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Case Study

Analysis of Environmental Impact and Municipal Waste Management Strategy: A Case of the Piyungan Landfill, Yogyakarta, Indonesia

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A B S T R A C T

The ever-increasing volume of municipal waste in Yogyakarta brings overload capacity problems to the Piyungan Landfill. This circumstance results in environmental pollution which harms the local residents. Therefore, this study was conducted to determine the impact of pollution in the Piyungan Landfill from an economic, environmental, and social perspective. Furthermore, this study aims to formulate a waste management strategy in the landfill using the fishbone analysis to find out the root causes of existing problems, the stakeholder analysis method to determine the role of each stakeholder involved, and the SWOT analysis method to determine potential strategies for waste management. From those analysis methods, it is concluded that there are six root causes in the landfill, namely the waste management process, the amount of waste, landfill facilities, the technology used, the implementation process, and government policies. This study recommends several waste management improvements from the combination of strengths and opportunities factors (SO Strategy). The combination of these strategies includes: (1) establishing cooperation policies with foreign parties. (S1, O1); (2) optimizing budget and waste management technology. (S2, O2); (3) providing transportation facilities and technology to optimize the recycled waste business. (S3, O2, O3); and (4) maximizing resources to optimize the recycled waste business. (S4, O3). These strategies are expected to be able to increase the capacity and capability of the Piyungan Landfill in managing waste and overcoming environmental pollution.

INTRODUCTION

The increasing population growth will be directly proportional to the waste produced. The increase in the volume of waste must be balanced with the provision of waste management facilities that can process waste optimally. The Piyungan Integrated Waste Management Site (Tempat Pembuangan Sampah Terpadu Piyungan) located in Bantul Regency, Yogyakarta, is the largest landfill in the Special Region of Yogyakarta. As shown in Figure 1, Piyungan Landfill is used as a place to collect and manage the household and industrial waste from three locations, namely Yogyakarta City, Sleman Regency, and Bantul Regency. This landfill was established in 1995 and started operating in 1996. The areas were 12.5 hectares with ten hectares as a place to collect waste, and the rest of the land is designated as a facility to support activities at the landfill.

There are some facilities such as the secretariat office, organic waste management site, leachate pond, and a place for weighing the volume of incoming waste. Based on the statement of the environmental agency or Balai Lingkungan Hidup (BLH) officer during the interview, the operational period of the Piyungan landfill is only until 2012. Because the provincial government has not found other land to accommodate waste, the working period of the Piyungan Landfill has been extended to 2021. After that, Piyungan Landfill does not accompany an additional active period. The current condition of waste management facilities has certainly caused various problems, one of which is the inability of the Piyungan Landfill to accommodate the waste that keeps coming. Since the capacity is overload, other issues begin to emerge, such as river pollution, the residents' rice fields pollution, and the smell of methane gas from the waste decomposition process. All those inconvenient situations disturb the residents.

Figure 1. Piyungan Landfill [Source: maps.google.com]

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In-Law number 18 of 2008 concerning Waste Management, waste is defined as the remains of daily human activities as well as from natural processes in the form of solids. Therefore, waste is something that must be managed so that the waste has added value, can be used or reused, and does not cause environmental pollution [1]. Waste is something that has been taken advantage of so that there is little or no benefit. The presence of waste is considered not essential and must be immediately removed because it has the potential to disrupt activities. Waste can still be given added value by going through several processing processes. Unmanaged waste can cause various other problems such as aspects of the environment, health, society, and others.

Furthermore, municipal waste management is a systematic, comprehensive, and sustainable activity that includes control, generation, storage, collection, transfer and transportation, processing and disposal of solid waste with the best practices of public health, economics and finance, engineering, administration, legal and environmental considerations [2]. The authorities to fund waste management are the government and related local governments, as stipulated in the same Law Solid-waste management includes the collecting, treating, and disposing of solid material. Improper disposal of municipal solid waste can inflict unsanitary conditions which lead to pollution of the environment and outbreaks of vector-borne diseases, such as diseases spread by rodents and insects. On other hand, the solid waste management process presents complex technical challenges. They also pose a wide variety of administrative, economic, and social problems that must be managed and solved. Nonetheless, waste management is essential to reduce the amount of accumulated waste and is count as an effort to increase more value to the waste. Generally, waste management can be implemented in well-known actions, namely reducing, reusing, and recycling (3R) [3].

Waste minimization is the key success factor to achieve environmental sustainability [4]. Therefore, the concept of 'reduce' should become a behavior that seeks to minimize the use of disposable items so that it can directly decrease the amount of waste generated from daily activities. Reduce does not require any waste treatment, but is a change in behavior and mindset towards the use of items that have the potential to produce waste. Meanwhile, reuse is an effort to reuse items that have been used following the original function of the goods or used for different purposes without going through a process so that they do not become waste [5]. Reuse is one method to reduce the amount of waste that is easy and cheap. Reuse can reduce the amount of landfill because waste that should be thrown away is reused as goods to support daily activities. Moreover, recycling can also be used as an option for waste management methods. Recycling is a sequential process that involves separating waste materials from waste stream or end-of-life (EOL) products, then processing them as raw materials for recycled products or components [6]. The recycling process can be defined as reprocessing waste or used objects that are no longer used in new items or products that can be reused. Utilizing waste into goods that have value will reduce the environmental burden on used waste, as well as create jobs, which is in line with the triple bottom line principle in the effort to develop sustainable manufacturing [7].

Designing waste management strategies can be conducted using the Strengths, Weaknesses, Opportunities, and Threats analysis (SWOT analysis). Ernawati et al. [8] analyzed the composition, quantity, and development of a waste management strategy using the SWOT analysis method coupled with a stakeholder analysis. The results of this study indicate that internal factors such as weak law enforcement, inadequate facilities and infrastructure, and management that are still based on landfill control have caused the waste management process in the Semarang city government not to run optimally. Mor et al. [9] studied waste management practices of municipal solid waste in Chandigarh, India, using a SWOT analysis. In that analysis, they stated that stakeholder analysis could be used to obtain a more varied alternative waste management. Zahorska et al. [10] conducted a study on the evaluation of metal waste management using the SWOT analysis method at an engineering company in the Slovak Republic. This research combines the SWOT analysis method with a hypothesis test to obtain the evaluation results of metal waste management. Eheliyagoda et al. [11] conducted a study on the analysis of urban waste management using the SWOT analysis in Balangoda, Sri Lanka. The results show that it has more strength aspects compared to other aspects so that it can support the waste management process. Shahba et al. [12] conducted a study on mining waste management using a multi-attribute decision-making method in a SWOT analysis. This method is combined with Analytical Hierarchy Process.

From the problem explained above, this research was conducted to determine the impact of pollution caused by waste in the Piyungan Landfill from an economic, environmental, and social perspective. Besides, this study aims to formulate a waste management strategy in the landfill using a fishbone analysis to find out the root causes of existing problems. The stakeholder analysis method was also used to determine the role of each stakeholder involved in designing the waste management strategy. Also, the SWOT analysis method is used to determine potential strategies for waste management. This research is expected can contribute to the knowledge in the field of municipal waste management strategy. Furthermore, the proposed recommendations can be useful suggestions to the local government and society.

METHOD

The research methodology consists of three main stages. Figure 2 shows the flow of the research method. The first stage in this research is to conduct field studies and literature studies. The field study was carried out by conducting a preliminary survey directly at the Piyungan Landfill. Meanwhile, literature studies are carried out by collecting reliable sources of information from journals, the web, and other literature. From these steps, the research problem and objectives can be formulated.

The second stage is the data collection and processing. To get primary data, direct interviews were conducted to gain some knowledge of the current condition. Some of the parties selected as resource persons were BLH officers, scavengers, and residents around the landfill. Table 1 presents the interviewees and the correlation between the questions and the desired information. The next step of this stage is to analyze the data using the fishbone diagram analysis, stakeholder analysis, and SWOT analysis. These three analysis methods have different ways and purposes.

Fishbone diagrams often referred to as cause and effect diagrams are a method used to analyze the causes of a problem in detail

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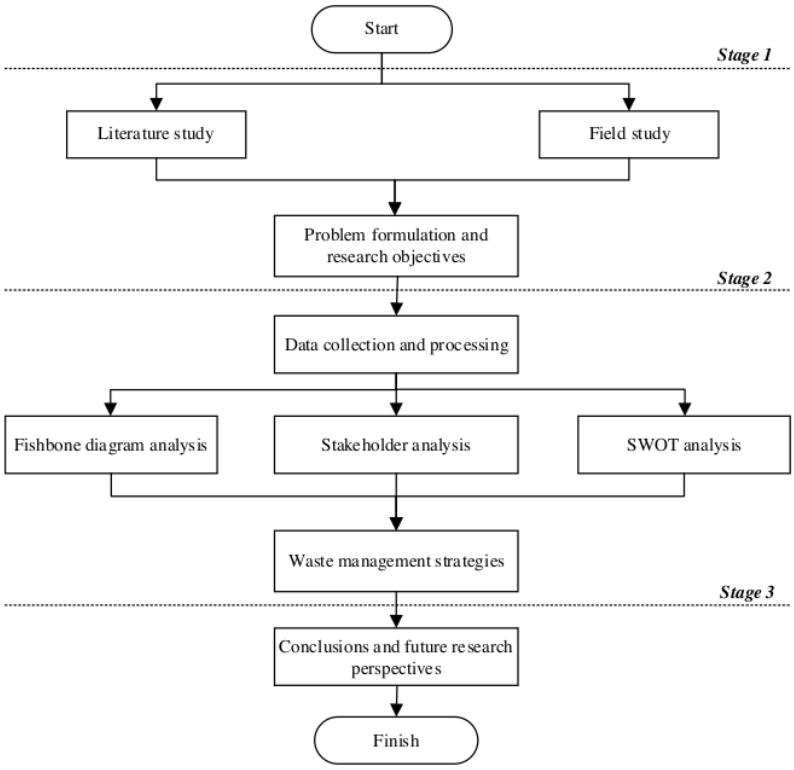

Figure 2. The Flow of Research Methodology

[13]. Fishbone diagrams are used to identify the root cause of the problem, to get ideas and solutions for problems, and to make it easier to find and investigating further facts. By knowing the root of the problem, the problem-solving strategies are easier to formulate because of sufficient references. A fishbone diagram is created by identifying the root problems, then the branch problems are more detailed to gain a deeper analysis of the problem root.

Several parties were involved to collect data and information about the Piyungan Landfill, i.e. two BLH officers, the head of the scavenger community, and two local communities. Since BLH officers are the direct executors and managers, they provided data and information regarding the procedures and management of Piyungan Landfill. The scavenger community leader is involved in finding out information about the waste separation procedure at the Piyungan Landfill because they carry out the waste separation process. Meanwhile, the community plays an important role as the stakeholder who feels the environmental impacts from landfill's daily activities.

Furthermore, stakeholders are individuals or groups who have a role and influence in the process of achieving goals in an institution or organization [14]. Therefore, a stakeholder analysis was carried out to identify and map the roles of the parties related to the Piyungan landfill. In this case, stakeholders are divided into two types, namely primary stakeholders and secondary stakeholders. Primary stakeholders are those who directly play a role and influence in policymaking in an institution or organization, while secondary stakeholders are those who do not directly play a role and influence in policymaking. Stakeholder

Table 1. Relationship Between the Question and the Required Information

Interviewees	Question	Desired Information
BLH officers	Does the Piyungan landfill already have a waste management procedure?	Knowing the procedures for managing organic and inorganic waste at Piyungan landfill
	How about the procedure of organic waste management?	
	How about the procedure of inorganic waste management?	
Scavenger	Has the waste been sorted according to the type?	Knowing the waste sorting procedure at Piyungan landfill
	How is the waste sorting process?	
	What is the follow up after the waste has been sorted?	
Citizen	Does waste pollute the environment?	Knowing the impact of the current pollution
	What are the impacts of pollution?	

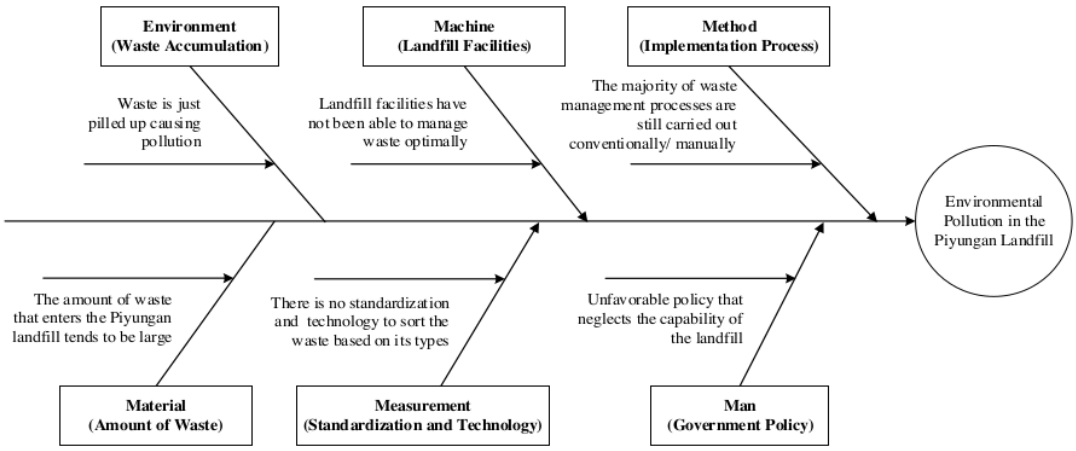

Figure 3. Fishbone Diagram of Environmental Pollution at the Piyungan

analysis is carried out to obtain more objective consideration to formulate solutions involving several related parties.

The last analysis method is the Strengths, Weaknesses, Opportunities, and Threats analysis (SWOT analysis). This is an analysis method which used to maximize strengths and opportunities, but at the same time, minimize weaknesses and threats [15], [16]. This method looks at the overall internal and external aspects that influence the strategic decisions. Strengths are advantages areas to the organization; weaknesses are internal areas to be improved; opportunities are external factors that may contribute to the organization or can build up strengths, and threats are the potential problems or risks caused by external factors. The SWOT matrix can produce four sets of strategic options, namely: (1) SO strategy is a strategy formulated by maximizing strengths to get all opportunities; (2) ST strategy is a strategy formulated by maximizing strengths to overcome threats; (3) WO strategy is a strategy formulated by minimizing weaknesses and maximizing existing opportunities; and (4) OT strategy is a strategy formulated by maximizing current opportunities to overcome threats [15].

The SWOT analysis provides the results of integrated strategy analysis. The results of strategic decisions are sought through the process of integrating the four aspects to provide some optimal alternative strategies in the management of the Piyungan Landfill. SWOT analysis also calculates the weight and total score. Weight is a value that shows how much influence between one situation and another in influencing each SWOT factors. Meanwhile, the score is the value of the current condition of the landfill [17]. The comparison of the calculation results between internal factors and external factors is used to determine the Internal-External Quadrant (IE Quadrant). The Internal-External Quadrant is the quadrant used as a reference for determining the most optimal combination of strategic decisions that will be implemented in the Piyungan landfill as a waste management solution.

Lastly, the final stage of this research is to conclude the overall analysis results to get a comprehensive view of the waste management strategy in the Piyungan Landfill. Moreover, this stage proposes several strategies to improve landfill management and to reduce potential environmental impacts.

RESULT AND DISCUSSION

This section discusses the results of fishbone diagram analysis, stakeholder analysis, and SWOT analysis. From all analyses, it can be concluded the problem root of waste management and the environmental pollution in the Piyungan Landfill, the stakeholder's role, and the proposed strategies to overcome the current problems.

Fishbone Diagram Analysis

From the results of interviews and FGDs with BLH officers, six main factors were compiled into a fishbone diagram, which were the root causes of the problems at Piyungan Landfill. The six factors are the waste accumulation, the amount of waste, landfill facilities, the standardization and technology, the implementation process, and the government policies. Figure 3 shows the results of the formulation of fish bones diagram.

Environment (Waste Accumulation)

There is no specific treatment for organic waste in this landfill. The waste management facility was unusable after a work accident that damaged the compost building and equipment. Until now, the damaged facilities have not been repaired either by the Piyungan Landfill or the local government. Organic waste is allowed to decompose naturally without any management process. On the other hand, the inorganic waste sorting process carried out at the Piyungan Landfill still uses conventional methods by relying on the scavenger community in the surrounding area. Organic and inorganic waste is sorted manually by scavengers. Organic waste will be abandoned, while inorganic waste from household use and industrial activities such as glass, iron, and other inorganic waste will be sorted, which will then be sent to landfills in other cities for processing. However, inorganic waste processes such as plastics are still allowed to pile up at the Piyungan Landfill. BLH officers said that landfill did not yet

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Table 2. Total landfill waste in January-April 2020 [19]

Period	Total Waste
January 2020	1.884,265 ton
February 2020	1.861,203 ton
March 2020	2.088,909 ton
April 2020	1.515,218 ton

have adequate facilities to carry out an automatic waste sorting process. The absence of automatic waste management facilities is one of the reasons why most of the organic and inorganic waste is allowed to accumulate in a mixed state. The inability of Piyungan Landfill to manage waste has resulted in a buildup of waste. Unmanaged waste can cause severe pollution such as unpleasant odor, sources of various disease, and other pollution.

Material (Amount of Waste)

The amount of waste that enters every day at Piyungan Landfill tends to be large. The total waste in this landfill can be seen in Table 2. This can cause the landfill to be no longer able to accommodate the waste, resulting in overload. The average volume of waste that enters the Piyungan landfill per day can reach 600 tons/day [18]. According to BLH officers, the composition of waste that enters the Piyungan landfill is dominated by organic waste by 50-60%, plastic waste by 15%, while the rest are other types of waste. A frequent amount of daily waste causes overcapacity because there is no additional land for waste dumps.

Machine (Landfill Facilities)

Inadequate facilities in terms of waste management buildings and the necessary equipment cause the waste management process to be not optimal. The Piyungan Landfill does not yet have a proper waste management mechanism, so the waste is only allowed to pile up. Generally, waste piles are only covered with soil so that the top that is covered can be used as a new pile of waste. The landfill also serves as a road for waste transport vehicles to the landfill. This hoarding process also cannot be used as a long-term solution due to the limited space and the increasing volume of incoming waste.

Measurement (Standardization and Technology)

There is no detailed standardization to sort the waste based on its types. The makeshift technology at the Piyungan Landfill causes the waste management process to be less effective and efficient, so that much of the waste is not managed.

Method (Implementation Proces)

The sorting process of waste that is still manual, unmanaged waste, accumulated waste without being adjusted to the type of waste are some examples of waste management processes that need to be improved and improved. Improvements and improvements in these aspects can increase the effectiveness and efficiency of the waste management process.

Man (Government Policy)

The government policy that does not pay attention to Piyungan Landfill's capacity is also one of the causes of environmental pollution around the Piyungan Landfill. An example of an unfavorable policy is to extend the contract period for Piyungan Landfill to still accommodate the waste, even after the capacity is overloaded.

Environmental Pollution in the Piyungan Landfill

All mentioned problems above have resulted in several environmental pollution around the Piyungan Lanfill, such as methane gas, leachate water, and plastic waste. From the decomposition process, organic waste produces methane gas (CH4), which causes a strong odor. Methane gas (CH4) can be produced from several processes, including the decomposition of organic waste, the process of decomposing animal and human waste. Carbon dioxide (CO2), hydrogen dioxide (H2O), and methane gas are included in greenhouse gases, which have a function to absorb and transmit solar heat. These three gases also function to reflect long-wave radiation so that the earth gets twice as heated [20].

If methane gas is not appropriately managed, it has the potential to cause environmental pollution. Residents feel very disturbed by the smell of methane gas that arises from the decomposition of organic waste. According to the information given by the head of the scavenger community, the smell of methane gas will get stronger when the rainy season arrives and can be smelled from a radius of five kilometers from the Piyungan Landfill. Methane gas is a flammable gas. A high concentration of methane gas in a wild place has the potential to cause an explosion. The oxygen level in the surrounding environment will also decrease, along with the increasing levels of methane gas. Low oxygen levels cause respiratory problems in the surrounding community [21].

The uncontrolled increase in the amount of methane gas can cause other problems. Methane gas can rise into the atmosphere and destroy the earth's ozone layer, even though ozone is essential for the survival of life on earth. Methane gas can perforate the ozone layer. If the ozone layer is perforated, the radiation from the sun's heat will be directly received by humans. Direct radiation can cause skin disorders in skin cancer.

Apart from methane gas, the decomposition of organic waste also has leachate water when the rainy season. Leachate is a liquid formed from a pile of waste that is washed off by water from outside the waste. Leachate is considered a pollutant that can harm the environment [22]. The water flows to the leachate pond at the bottom of the landfill. However, leachate is still booming in the area around the landfill when the rainfall is hefty. The ratio of leachate ponds that is not proportional to the area of the landfill results in leachate water being unable to be accommodated optimally.

Leachate discharged directly into the river can cause silting of the river. Solid substances that are still dissolved in the leachate will settle to the bottom of the river so that the riverbed surface will rise. This process can also kill plants and river biota that live at the bottom of the river. Also, the turbidity of leachate can block sunlight from entering the river. If the sunlight cannot enter the river, the photosynthesis process carried out by river plants does not run optimal, which results in a decrease in oxygen levels in river water. The decrease in oxygen levels disrupts the sustainability of the ecosystem in the river. Bursting leachate can pollute the surrounding environment because of the toxic substances in the leachate. Toxic substances contained in

leachate include heavy metals, cadmium, chromium, and other hazardous substances [23]. These substances can cause degenerative diseases when they enter the human body.

Moreover, leachate around the Piyungan Landfill can contaminate the springs near home residents. Contaminated spring water by leachate can cause mild to severe illness because leachate contains bacteria. One of the bacteria contained in leachate is the Escherichia coli bacteria. Escherichia coli bacteria contained in leachate are very high. The entry of Escherichia coli bacteria into a person's body can cause several conditions such as stomach cramps, bloody diarrhea, loss of appetite, dehydration. It can even lead to more severe conditions if treatment is not taken immediately [24].

Furthermore, the accumulation of plastic waste which is left unattended without any management process causes the plastic waste to enter and pollute the natural river flow around the Piyungan landfill. The river flow is disrupted due to piles of plastic waste. If the plastic pile continues to increase, the river can overflow the area around the river, which can lead to floods. Moreover, plastic waste can also harm the ecosystem in the river. Fish and other aquatic animals can be contaminated by the content of polychlorinated biphenyls (PCBs), which will not disappear and remain in fish or other aquatic animals. PCBs are toxic substances that can cause degenerative diseases such as heart disease, cancer, diabetes, and other diseases when they enter a person's body [25]. Plastic waste not only pollutes the river environment, but also can enters and pollutes the resident's rice fields. Contamination of rice fields with plastic waste can cause crop failure and has a direct impact on the economic situation of the residents, most of whom are scavengers and farmers. Besides that, crop failure also has an impact on the loss of rice field maintenance costs that have been incurred by residents during the planting period. Even though the residents are successful at harvesting, the toxic compounds contained in plastic waste will contaminate the plants in the rice fields. Plants in rice fields can absorb bisphenol A (BPA). When these plants are consumed, the BPA compounds will move into the human body and can lead to degenerative diseases [26].

Stakeholder Analysis

The primary stakeholders at Piyungan Landfill consist of the environmental services or Dinas Lingkungan Hidup (DLH) and BLH officers, while secondary stakeholders consist of local residents and industries. Table 3 shows the results of the identification of primary stakeholders, while Table 4 shows the results of the identification of secondary stakeholder analysis.

Table 3. Primary Stakeholders Analysis

Stakeholders and basic characteristics	Interests and how affected by problems	Capacity and motivation to bring change	Possible actions to reach the interests of stakeholders
Environmental services: Policymakers, access to local government	➢ Determining a good landfill policy ➢ Receiving a warning from the local government ➢ Accepting communities' complaints	➢ Very interested in determining policies and controlling landfill management ➢ Having high motivation to improve landfill management	➢ Designing landfill management procedures ➢ Providing support facilities ➢ Establishing good cooperation with external parties to manage the landfill
BLH Officers: Landfill manager, landfill procedure executor, landfill supervisor	➢ Carrying out the landfill management procedure ➢ Accepting a warning from DLH ➢ Directly communicating with residents	➢ As a direct executor of landfill management procedures ➢ Changes depending on procedures devised by DLH	➢ Carrying out landfill management according to the procedure ➢ Cooperating with local communities to maximize landfill management

Table 4. Secondary Stakeholders Analysis

Stakeholders and basic characteristics	Interests and how affected by problems	Capacity and motivation to bring change	Possible actions to reach the interests of stakeholders
Local residents: Majority work as farmers and scavengers at the landfill, sorting waste at the landfill	➢ Depending on landfill as a source of family finances ➢ Poor condition of neighborhood and family health	➢ Have access to convey aspirations to the landfill manager and local government. ➢ High motivation of scavenger community in changing situation	➢ Conveying aspirations to the landfill manager and local government ➢ Helping the implementation of waste management procedures ➢ Increasing awareness of the importance of a clean-living environment among societies
Industries: Industrial operations are varied; waste management is minimal; the implementation of waste management regulations is not yet strict	➢ Managing and developing local industries ➢ Gaining maximum profit ➢ Maintaining company's reputation ➢ Concerning in strict regulation	➢ Have the financial and technical ability to carry out independent waste management ➢ Low motivation of changes	➢ Increasing awareness of protecting the environment ➢ Implementing the maximum management rules

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Primary Stakeholder

DLH, as the policymaker, can directly design and regulate waste management at the Piyungan landfill so that it can have better implementation. Besides, DLH can also collaborate with external parties, both from the private sector and other agencies, to manage the landfill. Cooperation can be realized in the form of improved procedures and the provision of adequate facilities for waste management. DLH can carry out controlling periodically to ensure the success of the waste management process and carry out continuous evaluation and improvement.

BLH as the executor of landfill management procedures directly supervised and observed deficiencies in the existing landfill management procedures. The deficiencies that exist can then be informed to DLH as material for evaluation and improvement. Besides, the BLH can also collaborate with the community around Piyungan to actively assist and maximize the waste management process, such as separating and sorting between organic and inorganic waste.

Secondary Stakeholder

The residents who live around the Piyungan landfill are the parties who directly feel the negative impact of the problems that arise at the landfill. Still, residents cannot directly design and improve waste management procedures. The majority of residents also pocket their source of livelihood at the Piyungan landfill as a scavenger. The large number of residents who become scavengers decide to form a scavenger community. Through this community, residents can convey their aspirations about improving waste management procedures.

The Industrials sector in Yogyakarta, Sleman, and Bantul are some of the most significant contributors to the Piyungan landfill. Various industries dispose of their waste at the Piyungan landfill. The low awareness of the environment causes many industries to have no independent waste management procedures. Low awareness has led to the accumulation of more and more waste in landfills. Increasing awareness of the importance of preserving the environment can increase the motivation of actors in the industrial sector to pay more attention to the problem of industrial waste or industrial waste. The industry can play an active role in reducing waste accumulation at landfills by maximizing the implementation of independent waste management regulations.

SWOT Analysis

ed on the results of the field studies conducted, several internal and external factors influence the landfill management process. Internal factors consist of strengths and weaknesses, while external factors consist of opportunities and threats. These factors can be directly controlled by the Piyungan Landfill management. The existence of internal factors will add points to the aspect of strength, while the absence of internal factors will add points to the aspect of weakness. Moreover, external factors are factors that cannot be directly controlled by the Piyungan landfill. The existence of external factors will add points to the aspect of opportunities, while the absence of external factors will add points to the aspect of threats.

After identifying all factors, then Internal Factor Evaluation (IFE) and Exte Factor Evaluation (EFE) can be formulated [17]. IFE table is a strategy tool used to evaluate a firm's internal environment and to reveal its strengths as well as weaknesses. As shown in Table 5, it presents internal variables which are then ven weight and rating for each variable. Furthermore, the External Factor Evaluation (EFE) table is a strategy tool used to examine the company's external environment and to identify the available opportunities and threats. It presents the external variables, which are then given weight and rating for each variable, as shown in Table 6. The SWOT analysis data was obtained from the results of FGDs with DLH as the policymaker. DLH directly regulates the final landfill management mechanism and is also involved in determining the value of IFE and EFE as an integrated landfill management expert.

From the results of IFE and EFE calculations, the total IFE results are 3.062, and EFE is 2.270. The difference from the calculation of the two aspects of 0.79 is positive so that the two points are in quadrant I, namely maximizing internal factors that consist of strength and opportunity (see Figure 4).

Table 5. IFE Table

No.	Internal Factor	Weight	Score	Total Score
Strengths				
1	Ability to design and establish better policies for waste management	0.200	4	0.800
2	Sufficient budget to improve facilities	0.200	3	0.600
3	Adequate transportation facilities	0.200	3	0.600
4	Competent human resources	0.200	3	0.600
Weaknesses				
1	Inadequate infrastructure	0.067	2.9	0.194
2	Lack of attention from local government	0.067	2	0.134
3	Poor waste management facilities	0.067	2	0.134
	Total	1.000		3.062

Table 6. EFE Table

No.	External Factor	Weight	Score	Total Score
Opportunities				
1	Good cooperation with Foreign Parties	0.090	1	0.090
2	Evolving waste management technology	0.270	2	0.540
3	High potential of recycled waste business	0.270	2	0.540
Threats				
1	The increasing amount of waste	0.090	4	0.360
2	Low public awareness regarding environmental sustainability	0.090	2	0.180
3	Potential community conflict	0.090	3	0.270
4	Irresponsible facility procurement	0.090	3	0.270
	Total	1.000		2.270

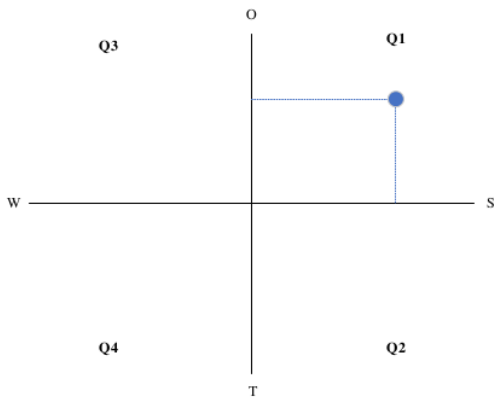

Figure 4. IE Quadrant

From the analysis of internal and external factors, a SWOT matrix can be formulated as shown in Table 7. The SWOT matrix is made to determine the choice of strategies according to the conditions of the landfill. The SWOT matrix is used to determine the optimal strategy combination based on the IE quadrant. Based on the results of the IE quadrant analysis and strategy formulation in the SWOT matrix, it can be seen that the optimal strategy to be implemented in the landfill is a strategy that combines aspects of strength as well as aspects of opportunities or SO strategy.

There are four proposed strategies in the SO strategy. The combination of S1 and O1 will produce a strategy to formulate a policy of cooperation with foreign parties that can provide material assistance and insight into waste management for the Landfill. Second, the combination of S2 and O2 will produce a strategy to optimize the landfill budget, which is large enough to procure tools and other facilities such as a waste management building to increase the waste management capacity of the landfill. Third, the combination of S3, O2, and O3 will produce a strategy to provide transportation facilities and technology to support recycling activities of waste into products that are suitable for use. Last, the combination of S4 and O3 will produce a strategy to maximize the resources owned by the landfill as a supporting aspect of the waste recycling business.

Waste management strategies towards environmental sustainability

Establishing environmental sustainability needs cooperative actions from many stakeholders. Local government and societies should collaborate to manage and treat the municipal waste. The government should bring more innovation to treat unvaluable waste to valuable products or materials, while the societies should manage household waste independently at their homes. Education to local residents and societies should be considered as key activities to build environmental awareness among them.

Methane (CH_4) can be used as an environmentally friendly energy source. The power plant can use methane gas as an energy source to power the turbines. Besides, it can also be used as energy for household-scale gas stoves and small and medium enterprises. Methane gas management that is carried out correctly will have a positive impact on the surrounding environment, both from the economic point of view of the residents and environmental sustainability [27].

Furthermore, liquid waste such as leachate sediment content that comes from organic waste is a natural fertilizer that can be used as a nutritional enhancer for plants. Fertilizer from leachate can be made through the composting process. According to research by Romero et al. [28], plants treated with leachate fertilizers are more fertile than those given commercial fertilizers. Fertilizer from leachate is also efficient from an economic point of view

Table 7. SWOT Matrix of the Piyungan Landfill

	Strengths (S) 1. The policy of the landfill 2. The budget of the landfill 3. Transportation facilities 4. Human resources	Weakness (W) 1.Transportation infrastructure 2.Government policies 3.Waste management facilities
Opportunities (O) 1.Cooperation with foreign parties 2.Waste management technology 3.Potential of recycled waste business	1. Establishing cooperation policies with foreign parties. (S1, O1) 2. Optimizing budget and waste management technology. (S2, O2) 3. Providing transportation facilities and technology to optimize the recycled waste business. (S3, O2, O3) 4. Maximizing resources to optimize the recycled waste business. (S4, O3)	1. Establishing cooperation with foreign parties for handling transportation infrastructure. (W1, O1)
Threats (T) 1.The amount of waste that continues to increase 2.Low public awareness regarding environmental sustainability 3.Community conflict 4.Irresponsible facility procurement	1. Allocating landfill budgets and maximizing the role of human resources for environmental awareness extension. (S2, S4, T2) 2. Optimizing the role of human resources to improve relations with the community. (S4, T3) 3. Establishing policies governing the procurement of facilities. (S1, T4)	1. Maximizing transportation infrastructure for waste transportation. (W1, T1)

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because the raw material is readily available and does not require a complicated process.

For societies, independent waste treatment should become a new lifestyle. Some of household waste consists of food scraps and yard waste which can be composted and used as natural fertilizer [29]. Making compost keeps these materials out of landfill and reduce the methane emissions which is potential to create greenhouse gases. Moreover, composting can enrich soil, help retain moisture, and reduce the need for chemical fertilizer.

On the other hand, the inorganic waste, such as aluminum can, glass-bottle, and plastic waste from food and drink packaging, should be reused and recycled to preserve the materials [30]. Recycling allowed saving large amount greenhouse gas emission particularly in the case of aluminum can and glass-bottle. Moreover, plastic waste can be managed into eco-bricks. Eco-bricks are pieces of plastic waste that are arranged and compacted to make them strong. Eco-bricks can be used as a foundation for household furniture such as tables, chairs, garden decorations, and others [31]. Making eco-bricks from plastic waste is one form of waste management, namely reuse. Plastic waste is reused so that it does not scatter and does not pollute the environment. Besides being turned into eco-bricks, plastic waste can also be managed as handicraft souvenirs. Yogyakarta Province is a province that has many tourist objects that have their characteristics, such as beaches, museums, historical sites, and others. Souvenirs can be sold to local and foreign tourists. In addition to being able to reuse plastic waste, it can also be a source of income for the surrounding community.

Implementing the selected SWOT strategy will increase Piyungan Landfill management's performance, which will reduce the level of environmental pollution. The establishment of cooperation with foreign parties can open up opportunities for more optimal waste management innovations. They should be able to optimize costs and technology as well as to reduce the negative impacts. The availability of adequate transportation facilities and technology is significantly potential to optimize the recycling process and to reduce the amount of waste that enters to the Piyungan Landfill. All these strategies are expected to decrease the environmental impacts both directly and indirectly.

CONCLUSIONS

The Piyungan Landfill is an integrated garbage dump that accommodates waste from three regions, namely Bantul, Sleman, and Yogyakarta. Extending the service life of landfill without paying attention to the ability of the landfill to accommodate waste causes several problems, one of which is pollution to the environment. From the analysis of the fishbone diagram, there are six main factors cause pollution around the Piyungan Landfill environment, which are the waste management process, the amount of waste, landfill facilities, the technology used, the implementation process, and government policies. A stakeholder analysis was also carried out to identified the role of parties involved in waste management at the Piyungan Landfill. The primary stakeholders are DLH and BLH, while the secondary stakeholders are the local community around Piyungan Landfill and industry. The results of the SWOT analysis resulted in a combination of strategies between the strength and opportunity aspects of the Piyungan Landfill. The combination of these strategies includes: (1) establishing cooperation policies with foreign parties. (S1, O1); (2) optimizing budget and waste management technology. (S2, O2); (3) providing transportation facilities and technology to optimize the recycled waste business. (S3, O2, O3); and (4) maximizing resources to optimize the recycled waste business. (S4, O3). The implementation of the four collaborative strategies is expected to increase the capability and capacity of the Piyungan Landfill in managing municipal waste. Furthermore, it is critical to build an integrated collaboration between local government and societies. More innovation on waste management should be the priority for the government, while the societies should responsible to manage their household waste.

In the future, it is important to conduct more profound research about the effectiveness and efficiency of implementing combination strategies that have been obtained from the results of SWOT analysis. More in-depth research on the causes of the overloaded Piyungan Landfill is also necessary to determine the causes from upstream to downstream.

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