads to an inability of those national level regulations to reach the local implementations, according to the YPDT representative.

"Because it refers to the national government regulation, those who are littering will be fined based on this regulation. But the problem is the government is not firm about this regulation. Thus, the locals who are littering did not feel guilty anymore. Not only in Lake Toba region, but also in entire Indonesia region." - YPDT representative

The representative from Toba Clean Movement agreed with the statement by the YPDT representative. According to him, the approach of creating regulations was based on a top-down approach which leads to a lesser understanding of those policies by locals.

"Waste regulations are not done in the grass root but at the central and as a result, the people don't know these regulations or policies or what is expected of them"- Toba Clean Movement representative

Furthermore, the representative from Toba Clean Movement agreed with the YPDT representative that there is a lack of regulation and enforcement by the government, who are responsible for managing waste. The YPDT and Toba Clean Movement representatives both mentioned that the government talked about improving regulation and enforcement on waste management often, but action remained absent.

"Usually the government talks about separation the waste. But, for many years, only talk... No solution." - BPODT representative

"We push the government to follow the regulations but in fact the government is ignoring the regulations"- YPDT representative

The Samosir government representative spoke about the need for economic contributions by the population for the improvement of waste management. However, since some people are unable to contribute, and some are unwilling, this is an obstacle towards improving waste management in this manner.

"On the one hand, we want to improve cleanliness. But on the other hand, there are people who have enough money, and there are people who do not. There are those who are able to contribute but not willing, and there are those who are unable but willing." - Samosir government representative

The YPDT interviewee states that conflict of interest can also impact the policy implementation by the government. According to the YPDT representative, this is evident in the ministry of environment in the Lake Toba region, which has kept a blind eye to companies who pollute the environment with their waste and those who do not properly manage their waste. He mentioned that the waste management rules and regulations are very good and clear, but the ministry of environment will give out permits to companies generating harmful waste due to a conflict of interest. The example he gave was that of large aquaculture companies, who have connections to the government.

"Sometimes we make a request as well as yesterday we made a request to PT. Suri Tani Pemuka. They provide composter as well as trash cans. Then it is divided among places needed it." - Simalungun government representative

"There are also 2 big companies, they produce fish in cages in Lake Toba. They use fish feed (Pellet), which is bad for the water. Some people in the government they corrupt and take the money, they don't care about the environment, so they give contracts to the company." - YPDT representative

Loss of Local Wisdom

The general census among the interviewees is that local wisdom and philosophies do not have a strong effect anymore on the way people handle waste in the Lake Toba region. There was some differentiation amongst the different people interviewed on the importance of local wisdom for waste management. Out of all interviewees, the local and tourist representative from the YPDT placed the highest importance on the influence of local wisdom on waste management.

"We want to go back to the old local wisdom. Local wisdom is very important to maintain the Lake Toba. Not only Lake Toba, also the forest, the land." - YPDT representative

The government representative from Samosir described one local wisdom that relates to waste management that is still present amongst Batak people in the area, however only at certain times of the year. During festivities, a local women's empowerment association (PKK) puts up posters of "Poda

na Lima" wisdom, which is a local wisdom on the importance of cleaning different aspects of life, including the heart and the environment.

"Yes, the "Pod na Lima" culture influences people's habits, but only incidentally or temporarily, we hope it will be sustainable and involve the village government." - Samosir government representative

Another example of a local wisdom that influences how people in the region handle waste is the spirit of "Opung".

"If people make the lake dirty, then the "Opung", the grandfather that passed away, will get angry. That is why they don't want to make Lake Toba dirty. The spirit of "Opung" stays in lake Toba, that's why the people, especially Batak people in lake Toba, are very respectful to the spirit and they do not want to make the spirit angry... the Opung will not bless their land and the water." -YPDT representative

According to the YPDT representative, local wisdoms are similar across all districts in the Lake Toba region. However, while beliefs such as the spirit of Opung are still present in older generations, the younger generations have lost this wisdom. Especially those that leave the region to study lose the beliefs in local wisdom, due to the exposure to science and organized religion.

Besides the above-mentioned reports on the importance of local wisdom for waste management, the other interviewees did not mention local wisdom as an important factor. The representative of the Simalungun government, when asked about it, noted that some still believe in the local wisdom, and some do not. All in all, she did not see these traditional beliefs as a strong influential factor.

Inadequate Waste Management Systems

Based on the interviews with several stakeholders (Toba Clean Movement, Simalungun and Samosir local government, and YPDT), it can be concluded that the current waste management systems are inadequate. A lack of waste infrastructures is an aspect that all stakeholders agreed on. According to the Simalungun government representative, they do not have enough containers, nor enough trucks to collect the waste. The number of trucks is still very few, not even every sub-district has their own truck. This is also the case for the Samosir district. Due to the lack of facilities, they only concentrate on several touristic places. In Toba district, based on the interview with Toba Clean Movement, he mentioned that this low number of trucks resulted in a low percentage of waste collection. Currently, almost 90 % of the waste cannot be collected.

"For example, some districts have only 3 trucks to collect all the waste generated in the whole region and this poses a great problem because 90% of waste generated in these areas were not collected" - Toba Clean Movement representative

"The only problem is that our infrastructure is lacking. The sub-districts have not yet received even one truck per sub-district. Some, one truck for two sub-districts. And one district is very large." - Simalungun government representative

"Not every area has their own trash containers nor trucks. For now, besides Pangururan and Simanindo cities as key tourism areas, we only serve national roads such as Tele, Tomok and Onan Runggu Harbor"- Samosir government representative.

"But there is no sanitary landfill because there is still a shortage of heavy equipment." - Simalungun government representative

According to YPDT, the separated trash bins do not exist in every places, not even in touristic places. Besides a lack of bins, containers, and trucks, the Simalungun government representative also stated that the locations of the TPA are far away from some sub-districts. Even some densely inhabited sub-

districts like Girsang Sipangan Bolon still use a temporary TPA due to the lengthy process of getting land from the ministry of environment and forestry (KLHK). Moreover, there is not one permanent TPA found in the entire Samosir district.

''We also don't have a TPA as a place for final waste processing. Currently, we are still transporting and disposing of garbage"- Samosir government representative

Education and awareness

There seemed to be a lack of education and awareness amongst people surrounding waste management in the Lake Toba region. The Simalungun government representative stated that only part of the locals followed the rules and were aware with the waste problem. Furthermore, the representative from the YPDT mentioned that people were not well educated on waste separation. The YPDT has led some seminars on this issue to educate the local population. However, in his view, the education needed to be done by the government as they had more power and locals listened to them better. The interviewee recommended that regular socialization and education needed to be also done in school. The purpose of this education is not only to make the public aware of waste separation, but also to have the correct operation of waste separation methods. Besides, he also argued that in the urban area this problem was less prominent as they receive more education from social media or others source of information. While this is not the case for people living in rural areas, and especially those with low incomes. According to him, the height of income influenced the education level of people, hence it will affect their awareness of sustainable waste management. The poorer people in the Lake Toba area are therefore the ones that should be targeted the most by education campaigns, according to him.

According to the representative from Toba Clean Movement, the reason people do not separate their waste in was that there is lack of awareness on what to do with the waste after they are being separated. He also expected that the government to become the role model for this separation activity.

"If the people separated the waste, after that, nobody knew what to do." - Toba Clean Movement representative

"I think that the government should educate the society about how they should separate their waste... Because even if separate bins were available, if they are not educated. They will keep doing same the things." - YPDT representative

"We only make suggestions to the society, but we have no power, that's the problem. If we educate the people, they say 'who are you?'. They will look down at us." -YPDT representative

Insufficient Budget

That the budget for waste management is inadequate is something all interviewees agree on. The interviewee from the Toba Clean Movement is frustrated by the lack of funds that the local government provides so that things can be put into practice:

"But the local governments in the Lake Toba region provide no funding for waste management" - Toba Clean Movement representative

The lack of investment can be explained by the inadequate availability of money that the local government has. As mentioned in the inadequate systems, the Simalungun district does not have a solid infrastructure for waste management, things like waste bins, trucks, facilities to treat waste are all falling short.

"For 2021, the total budget is 5.6 billion rupiah to pay the cleaning staff" – Simalungun government

"For this year, there are procurement of 3 trucks, 2 Arm roll units, and 4 units of container, and 12 units of tricycle rickshaws. For this year there is a budget of 3.5 billion for that ˝Simalungun government" - Simalungun government

In Simalungun, the government has set aside a budget to procure waste containers for the separation of organic, inorganic and toxic waste. However, they are constrained by funding because the funding budgeted for the procurement was diverted during the pandemic.

The local government in Samosir runs into the same problems.

"The budget for this year is 1.2 M, and reduced from last year" - Samosir government representative

"For the last 3 years, we have never procured trash cans again due to budget constraints" - Samosir government representative

The budget constraints make it hard to improve infrastructure for waste management, because it is just enough for the current waste management system to keep functioning:

"We only have a budget for truck fuel, motorized tricycles, maintenance of infrastructure and daily wages for freelancers." - Samosir government representative

Although in some areas of Lake Toba region, for example, Humbang Hasundutan already has a waste bank and it is successfully operating, there is still no waste bank in Samosir. One of the main reasons is that the budget is insufficient, and other start expenses like training of staff are also needed.

"If there is a budget available, one approach to processing waste is a waste bank. What we work on first are schools and offices. At the end of the new year, we will pay after we sell this, later all the waste, which has economic value, will go to the field as much as possible." - Samosir government representative

The amount of money that is available depends on the local revenue. This means there is no generalized amount of money available for waste management, and it depends on the subdistricts what the amount exactly is

"Increasing the budget for waste management depends on the availability of the district budget, which depends on local revenue." – Samosir government representative

There are plans for a cost recovery system, where inhabitants pay money for waste management. However, for the government to ask for a larger contribution from the local inhabitants, they will have to explain the reasons for their contribution to the locals. They cannot increase the amount of taxes the inhabitants pay without explanations:

"If that's the case, there must be socialization to the community first. Explain that the funds are needed to support infrastructure development." – Simalungun government representative

If budget constrains government action, it is also possible for a third party to assist through agreements that are made with the government regarding CSR (corporate social responsibility). There is already a collaboration with the PT. Suri Tani Pemuka. They provide some of the trash cans and composters to the local government:

"Sometimes we make a request as well as yesterday we made a request to PT. Suri Tani Pemuka. They provide composter as well as trash cans. Then it is divided among places needed it." - Simalungun government representative

5. Discussion

In this section we will highlight the most interesting findings of our combined literature and interview research.

All the data from academic literature and governmental sources, and the information obtained through interviews agree that organic waste takes up a large amount of the total generated waste. Households, markets, shops and restaurants are the largest waste generators of the area, as well as companies active in aquaculture.

Generally, collection rates were found to be low. The Simalungun collection rate was estimated to be 18.3%. This estimation was echoed by the representative from Simalungun government, who thought it likely to be around 20%. However, the value of 47.1% of waste collected in Samosir in the literature was contradicted by the data from the Ministry of Environment and Forestry (32.14%) and the representative of the local government in the interview, as they estimated that the amount of waste that is collected is more likely to be around 20%. The data shows that it was estimated that the amount of waste that was collected in Samosir was 10,402.50 tonnes per year, in the interview it was estimated to be around 7600 tonnes per year. Even though the information does not completely match, it does give an indication of the waste collection ratio in the area.

According to the literature, 69% of the collected waste is transported to the landfill in Indonesia (Meidiana & Gamse, 2010). The interviewee of Samosir government also revealed that dumping the waste in the landfill is the main treatment method. According to the information provided by the interviewee of the Simalungun government, the waste treatment method is to be brought to a temporary landfill and piled up, which was consistent with the statement of the interviewee of the Samosir government. That local landfills lack heavy equipment to process more waste treatment, and most of them are temporary landfills was also important information obtained from interview with the representative from Samosir government. In addition, Khair et al. (2021) mentioned that open burning of waste still exists in some landfills. This information indicated that landfill waste treatment system in Lake Toba region needs to be improved. Nevertheless, both government representatives mentioned that there have been attempts to recycle organic waste and use it as compost.

Composting as organic waste treatment is used incidentally in the Lake Toba region. The interviewees of the Samosir government stated that they have used some organic waste and processed it into compost in their composting facility Palipi. Even though, they are currently only using the water hyacinth waste, while the household and market organic waste have not been used yet, because this waste has not been separated at source. The fact that the government is experimenting with composting indicated that the government has the willingness and practice to recycle organic waste and make it into compost.

So far, the precedent for successfully implementing BSF processing in Indonesia is in Java, according to Supena et al., (2021). Literature on BSF treatment in the Lake Toba region was not found, but interviewees from the Simalungun government and Toba Clean Movement provided useful information on pilot projects. Interviewees of the Toba Clean Movement indicated that the Sianipar Sihailhail area has successfully practiced feeding BSF with organic waste in Sangkar nihuta. The Toba Clean Movement representative expressed a strong desire to start their BSF projects in other regions beside Sangkar nihuta. The representative of Simalungun government also expressed that they hope to successfully implement the BSF project in the future because they have already trained relevant staff and built some part of the infrastructure for the cultivation. However, currently they still lack the larvae. Moreover, there seems to be a lack of knowledge as all their BSF died on the first trial. According to them, the possible reason for this is due to the lack of sunlight (Simalungun Government

representative, personal communication, December 9, 2021). Nevertheless, these initiatives do show a willingness to work with BSF in the future.

Further plans for the future have also been identified. Firstly, in the literature it was found that the Indonesian government aims at achieving the 3R policy of reduce, reuse, recycle by building more waste banks. Some waste banks already exist in the area, according to the literature and the interviewees from the Toba Clean Movement and the Simalungun local government. From the interviews, it could be found that all the interviewed representatives agreed that building more waste banks is a promising way of improving waste management in the Lake Toba region. Beneficially, waste banks can grow to become economically autonomous in serving their own financial needs such as operational cost and salaries of employees. Moreover, they can be means of generating income and providing job opportunities for the locals.

Secondly, from literature, provision of more trash bins was not indicated as a future plan towards sustainable waste management. However, from the interview, all interviewed government representatives have expressed plans to provide more trash bins for separation. They stated to have included this in next year's regional budget.

Also regarding future plans, the different interviewed government representatives said they are considering to separate waste at the landfills. Currently, efforts are being made to support this by the Simalungun government. They are currently training employees to conduct waste separation and compost production on waste landfills. This will not only help to reduce the quantity of generated waste on the landfill, but also create source of income as the separated waste could be sold. In addition, separation of waste on the landfills could help in removing toxic waste that could cause pollution to the surrounding environment through runoff and becoming potential health hazard. Nevertheless, it is important to note that this option does not provide source separated waste, making it unusable for certain waste management strategies.

However, several obstacles exist to improving waste management in the Lake Toba region. First of all, globalization has had a strong impact on the Lake Toba region. Local wisdoms that existed amongst the Batak population used to have positive impacts on the way people handled their waste. Now however, especially the younger generations have become unfamiliar with this local wisdom, and it no longer has a substantial effect on their mindset regarding waste management. Besides the loss of local wisdom in the native inhabitants, the region also has seen a steady increase of outside visitors. Especially domestic tourism has become a large source of income for the region. While this has a positive effect on the economic development of the region, it is also an additional difficulty for improving waste management. Especially the domestic tourists seem to be less concerned about sustainably managing their waste during their visit to the Lake Toba region, which often results in littering of trash on the streets and in the lake. This is also negatively influenced by the insufficient waste infrastructure in the area, such as a low amount of waste bins in public areas.

The availability of waste management infrastructure plays key role in establishing a sustainable management system. Based on the literature review and interviews, it showed that this is still a big problem in the Lake Toba region. In the literature, it was mentioned that waste separation is not common in the Lake Toba region. This is also supported by the interviews with representatives from the local governments and NGOs. This lack of waste infrastructure impacts the amount of waste that is separated at source. As a result, this could lead to higher costs to manage waste. Moreover, some of the waste loses its potential value due to contamination with other waste. Besides a lack of waste bins, based on the interviews, there are also insufficient amounts of available waste collection trucks in the Lake Toba region. Some sub-districts did not yet have a single truck. As a result, 90% of the generated waste in the Lake Toba region is not collected.

Lack of education and awareness is another obstacle that could influence the success of waste management. The literature does not emphasize much on this aspect, but it was a main issue

mentioned by all interviewees. They argued that this lack of awareness impacts several behaviours, for example littering, harmful waste treatment, and lack of separation. The YPDT representative emphasized the role of the government in educating the people. Nonetheless, causality is not implied. It may not be solely because of a lack of awareness that people treat their waste unsustainably, as inadequate current waste management systems sometimes leave people no other option then to independently handle waste.

Insufficient waste management regulations and policy enforcement has also come forward as an obstacle to improving waste management in the Lake Toba region. The literature described that while policies on waste management exist on the national and local level, enforcement of these policies is often lacking. Trimurni and Dayana identified in their 2016 study that a lack of coordination of tasks between the different levels of government might be a contributing factor to this. This complex coordination between different levels of government was echoed by the interviewee from the YPDT, who said that while national regulations exist and are good, they are not implemented on the local level due to a break in communication in the middle level governments. The governmental interviewees also stated that no sanctions exist yet, due to a lack of local regulations. From this information it can be deduced that there is insufficient implementation of national regulations on the local level, and therefore an inability to enforce.

Several explanations for this issue have been revealed through the research. Firstly, insufficient budget has negatively influenced proper management of waste in the Lake Toba region. In the case of the local government of Samosir, only 0.14% of the budget goes to the environmental agency and only some of this budget goes to waste management. This limited budget led to the inability to provide sufficient infrastructure for waste management. The low budget is also a result of the low regional incomes and the absence of direct funding from a waste fee for waste management. Moreover, during the Covid-19 pandemic even less budget was available because part of the budget was diverted to other priorities.

Furthermore, some criticism has come forward on the issue of lack of transparency, for example around waste fee management. During this research, data for waste management budgets and the revenue from waste collection fee was often inaccessible. This lack of transparency can create a sense of distrust among those who must pay the collection fees. Moreover, the current concept of waste fees as regional revenue instead of a direct waste management fund limit capacity for a full cost recovery system. Further conflicts of interest seem to arise from cooperation with large aquaculture producers.

Research limitations

There were number of restraining factors that posed as barriers during the project. Some of these restraining factors include having limited time for the project which constrained reaching out for wider data collection such as extending questionnaires to get public views on waste management in the Lake Toba region. There was also problem of finding suitable time for interview given the six hours difference between the Netherlands and Indonesia. It was only possible to find and interview one representative per stakeholder and their individual view may not be a fair representation of the entire group. During the interview, there was difficulty in communication which was as a result of language barrier which required a lot of time and effort to translate. There was lack of available data on waste generation, collection and treatment in the Lake Toba region and the one that was provided both on the literature and during the interview were all based on estimation which may not provide exact or accurate information. This estimate is evident on the varying quantity of waste generated in different district, as obtained from the different consulted literature and interviewed representatives' responses.

Conclusions and Recommendations

Conclusions

Waste that is generated in Lake Toba comprises for a large part of organic waste. However, the quantity of (organic) waste that is generated, collected and treated in the Lake Toba region has not been measured in a detailed manner. The information that is available shows that the main waste generators are households, open or traditional markets, restaurants, hotels and some companies that specialise in aquaculture. In Simalungun, the district in Lake Toba with the highest number of inhabitants, the generated waste is estimated to be 187.506 tonnes per year. Most of the generated waste in this area is not collected, only around 20%. This portrays the situation that the waste management system is in.

The current system is unable to process all the waste that is generated. Moreover, waste separation at source is not a common practice by most actors in the area. The waste management infrastructure falls short as there are too few bins. Bins that separate waste are even more rare. There are not enough trucks to collect the waste, which results in waste being dumped in nature. There are too few waste treatment facilities to bring the collected waste to. In the market, all waste (organic and inorganic waste) is collected in general bins and transported to the landfill by the government. In the landfill, almost all the waste is piled up, buried or even burned in some areas. Only a small part of the organic waste is currently being recycled. It is used on small scale to create compost or other liquid fertilizers, or as feed for BSF larvae.

Multiple inhibiting factors in the implementation of sustainable (organic) waste management systems exist. They can be divided into economic, political and socio-cultural obstacles. Economically, many of the problems can be attributed to a shortage of government budget for waste management, and an absence of contribution of waste fees by the local population. Politically, local regulations often do not exist, and the existing ones are insufficiently enforced. Several socio-cultural factors inhibit more sustainable waste management too. There is a lack of public communication and education on the impact of poor waste management amongst local inhabitants and domestic tourists. As a result, only some follow regulations. Furthermore, the local wisdom that previously guided the Batak towards sustainably managing waste has been forgotten by younger generations.

Recommendations

In the report several obstacles to achieving sustainable waste management in the Lake Toba region were identified. Five recommendations can be made for tackling these obstacles (not necessarily in this order).

First, establish local regulations that enforce waste collection and separation by providing fines or penalties when they are not followed. Even though national regulations exist, this does not seem enough, and local regulations should be made to reinforce them.

Second, encourage citizens' awareness and participation as they are the key player in waste management, especially in collection and separation. Potential exists in highlighting the importance of waste management through Batak local wisdom, and by including waste management in education in schools, and spreading awareness through social media. Every stakeholder included in this project already attributes to this. However, it is important for the government to take a prominent position in this campaign because the locals tend to be more willing to participate if it is done by the government as opposed to unfamiliar private parties.

Third, increase funding. Lake Toba makes use of the private sector to contribute to waste management. Currently, several waste management activities are supported by the CSR program of several companies. Since only a small number of companies operate in Lake Toba, this could be

expanded upon, by collaborating with other companies outside of Lake Toba within the North Sumatera province for example. A proper waste fee needs to be introduced. Instead of only asking for a fee of in certain locations, all the regions together should collect a fee to acquire more budget for waste management. It is then required for all the regions to get benefit from this fee. The amount needed should be calculated based on the needs and the capability of the locals. Furthermore, the system for managing this waste collection fee needs to be managed differently. The money of coming from the fee must be directly used for waste management, instead of being added to the total budget for the government, where it can end up in other projects.

Fourth, provide more infrastructure in the form of separated trash bins and containers near the markets. These places are the areas where most organic waste produced. It is also required to provide more separated bins in both touristic and rural areas. This way, a large amount of waste can be collected and valuable organic waste from households can be transported to the organic waste treatment facilities. To improve waste collection, more trucks that could handle the separated waste for all sub-districts are needed. Especially non-touristic areas are often not included in the collection process. Finally, infrastructure for waste treatment in landfills is necessary. Waste separation at source must be backed up by proper infrastructure in a final landfill. Not only to make the waste more economically and environmentally sustainable, but also to get trust from people on handling their separated waste. Besides improving the infrastructure hardware, it is also required to give a training to the relevant stakeholders, for example on how to handle separated waste.

Fifth, establish (organic) waste management that is economically sustainable and ecologically friendly. Several options for sustainable waste management in the Lake Toba region will be further discussed below.

Options for sustainable waste management in the Lake Toba region

Currently, most of the organic waste that is being used ends up as compost. This compost is used to produce organic fertilizers. The fertilizers are often funneled back into the agricultural undertaking where they come from. This means that it is mostly recycled, but little profit is being made. Apart from composting, the waste treatment that is widely practiced in developed countries but not mentioned in this region is biogas-to-energy, which is an approach that requires high start expenses. An economical alternative of this approach is to recover landfill gas. However, this still requires investment in the construction of methane power generation equipment, and it does not really improve the recovery rate and conversion rate of organic waste.

Breeding BSF larvae is a feasible and affordable waste treatment for the Lake Toba region. Because BSF has a high organic waste consumption rate and can be sold to farmers as organic feed, this method fits the demand for an economically sustainable treatment method that is ecologically responsible as well. Treatment of organic waste using earthworms is also an option with similar benefits, however, since the commissioning companies already have existing experience with BSF, this is the more feasible option. The advantage that the BSF method has over the composting method is the amount of revenue it can bring in, and the advantage of this method over biogas-to-energy is that it requires less budget. What the method requires is a waste management system that can realize waste separation and organic waste recycling.

Possible collaborations

In order to establish sustainable waste management in Lake Toba, it is necessary to collaborate with the local governments. In Simalungun, waste is managed by the sub-districts, thus in order to be involved with waste management collection and separation, collaboration must go through this level of government. In Samosir, the waste management is fully controlled by the district government. It is worth to work with all district level governments to get support. Examples of support they can give are providing laws or regulations to compel people to separate their waste, and getting funds from CSR of companies around the lakes if needed. However, based on the interview with Toba Clean

Movement, when they approached the local government with their ideas, they were met with resistance. In their experience, when the national/ministry level of governments became interested in the project, the local governments were willing to collaborate. Thus, it is necessary to be able to be independent in the first phase of introducing the new waste management systems.

Establishing collaboration with local NGOs and the current existing alternatives for waste management systems owned by the government might prove to be beneficial. A public waste bank in Tiga Ras, Simalungun, is currently working on economic waste management by separating and selling the plastic, but the organic resources are minimally managed. This indicates an opportunity to collaborate. This is also the case in the Samosir district. A lot of organic waste from the local market is not being used by the government for composting, like it is in Simalungun. This means there are ample opportunity here to obtain organic waste. In the Toba district, the Toba Clean Movement has started working on innovative waste management initiatives. Collaborating with them can help to increase the knowledge on the local context of waste management, and will accelerate the process of raising the local population's awareness.

Working together with large organic waste producers like factories is also a valuable option. For example, the waste produced by large palm mills is very fitting for insect-based treatment. However, it is already being used by the companies themselves as compost in their farms. This may make them unwilling to dispose of their organic waste. Another option could be to collaborate with large aquaculture producers in the area, who also produce waste that is protein and fat heavy. There is however no data on actual quantity of organic waste produced by large aquaculture organizations. Further research on the possibility of this unused waste is recommended.

Possible locations

Overall, the Simalungun, Samosir and Toba districts in Lake Toba all produce enough organic waste for organic waste treatment methods to be beneficial. Simalungun is the district with the highest number of inhabitants and thus it also produces the highest quantity of waste. Parapat is a touristic area located in Simalungun, which means that it contains several hotels and restaurants. Due to the high number of tourists, the government is more likely to invest in this area. Simalungun is also home to a multitude of organic waste producers with high fat and protein contents in the palm oil industry. This means there is a lot of waste present that is easier to sort at the source, as is needed for the BSF method. The Simalungun district has experience with the BSF method, though it was not successful. This means that collaborating with Waste4Change and Afvalzorg might be able to turn this pilot project into a successful endeavour. It also means it might save time and energy since the people there already have had training and a better understanding of the process. The downside of the Simalungun district is the fact that some of the organic waste (from palm mills for example) is already used for compost. This might mean that there would be competition for the same resources, especially since the palm mills mentioned in the interview are government-owned.

Aside from Simalungun, the Samosir and Toba districts can also be considered. Samosir is one of the most touristic places of Lake Toba and it is also the one with the highest waste collection rates. Only little has been done with regards to treating organic waste. The downside is that Samosir does not have large organic waste producers like palm mills or a sizeable aquaculture sector on the island, and no waste banks are present either. Everything must be built from the ground up.

The Toba district is the place where the Toba Clean Movement is located. This can be seen as an opportunity to collaborate with an organisation that has already made headway in creating a more sustainable waste management system in the region. The Toba Clean Movement is working on BSF as well. Settling in this area can create friction due to competition, but it seems that collaboration could be beneficial to both parties.

Bibliography

Adams, K. M. (2018). Revisiting "wonderful Indonesia": Tourism, economy, and society. In *Routledge handbook of contemporary Indonesia* (pp. 197-207). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781315628837-16/revisiting-wonderful-indonesia-kathleen-adams

Adhikary S. (2012). Vermicompost, the story of organic gold: A review. Agricultural Sciences, 3, 905-917. https://goo.gl/pZ9fxa

Afvalzorg (2021). https://www.afvalzorg.nl/diensten-stortlocaties/stortgas/stortgasmodellen/

Alongi, D. M., McKinnon, A. D., Brinkman, R., Trott, L. A., & Undu, M. C. (2009). The fate of organic matter derived from small-scale fish cage aquaculture in coastal waters of Sulawesi and Sumatra, Indonesia. Aquaculture, 295(1-2), 60-75. https://www.sciencedirect.com/science/article/pii/S0044848609005675

Amir, M., & Anto, R. P. (2018). A Study Policy Implementation of Waste Management in Konawe District-Indonesia. *Journal of Sustainable Development*, *11*(1), 90. https://doi.org/10.5539/jsd.v11n1p90

Astroulakis, Nikos. (2011). The development ethics approach to international development. International Journal of Development Issues. 10. 214-232. Doi: 10.1108/14468951111165359.

Bahraini, A. (2021). Waste Bank to Support Indonesia Clean-from-Waste 2025. Waste4Change. Accessed on 18 November 2021, from https://waste4change.com/blog/waste-bank-to-support-indonesia-clean-from-waste-2025/#:%7E:text=Waste%20Bank%20is%20a%20concept,waste%20worth%20the%20money%20borrowed

Bahraini, A. (2021, August 11). *FaktualNews.co: "BSF: A Solution to Overcome Organic Waste, A Low-Cost Animal Feed Alternatives."* Waste4Change. https://waste4change.com/blog/waste4change-featured-faktualnews-co-bsf-solution-overcome-organic-waste-low-cost-animal-feed-alternatives/

Bekchanov, M., & Mirzabaev, A. (2018). Circular economy of composting in Sri Lanka: Opportunities and challenges for reducing waste related pollution and improving soil health. *Journal of Cleaner Production, 202*, 1107-1119. https://www.sciencedirect.com/science/article/pii/S0959652618325290

Bhat, S. A., Singh, J., & Vig, A. P. (2018). Earthworms as organic waste managers and biofertilizer producers. Waste and biomass valorization, 9(7), 1073-1086. https://link.springer.com/content/pdf/10.1007/s12649-017-9899-8.pdf

Boeije, H. (2009). *Analysis in qualitative research*. Sage publications.

Brunner, P. H., & Rechberger, H. (2015). Waste to energy–key element for sustainable waste management. *Waste management*, *37*, 3-12. https://doi.org/10.1016/j.wasman.2014.02.003

Budiono, A. (October 2021). "Interview: Ardi Budiono, President Director PT Suri Tani Pemuka". Aquafeed.com, Vol 13 Issue 4. https://issuu.com/aquafeed.com/docs/aquafeed_vol_13_issue_4_october_2021/s/13739915

CCET (2020). The Development of a City- (District) Level Waste Management and Action Plan in the Lake Toba Region. Accessed on 18 November 2021, from

https://www.ccet.jp/projects/development-city-district-level-waste-management-and-action-plan-lake-toba-region

CELTH (2020). Living Lab Sustainable Tourism Destinations Lake Toba. Report Lake Toba on 2 day Workshop in March 10-10,2021.

Danaparamita, A. (30 August 2016). "Why did millions of fish turn up dead in Indonesia's giant Lake Toba?". Mongabays. https://news.mongabay.com/2016/08/why-did-millions-of-fish-turn-up-dead-in-indonesias-giant-lake-toba/De Vaus, D. (2001). *Research design in social research*. Sage.

Dohogne, J.-J. (2014). Horizon 2020: Waste Management Costs & Financing and Options for Cost Recovery. 32

Elwell, F. W. (2013). Sociocultural systems: principles of structure and change. AU Press, Athabasca University. https://books.google.nl/books?hl=en&lr=&id=pQNB7d6RQGcC&oi=fnd&pg=PR1&dq=Sociocultural+systems:+principles+of+structure+and+change&ots=p1EgmeBYn4&sig=1ScNUmlYH7wAaq7qfyy20I10rKE&redir_esc=y#v=onepage&q=Sociocultural%20systems%3A%20principles%20of%20structure%20and%20change&f=false

Fathoni, H. S., Setyowati, A. B., & Prest, J. (2021). Is community renewable energy always just? Examining energy injustices and inequalities in rural Indonesia. Energy Research & Social Science, 71, 101825. https://doi.org/10.1016/j.erss.2020.101825

Gaevoy, V., Meidiana, C., & Gamse, T. (2010). Development of Waste Management Practices in Indonesia. *European Journal of Scientific Research, 40(2),* 199-210. *https://d1wqtxts1xzle7.cloudfront.net/35861642/20130220223550879532_ejsr_40_2_04-with-cover-page-v2.pdf?Expires=1639146742&Signature=Wacjmf6j~VPFBWq3MmKJC0qy-jJHIUGbtEyX3uZLhHiN1xWASEUjz-CeZ1L6i8BDGZy7GLmCqqlOQLUcNTXzczin0kN4zqT1AXCrCQzFMVNaWWphW59hhmlVK5ZOcmvSLXWpauIupYzP16ZpNP4PLZ08BkxnkLiCaRch0wNAGoVlDOX4RJZMTXVBk2HI9o9IwOJCoK6dZo~20Vb4Cmx~Ljprf~BNfM2qoziAiX4vXZrl~mHjvqLtrLf00aWqnVEn0qqR5rplfY6UnC5Ujexpo1CTqy1dlq6h8O978wqSIKT~vuwa87SCSqURRPdWym7Ujv5NJrMOyeTqEfr6f0KQ-q__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA*

Governmental regulation of North Sumatra No 03/2020. Kebijakan dan Strategi daerah Provinsi Sumatera Utara dalam Pengelolaan Sampah Rumah Tangga dan Sampah Sejenis Rumah Tangga.

Gunawan, A. (6 Febraury 2019). "Fish breeding firm under fire for polluting Lake Toba". thejakartapost.com. https://www.thejakartapost.com/news/2019/02/05/fish-breeding-firm-under-fire-for-polluting-lake-toba.html.

Halide, H., Jompa, J., & McKinnon, A. D. (2009). Wild fish associated with tropical sea cage aquaculture in South Sulawesi, Indonesia. Aquaculture, 286(3-4), 233-239. https://www.sciencedirect.com/science/article/pii/S0044848608006935

Harahap, R. H. (2020). Kearifan Tradisional Batak Toba Dalam Memelihara Ekosistem Danau Toba. *Prosiding Seminar Nasional Pendidikan Antropologi (SENASPA)*, *1*, 1–18. http://senaspa.unimed.ac.id

Heywood, A. (2019). *Politics* (5th ed.). Springer.

Husin, S., & Tegnan, H. (2017). Corruption Eradication within the Protection of the Environment in Indonesia. *Asian Journal of Water, Environment and Pollution*, *14*(4), 99–108. https://doi.org/10.3233/AJW-170040

IGES, (2008). Climate Change Policies in the Asia-Pacific. IGES, Japan.

Ikhwan, Z., Harahap, R. H., Andayani, L. S., & Mulya, M. B. (2021). Model of the Importance of Socio-Cultural in Waste Management on Penyengat Island. *Lakhomi Journal Scientific Journal of Culture*, *2*(4), 142-147. https://doi.org/10.33258/lakhomi.v2i4.532

Institute for Global Environmental Strategies (IGES). (2019). Work Plan for Reduction of SLCPs from Municipal Solid Waste Management in Medan City, Indonesia. https://www.iges.or.jp/en/publication_documents/pub/policysubmission/en/6965/CCAC+Work+Plan_2019-2025_EN03_s.pdf

Istrate, I. R., Iribarren, D., Gálvez-Martos, J. L., & Dufour, J. (2020). Review of life-cycle environmental consequences of waste-to-energy solutions on the municipal solid waste management system. Resources, conservation and recycling, 157, 104778. https://doi.org/10.1016/j.resconrec.2020.104778

Khair, H., Rachman, I., & Matsumoto, T. (2019). Analyzing household waste generation and its composition to expand the solid waste bank program in Indonesia: a case study of Medan City. *Journal of Material Cycles and Waste Management, 21(4),* 1027-1037. https://doi.org/10.1007/s10163-019-00840-6

Khair, H., Suryati, I., Siregar, R. L., Sibagariang, H. D., & Utami, R. (2021). Solid waste management in Lake Toba area. *IOP Conference Series: Materials Science and Engineering*, 1041(1), p. 012034. doi: 10.1088/1757-899x/1041/1/012034.

Kornprobst, T., Matheis, T., Schlegel, A., Vitello, F., Fritzsche, J., Fußer, M., Starke, C., Zemeitat, T., & Klüber, D. (2020). *Postcolonialism & Post-Development: Practical Perspectives for Development Cooperation*.

Kumar, S., Singh, S., & Banerjee, S. (2020). Solid waste management in developing countries. *Journal of Critical Reviews*, *7*(10), 1282–1285. https://doi.org/10.31838/jcr.07.10.252

Kurniawan, T. A., Avtar, R., Singh, D., Xue, W., Dzarfan Othman, M. H., Hwang, G. H., Iswanto, I., Albadarin, A. B., & Kern, A. O. (2021). Reforming MSWM in Sukunan (Yogjakarta, Indonesia): A case-study of applying a zero-waste approach based on circular economy paradigm. *Journal of Cleaner Production*, *284*. https://doi.org/10.1016/j.jclepro.2020.124775

Londhe PB, Bhosale SM (2015) Recycling of solid wastes into organic fertilizers using low cost treatment: vermicomposting. International Journal of Innovations In Engineering Research and Technology 2: 1-11. https://goo.gl/0FouGw

Meidiana, C., & Gamse, T. (2010). Development of waste management practices in Indonesia. *European journal of scientific research*, *40*(2), 1992 0.

Miller, D., & Sem mens, K. (2002). Waste management in aquaculture. West Virginia University Extension Service Publication No. AQ02-1. USA, 8. https://freshwater-aquaculture.extension.org/wp-content/uploads/2019/08/WasteManagemetninAquaculture.pdf

Ministerie van Landbouw, Natuur en Voedselkwaliteit. (2019, May 9). *Making money from maggots in Tanzania*. Tanzania | Agroberichten Buitenland. https://www.agroberichtenbuitenland.nl/landeninformatie/tanzania/achtergrond/latest-developments/making-money-from-maggots-in-tanzania

Ministry of Environment (2005). Indonesia Country Fact Sheet. Jakarta, Indonesia. MoE, Jakarta

Ministry of Environment (2008). Indonesian Domestic Solid Waste Statistics Year 2008. MoE, Jakarta

Ministry of Forest and Environment of Indonesia (2020). Fasilitas Pengelolaan Sampah. Accessed on 18 November 2021, from https://sipsn.menlhk.go.id/sipsn/public/home/fasilitas/tpa-tpst

Pathma, J., & Sakthivel, N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. SpringerPlus, 1(1), 1-19. https://springerplus.springeropen.com/articles/10.1186/2193-1801-1-26

Polprasert, C. (2007). Organic waste recycling: technology and management. *IWA publishing.* http://library.oapen.org/handle/20.500.12657/30981

Presidential Regulation of Indonesia No 97/2017. Kebijakan dan Strategi Pengelolaan Sampah Rumah Tangga dan Sampah Sejenis Rumah Tangga.

Rakkini, V. M., Vincent, S., Kumar, A. S., & Baskar, K. (2017). An overview: organic waste management by earthworm. Journal of Civil Engineering and Environmental Sciences, 3(1), 013-017. https://www.peertechzpublications.com/articles/JCEES-3-115.php

Raksasat, R., Lim, J. W., Kiatkittipong, W., Kiatkittipong, K., Ho, Y. C., Lam, M. K., ... & Cheng, C. K. (2020). A review of organic waste enrichment for inducing palatability of black soldier fly larvae: Wastes to valuable resources. *Environmental Pollution*, 115488. https://doi.org/10.1016/j.envpol.2020.115488

Samosir Local Government. (2021). Regional government budget of Samosir: Local Government information system (unpublished).

Saragih, B., & Sunito, S. (2001). Lake Toba: Need for an integrated management system. *Lakes & Reservoirs: Research and Management*, *6*, 247–251. **https://doi.org/10.1046/j.1440-1770.2001.00155.x**

Sekito, T., Prayogo, T., Dote, Y., Yoshitake, T., & Bagus, I. (2013). Influence of a community-based waste management system on people's behavior and waste reduction. Resources, Conservation and Recycling, 72, 84–90. https://doi.org/10.1016/j.resconrec.2013.01.001

Shamini K, Fauziah SH, Emenike CU (2011) Vermicomposing of spent tea: A sustainable approach for solid waste management. Proceeding of the 12th International conference on Environmental Science and Technology, Rhodes, Greece, 8-10 September A-1695-A-1700. https://goo.gl/74glhZ

Sianturi, N. M., Kamarudin, M. K. A., Toriman, M. E., Wahab, N. A., Hakparn, S. chate, Lertbunchardwong, K., Potikengrith, T., Islam, M. S., & Harith, H. (2018). Assessment of environmental management in Lake Toba, Samosir District, North Sumatera Province, Indonesia. *International Journal of Engineering and Technology*, *7*(3.14), 337–343. https://www.researchgate.net/profile/Mohd-Khairul-Amri-Kamarudin/publication/327682154_Assessment_of_environmental_management_in_Lake_Toba_Samosir_Regency_North_Sumatera_Province_Indonesia/links/5bb0306b45851574f7f142f8/Assessment-of-environmental-management-in-Lake-Toba-Samosir-Regency-North-Sumatera-Province-Indonesia.pdf

Sinha, R. K., Herat, S., Agarwal, S., Asadi, R., & Carretero, E. (2002). Vermiculture and waste management: study of action of earthworms Elsinia foetida, Eudrilus euginae and Perionyx excavatus on biodegradation of some community wastes in India and Australia. https://link.springer.com/article/10.1023/A:1016583929723

Sumut Expose, Informasi Wisata Sumatera Utara. (2010). Indonesia Census. Retrieved November 16, 2021, from http://sumut-expose.blogspot.com/

Supena, M. H., Asnawi, A., Sobariah, S., Suratman, S., Wiryati, G., & Subagio, A. (2021). Business analysis of black soldier fly (BSF) as an alternative feed for fish cultivation in Bogor City, West Java. In E3S Web of Conferences (Vol. 322, p. 05007). EDP Sciences. https://doi.org/10.1051/e3sconf/202132205007

Suryati, I., Khair, H., Siregar, R. L., Sibagariang, H., & Utami, R. (2021). Study on solid waste generation in Lake Toba area. *IOP Conference Series: Materials Science and Engineering*, 1041(1), p. 012032. IOP Publishing. https://doi.org/10.1088/1757-899X/1041/1/012032

Syandri, H., Azrita, A., & Mardiah, A. (2020). Water quality status and pollution waste load from floating net cages at Maninjau Lake, West Sumatera Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 430, No. 1, p. 012031). IOP Publishing. https://iopscience.iop.org/article/10.1088/1755-1315/430/1/012031/meta

Tatsuno, M., Dickella Gamaralalage, P. J. and Onogawa, K. (2021) 'Moving from waste to resource management: A case study of Lake Toba, Indonesia', Waste Management and Research, 39(11), pp. 1365–1374. https://doi.org/10.1177/0734242x211050774

Transparency International (n.d.). What is corruption? Accessed on 23 November 2021, from https://www.transparency.org/en/what-is-corruption

Transparency International. (2020). Corruption Perceptions Index 2020 for Indonesia. Accessed 22 November 2021, from https://www.transparency.org/en/cpi/2020/index/idn.

Trimurni, F., & Dayana, M. (2016). Community Participation in Tourism Management in Samosir District, North Sumatera Province. Proceedings of the 1st International Conference on Social and Political Development (ICOSOP 2016). https://doi.org/10.2991/icosop-16.2017.59

Trimurni, F., & Dayana. (2018). The participation of community-based organizations on waste management in the city municipal of Medan. IOP Conference Series: Earth and Environmental Science, 126, 012141. https://doi.org/10.1088/1755-1315/126/1/012141

Waste4Change. About. Accessed on 9 December 2021, from https://waste4change.com/about.

Waste-management. (2017, September 14). Waste Management System Definition. Accessed on 15 November 2021, from https://waste-management.pro/ManagementSystem/waste-management-system-definition

Wibisono, H., Firdausi, F., & Kusuma, M. E. (2020). Municipal solid waste management in small and metropolitan cities in Indonesia: A review of Surabaya and Mojokerto. *IOP Conference Series: Earth and Environmental Science*, *447*(1). https://doi.org/10.1088/1755-1315/447/1/012050

Williams, D. A. (2019). Understanding effects of corruption on law enforcement and environmental crime. Targeting Natural Resource Corruption.

Willmott, L., & Graci, S. (2012). Solid Waste Management in Small Island Destinations: A Case Study of Gili Trawangan, Indonesia. *Solid Waste Management in Small Island Destinations: A Case Study of Gili Trawangan, Indonesia*, *31*, 71–76. https://doi.org/10.7202/1036566ar

World Bank (2016). Lake Toba: Baseline Demand & Supply, Market Demand Forecast and Investment Needs.

World Bank Group (2021). Extending operational support for waste management and delivery to cities in Ethiopia. Accessed on 19 November 2021, from https://www.worldbank.org/en/news/feature/2021/06/08/extending-operational-support-for-waste-management-and-delivery-to-cities-in-ethiopia-tdlc

Wulandari, D., Utomo, S. H., & Narmaditya, B. S. (2017). Waste Bank: Waste Management Model in Improving Local Economy. International Journal of Energy Economics and Policy, 7(3), 36–41.

Zurbrügg, C., Dortmans, B., Fadhila, A., Verstappen, B., & Diener, S. (2018). From pilot to full scale operation of a waste-to-protein treatment facility. Detritus, 1(1), 18. https://www.dora.lib4ri.ch/eawag/islandora/object/eawag:21131/datastream/PDF/Zurbr%C3%BCgg-2018-From_pilot_to_full_scale-(published_version).pdf

Appendix 1A

Interview Blueprint YPDT

RQ: What are the sociocultural factors that inhibit sustainable organic waste management in the Lake Toba region?

Explain definition:

- Waste management

Objectives:

- To identify the beliefs/values locals (natives and non-natives) and tourists (domestic and international(less)) have on waste collection and separation in the Lake Toba area.
- To identify current behaviour of locals (natives and non-natives) and tourists (domestic and international(less)) in the Lake Toba area towards waste collection and separation.
- To identify what would need to change for the behaviour of locals (natives and non-natives) and tourists (domestic and international(less)) towards waste collection and separation to change.

Topic 1: Current behavior of locals and tourists towards waste collection and separation

Aspects:

- Disposal (littering, separating, throwing to 1 bin)
- Treatment (technique: burying, burning, composting; collective or individual)

Questions:

Main Question: What is the current observable behaviour of locals and tourists towards waste collection and separation?

- How clear are the regulations on waste management?
- What are people's views towards littering?
    - Mainly the native locals or non-native locals?
    - What about the tourists?
- What is the current status of waste separation?
    - Are there opportunities for waste separation provided in the form of different bins?
    - Do tourists separate?
    - Do locals separate on household level? Difference between native and non-native?
    - Do shops, restaurants and hotels separate their waste?
- What do people do to get rid of their waste?
    - Burying, burning, composting
    - Do they do this collectively or individually?
    - Let it be collected
    - What about places like restaurants and shops?
    - Sell separated waste?
- What times of the year do you see most littering/ waste generation?
    - Events? Tourist peak times?

Topic 2: Beliefs/values of locals and tourists towards waste collection and separation

Aspects:

- Socio-economic status (no resources, time)
- Broader social attitudes/values
- Education
- Local/ traditional wisdom

Questions:

Main question: What are the beliefs and values of locals and tourists towards waste collection and separation?

- What is the influence of socio-economic status on waste management?
  - How do you see the difference between how people with high incomes or low incomes manage waste?
- What is education on waste management like?
  - Is it discussed in school?
  - Through campaigns? Who leads those?
  - How do parent talk to their kids about waste?
- What is the general societal attitude towards waste management?
  - Do people find it important to not litter and separate waste?
  - How do people talk to each other about handling waste?
  - How do people react to someone that throws waste on the street?
- What are the local wisdoms that influence waste collection and separation?
  - Any traditional local beliefs?
  - How have these changed over the years?
- What are the differences between different cultures in the different regencies around Lake Toba that influence how people treat waste?
  - Do you see large differences in waste management between different regions?
  - How does the philosophy in Simalungun (habonaran do bona /the truth is the basic philosophy, Sapangambei Manoktok Hitei/ togetherness in Simalungun) influence how people handle waste?

Topic 3: Changes needed for different futures

Aspects:

- Waste infrastructure
  - Disposal (more and better bins, bins for separation)
  - Collection (more trucks)
- Education
  - Awareness campaigns (religious institutions)
  - Reintroducing local wisdom
- Leadership
  - Government or private (trust, likelihood to obey)
- Incentives
  - Enforcement (fines, waste fees)
  - Rewards (selling)

Questions:

Main question: What needs to change for locals and tourists to change their behaviour towards waste collection and separation?

- What do you think needs to change about the waste infrastructure provided?
  - Trash bins?
    - More and closer to people?

        - Better quality
        - Different bins for different sorts of waste
    - Collection trucks
        - More trucks?
        - More landfills that are closer to the area
- How do you see that education can influence how people manage their waste?
    - Education programs in schools
    - Awareness campaigns by trusted institutions
        - What institutions?
    - Do you see more possibility for introducing new, maybe western values, or reintroducing traditional values?
- Who do you think would be the best organization to lead the change?
    - If no answer, prompt: What do you think about: Local government? Religious institutions? International organizations? Local organizations? Private companies?
- What incentives do you think can change their behaviour towards waste management?
- -How do you think fines will influence people's participation? Would fine on improper waste management influence people's attitude towards sustainable waste management
- +How do you think possibilities for people to sell their waste would influence informal waste separation?
- How would a deposit system on products affect the informal waste separation? (Deposit meaning that you pay 25 cents extra which you can redeem later)

Appendix 1B

Interview Blueprint Toba Clean Movement

Theme: Waste management

● **RQ 1:** *What are the existing systems on separation, collection and treatment of (organic) waste in the Lake Toba region?*

○ **Objective 1.1: to know if the BPODT work with local initiatives in the separation, collection, and treatment of (organic) waste in the Lake Toba region? If yes, how?**

■ **Topic 1.1**: Interviewee's explanation on how the BPODT cooperate with local initiatives in managing waste

-> main question: how does the BPODT cooperate with local initiatives with respect to waste management?

- Collaboration with communities
- Collaboration with local waste private business
- Collaboration with market leaders
- Interest in waste management companies like Waste4change
- Interest in waste management companies like Afvalzorg

○ **Objective 1.2: to know if there is collaboration and coordination between the BPODT and the local, regional, and national government institutions**

■ **Topic 1.2**: interviewees' explanation on the collaboration and coordination between BPODT and the different levels of government in the Lake Toba area.

-> main question: how does the BPODT cooperate with the different levels of government to manage waste in the Lake Toba region?

- Collaboration with national government
- Collaboration with regional government (Lake Toba region)
- Collaboration with local government (within the Lake Toba region)

○ **Objective 1.3: to identify if they have current projects on waste management in the Lake Toba region**

■ **Topic 1.3**: interviewees' explanation on current projects on waste management in the Lake Toba region.

-> main question: Are there current or existing government projects on waste management in

any of these region? if yes,

- The current projects
- Financing of the project
- Management of the project
- Local collaboration and participation (inclusion)

- Waste Banks

○ **Objective 1.4: to identify existing government strategies in improving waste management in the Lake Toba region**

■ **Topic 1.4**: interviewees' explanation on current strategies by which the government aim to improve waste management in the Lake Toba region.

-> main question: what are the current strategies use by government in improving waste management in the Lake Toba region

- Current rules and regulation or policy
- Approach to implementation of rules (top down or bottom up, and why?)
- Workable policies (are these policies working)
- Available Landfills and capacity
- Treatment of landfills
- Interest in providing more landfills
- Sensitization of locals on waste management (projects)

● **RQ 2:** *What are the economic factors inhibiting sustainable waste management in the Lake Toba Region?*

○ **Objective 2.1: to identify the financial economic factors inhibiting sustainable waste management in the Lake Toba region.**

■ **Topic 2.1**: interviewees' explanation on the financial inhibiting economic factors on sustainable waste management in the Lake Toba region?

-> main question: what do you think are the financial economic factors that limit your capability to improve sustainable waste management in the Lake Toba region

- Own capability
- Government budget (% of government budget that goes into waste management, actual size)
- Source funding/collection fees
- High costs

Objective 2.2: to identify the capital/technical economic factors inhibiting sustainable waste management in the Lake Toba region.

■ **Topic 2.2**: interviewees' explanation on the capital/technical inhibiting economic factors on sustainable waste management in the Lake Toba region?

-> main question: What capital/technical economic factors that limit your capability to improve sustainable waste management in the Lake Toba region?

- Waste management facilities
- Containers (and are they separated?)
- Landfills
- Recycling facilities
- Resources for waste treatment

Objective 2.3: to identify the economic factors inhibiting the operational aspect of sustainable waste management in the Lake Toba region.

■ **Topic 2.3**: interviewees' explanation on the capital/technical inhibiting economic factors on sustainable waste management in the Lake Toba region?

-> main question: What economic factors limit your capability to improve the operation of sustainable waste management in the Lake Toba region?

- Collection services
- Service coverage (both rural and urban areas or inadequate)
- Maintenance of containers, vehicles, facilities
- Accessible roads to waste facilities and landfills
-

● **RQ 3:** *What are the political factors inhibiting sustainable waste management in the Lake Toba Region?*

○ **Objective 3.1: to identify the political factors inhibiting sustainable waste management in the Lake Toba region.**

■ **Topic 3.1**: interviewees' explanation on the structural inhibiting political factors on sustainable waste management in the Lake Toba region?

- Local, regional, national
- Power to do things
- Bureaucracy
- Transparency (subtly) how do you communicate actions with stakeholders? (Published monthly reports/budgets etc.)
- Enforcement (monitoring and regulating SWM rules)

Appendix 1C

Interview Blueprint Local Government

Blueprint

Theme: Waste management

● **RQ 1:** What are the existing systems and value chains on (organic) waste separation, collection and treatment in Simalungun regency?

○ **Objective 1.1:** To know what waste management systems are currently used and how they work

■ **Topic 1.1**: Interviewee's explanation of the waste management system

-> main question: what the current waste management system is implemented by government

- distribution and quantity of waste containers
- Frequency of transporting waste
- Transporting trucks (cost, who covers)
- Practice of waste sorting and recycling
- Use of landfill (owner, distance, capacity, treatment)
- Informal waste collection activities or initiatives

○ **Objective 1.2:** To know what waste producers are in the area

■ **Topic 1.2:** Interviewee's knowledge of large non-household organic waste producers

-> main question: Are there any large organic waste producers in the area

- Quantity of Palm mills
- Size of the palm mills
- Location of those palm mills (are they close to Parapat)
- Other main large organic waste producers (hotel, store, marketplace etc.)

● **RQ 2:** What are the economic obstacles to alternatives of waste management system?

○ **Objective 2.1:** to know the economic limitations for the implementation of waste management systems.

■ **Topic 2.1**: interviewees' explanation on how waste management is financed

-> main question: how does the Simalungun government allocate the money?

- Current waste management budget
- Possibility of improving budget in the future for waste management
- Willingness of undertaking start-up costs of waste management alternatives (addition of waste containers and trucks, acquisition and expansion of landfills, hiring and training employees).
- Willingness of undertaking operating cost of waste management alternatives (collecting, transporting, maintenance and repair facilities, etc.)

○ **Objective 2.2:** To pinpoint economic opportunities for organic waste collection

■ **Topic 2.2**: interviewees' explanations of attitude of other parties in the value chains

-> main question: whether other parties are willing to cooperate with the government's fiscal expenditure?

- Additional costs that need to be borne for local people in waste management
- Whether local people cover all waste management costs
- Whether government could provide subsidies for household and main organic waste producers to separate the waste.

● **RQ 3:** what are the political obstacles to alternatives of waste management system?

○ **Objective 3.1:** To know the political limitations for the implementation of waste management systems.

■ **Topic 3.1:** Interviewee's explanation of the policy and law and their implementation

-> main question: What are the political factors that affect the choice and strategy of the current waste management systems

- law and policy about waste management
- Enforcement of law and policy (how well do people listen)
- Development of a stricter policy of waste management (fine for improper behavior on waste management of local people)

● **RQ 4:** What are the sociocultural factors that inhibit sustainable waste management in the Lake Toba region?

○ **Objective 4.1:** To know the sociocultural limitations for the implementation of waste management systems

■ **Topic 4.1:** Interviewee's explanation on the effect of the behavior of the locals on the waste management systems

-> main question: How does the local culture and behavior affect the waste management systems in the Simalungun regency?

- Locals' view on waste management
- Number of bottom-up projects
- Willingness of locals to contribute to waste management
- Tourist behavior towards waste management

● **RQ 5:** what are local government' s attitude to cooperate with waste management companies like Afvalzorg (NL) and Waste4Change (ID) to try alternatives of waste management system

○ **Objective 5.1:** to know whether local government are willing to cooperate with commissioners and urge other parties to promote this partnership

■ **Topic 5.1:** Interviewee's explanation on their willingness to promote a cooperative relationship with Afvalzorg (NL) and Waste4Change (ID)

-> main question:

- Existing or tried waste management projects
- Future prospects or plans to improve waste management
- Interest in BSF alternatives of waste management system that has been already practiced successfully in Java
- Willingness to provide two waste management companies with local business opportunities