LCA

by Devi Angeliana

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Sustainability Life Cycle Assessment (LCA) Of Household Food Waste Management In Urban Areas

Devi Angeliana Kusumaningtiar[1*], Gisely Vionalita[1], Prita Dhyani Swamilaksita[2]
[1]Department of Public Health, Faculty of Health Sciences, Universitas Esa Unggul, Indonesia
[2]Department of Nutrition Science, Faculty of Health Science, Universitas Esa Unggul, Jakarta, Indonesia
*Corresponding author. E-mail: deviangeliana@esaunggul.ac.id

ABSTRACT

Food waste (FW) is a very serious problem, it is proven that Indonesia is the second largest producer of food waste in the world. This study aims to produce an effective and environmentally friendly waste management strategy by considering environmental impacts so as to obtain sustainable household waste management and environmental sustainability. The design used in this research is cross sectional by conducting direct observations and interviews at the Waste Bank. Interviews were conducted to identify more in-depth about waste management problems and about the characteristics of respondents and waste characteristics. While observations were made to calculate waste generation that refers to SNI 19-3694-1994. The results of research with organic waste processing with the Black Slodier Fly (BSF) method Organic waste processing with the BSF method produces impacts on global warming, acidification, eutrophication and ozone layer depletion. Of the four impacts that produce the smallest impact is the impact of global warming of 0.281 kg CO2 eq compared to other impacts. However, BSF processing can reduce environmental impacts, especially global warming, and the factor of consumption patterns and education affects people's behavior in generating food waste so that there are policy recommendations for Waste Bank stakeholders in processing food waste.

Keywords: Life cycle assessement, Food waste, Household solid waste, Environmental impacts COVID-19, Recycling

INTRODUCTION

In developing world, urbanization is occurring rapidly as people from rural areas migrate to big cities for better job opportunities and a better lifestyle (Lehmann, 2012)(Zhang, 2016). Increasing population density in the context of unplanned and unsustainable urbanization also challenges the accumulation of waste (Kundu & Roy, 2012). As a result, sanitation and hygiene for health are lacking. Sanitation and hygiene are essential for health and survival. Many countries are challenged in providing adequate sanitation for their entire population, putting people at risk of water, sanitation and hygiene (WASH)-related diseases. Worldwide an estimated 2.4 billion people lack basic sanitation (over 32% of the world's population) (U.S. Census Bureau, 2017). The man fund's decent drinking water access target in the 2020-2024 National Medium-Term Development Plan for access to decent drinking water is 100% and access to safe drinking water is 15%. Poor waste management can cause environmental quality to decline, causing surface water pollution, groundwater, air pollution. Food waste is food waste that has not been eaten and is discarded for various reasons and left to rot (Bernstad, 2014)(Hanssen, Syversen, & Stø, 2016)(Stenmarck, Hanssen, Silvennoinen, Katajajuuri, & Werge, 2011). According to Papargyropoulos et al in the United States food waste such as milk, vegetables and fruit can increase 22% of greenhouse gases (Papargyropoulou, Lozano, K. Steinberger, Wright, & Ujang, 2014). Some studies show that reducing food waste can have a beneficial impact on climate change (Priefer, Jörissen, & Bräutigam, 2016).

The limitations of waste management make the waste management system uncontrollable. Public awareness and knowledge of sorting waste and processing waste is still very low. This is also due to the government's low attention to environmental conditions and community sanitation, causing a lot of waste to accumulate in landfills or TPSTs in the village. Therefore, there needs to be an approach from various aspects to determine a sustainable waste management system. Waste banks are one of the solutions to the waste management system in the community. Waste bank is a waste management in public space to store community waste in the form of deposits (Friedberg E; Hilderbrand M.E., 2017)(Pariatamby A; Tanaka M., 2014).

Margajaya Village is part of the Bekasi City area, West Java, which is directly adjacent to DKI Jakarta. Margajaya Village is a sub-district of South Bekasi which has an area of 14.96 km2 with a population of 210,497 people. Waste handling in Margajaya Village already has a waste bank that manages organic/food and inorganic waste. Inorganic waste is managed at the RW level which is carried out once every 2 weeks and people who donate their waste will get a savings book from the results of the kilograms, while organic waste is managed by utilizing mangosteen (BSF) and the scope is still in the RT and is collected every day by the janitor every day but there are also people who come directly to the garbage bank. Sustainable waste management is very important, in this study waste management with the Sustainability Life Cycle Assessment

(LCA) approach as one of the tools that can be used to calculate and analyze the potential environmental impacts of waste management, especially to determine the potential impact of global warming if waste bank management is implemented within the village, so that it can determine the most environmentally friendly waste management that can be used sustainably. With the Sustainability Life Cycle Assessment (LCA) approach to waste management, it is hoped that it can provide an overview and solution for sustainable waste management by considering aspects of environmental impact and increasing products from waste management.

METHODS

The research used a cross-sectional study design, with hypothesis testing. Then modeling and simulation were carried out to identify problems in processing household food waste. The calculation of the minimum sample size of the waste bank is 100 households with purposive sampling technique. To find out the concept in improving environmental quality in the future, the Sustainability Life Cycle Assessment (LCA) model of household food waste processing is used. In achieving the research outcome, it is necessary to process and analyze data such as 1) testing a hypothesis 2) sampling the generation and characteristics of household waste 3) Life cycle Assessment (LCA) based on ISO 14040:2006 4) Determination of waste management scenarios. The calculation of household waste generation refers to SNI 19-3694-1994, which is carried out for eight consecutive days per sample, while the identification of household waste characteristics is based on SNI 19-2454-2002.

1. Scenario setting

The scenario setting of this research is to assess and compare the potential environmental impacts of waste processing before and after the implementation of the Waste Bank.

2. Life cycle assessment (LCA) based on ISO 14040:2006

LCA calculations are carried out with GaBi software using inventory data obtained from observations and calculations. This LCA calculation must have data on the estimated amount of waste generation kg/day/KK and the estimated total waste generation tons/day in the Waste Bank. The composition of waste consists of two types, namely unsaleable waste or STJ and saleable waste or SLJ. Saleable waste includes plastic bags, plastic cups and bottles, plastic buckets, paper, cardboard, books, slippers, cans, iron, rubber and used fabrics. Non-saleable waste includes food waste, kitchen waste and yard waste.

3. Data Interpretation

Data that has been collected both univariate and bivariate will be interpreted according to the results of the study. Data presentation can be in the form of tables, garfish or bar charts and others.

Conclusions and policy recommendations

The results of the study are expected to provide policy recommendations that are useful and can manage sustainable household waste.

Data analysis was conducted univariately and bivariately. Univariate analysis was used to describe the characteristics of respondents and the characteristics of household waste types, while bivariate analysis was used to analyze the relationship between household waste generation and community economic strata using the Chi square test with a p-value of 0.05.

RESULTS AND DISCUSSION

Table 1. Relationship between economic strata and household food waste generation

Economic strata	Food waste generation				Total		*p-value*	PR (CI 95%)
	A lot		A little					
	N	%	N	%	N	%		
High	6	16.2	31	83.8	37	100%	0.641	0,730 (0.307-1.735)
Middle	14	22.2	49	77.8	63	100%		

Table 1 shows that high economic strata with the highest proportion of food waste generation is 54.7% (75 people). Meanwhile, the number of drug items <3 items with inappropriate waiting time for pharmaceutical services was 45.3% (62 patien Based on the results of statistical tests, the p-value = 0.730 with $\alpha = 0.05$ was obtained. The p-value> α, so it can be concluded that there is no significant relationship between economic strata and household food waste management. From the analysis, the value PR = 0.730 or 1.366 was obtained. This shows that people who have a middle economic strata are 1.366 times more likely to generate a lot of food waste compared to people who have a high economic strata.

In this study, the potential environmental impact uses units of kg eq. Based on the analysis of potential environmental impacts in the scenario of processing organic waste with the Black Slodier Fly (BSF) method, it produces the potential impacts of global warming, eutrophication, acidification and ozone depleting.

Table 2. Potential impacts of organic waste treatment scenarios with the Black Slodier Fly (BSF) method

Scenario	Global warming	Acidification	Eutrification	Ozone depleting
Processing organic waste using the Black Soldier Fly (BSF) method	0.281 kg CO2 eq	2.37e-3 kg SO2 eq	6.43e-4kg N eq	7.65e-12 kg CFC 11 eq

The management of organic waste with the Black Slodier Fly (BSF) method produces a global warming impact of 0.281 kg CO2 eq, acidification of 2.37e-3 kg SO2 eq, eutrophication of 6.43e-4kg N eq and ozone layer depletion of 7.65e-12 kg CFC 11 eq. The biggest potential impact is the depletion of the ozone layer which is the result of the decay of waste which will form methane gas (CH4).

Most urban areas in Indonesia have not sorted their solid waste according to waste composition. Only a few households in urban areas segregate waste, even if they do, it is usually because there is a waste bank that can be used as a place to exchange segregated waste such as bottles, glass, paper, organic and others. Based on the results of the study, it shows that people with middle economic strata produce more food waste than people with high economic strata. This reflects that differences in consumption patterns, culture and education affect the amount of household waste generated (Van de Klundert & Anschutz, 2001; Nabegu, 2010). According to Pariathamby (2014)(Periathamby & Tanaka, 2014) the responsibility of household waste management is the responsibility of wives at 54%, husbands at 23%, adult women at 20% and the rest stated that it is the responsibility of adult men. The containerization pattern in this area is individual and communal containerization. Where all communities do individual disposal first as temporary disposal in a special container and then disposed of in communal disposal. However, some are also transported by waste bank officers to be collected in the waste bank which later if there is saleable waste, it will be sold and organic waste is processed as maggot feed.

The condition of the temporary landfill in the neighborhood is carried out by the local Cleanliness Department for no more than 3 days. This is because the landfill is not too big so it cannot accommodate too much waste for a long time. Neighboring communities that have the availability of facilities are good because they already have adequate facilities and waste storage is no more than 3 days. This is due to the attitude or awareness of the community to have good facilities as well as economic factors playing a role in the availability of facilities, because facilities require spending both for trash containers and the cost of paying monthly garbage that is transported by officers every day. With this problem, the policy suggestions that can be given to waste banks are as follows:

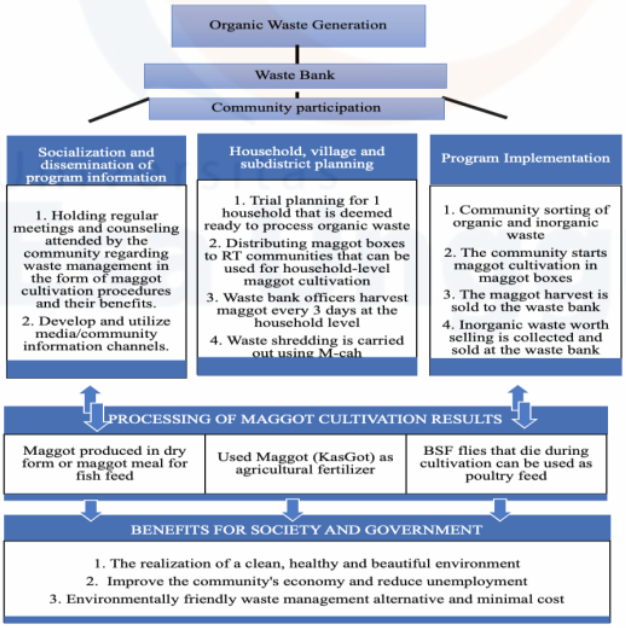

Figure 1: Organic and inorganic waste treatment policy

The management of organic waste with the Black Slodier Fly (BSF) method produces impacts on global warming, acidification, eutrophication and ozone layer depletion. Of the four impacts that produce the smallest impact is the impact of global warming of 0.31 kg CO2 eq compared to other impacts. With the processing of organic waste with maggot (BSF) can reduce the impact on the environment. According to Anasstasia's research (2020) with life cycle assessment (LCA) with the scenario of open landfilling waste processing and open waste burning can produce a greater impact on global warming than waste processing in waste banks, where open dumping waste processing is 13,057 kg CO2 eq and open waste burning is 10,850 kg CO2 eq (Anasstasia & Azis, 2021). Other research shows that open dumping is the highest form of waste management that has the potential to cause global warming impacts due to the absence of gas handling from the waste decomposition process and leachate processing (l. sivakumar Babu, Lakshmikanthan, & Santhosh, 2014)(Saheri, Mir, Ahmad Basri, Binti Mahmood, & Begum, 2012). The gas produced from the decomposition of waste will pollute the air, while the leachate produced will pollute the soil and groundwater.

Based on the scenario of processing organic waste with the Black Slodier Fly (BSF) method, the biggest impact still felt to the environment is the depletion of the ozone layer by 7.65e-12 kg CFC 11 eq. Depletion of the ozone layer can be caused by an increase in CFC and CO2 gases which can cause ozone bonds to break loose and thin out and can cause the greenhouse effect and an increase in UV-B radiation which has an impact on the vulnerability of resistance in humans, animals and plants. Where if organic waste is not processed, the impact on the environment will be even greater. Food waste is an inevitable part (34-53%) of total household waste (Braguglia, Gallipoli, Gianico, & Pagliaccia, 2018). It is estimated that more than 30% of food produced is wasted globally (Xu, Li, Ge, Yang, & Li, 2018), which is ~1.6 billion tons per year (Jain, Newman, Cepeda-Márquez, & Zeller, 2018). Therefore, there is a need for efforts to process organic waste, especially food waste in a sustainable manner. Every 1 kg of waste managed by a waste bank can produce a lower potential environmental impact compared to waste that is not processed.

CONCLUSION

The calculation of potential environmental impacts on waste banks by processing organic waste with the Black Slodier Fly (BSF) method can reduce the impact of global warming when compared to the findings of the open dumping environmental assessment which has the highest potential impact in the impact categories of global warming, ozone depletion and others. It was also found that the middle-income community generated more food waste than the high-income community. It can be seen that there are not only economic factors that influence waste generation but also various other factors such as consumption patterns, education and attitudes.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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Sustainability LCA

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Research Paper

Sustainability Life Cycle Assessment of Household Food Waste Management in Urban Areas

Devi Angeliana Kusumaningtiar[1*], Gisely Vionalita[1], Prita Dhyani Swamilaksita[2]

1. Department of Public Health, Faculty of Health Sciences, Universitas Esa Unggul, Jakarta, Indonesia.
2. Department of Nutrition Science, Faculty of Health Sciences, Universitas Esa Unggul, Jakarta, Indonesia.

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ABSTRACT

Background: Food waste is a severe problem, and Indonesia is the world's second-largest producer of food waste. A limited waste management system will decrease environmental quality, such as air, water, and soil pollution. So far, the waste management system is limited to reducing waste generation. The life cycle assessment is a method to analyze environmental aspects or environmental impacts at all stages in a resource's life cycle, from the initial process of raw materials to disposal. This study aims to analyze the environmental impact and provide waste management policies to obtain sustainable household waste management and environmental sustainability.

Methods: The study design used in this research is cross-sectional by conducting direct observations and interviews at the Waste Bank. Interviews were conducted to identify more in-depth findings about waste management problems and the characteristics of respondents and waste characteristics. Observations were made to calculate waste generation that refers to Indonesian national standard methods of sample collection and measurement of urban waste generation and composition (SNI 19-3694-1994.) The sampling technique was carried out by the total sampling method, resulting in 100 households.

Results: The research results with organic waste processing with the black soldier fly method. This method impacts global warming, acidification, eutrophication, and ozone depletion. Of the four elements that produce the most negligible impact is the impact of global warming of 0.281 kg CO_2 eq compared to the other effects.

Conclusion: BSF processing can reduce environmental impacts, especially global warming. Meanwhile, education affects people's behavior in generating food waste; therefore, there are policy recommendations for Waste Bank stakeholders in processing food waste.

Keywords: LCA, Food waste, Household waste management, Economic status

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*** Corresponding Author:**
Devi Angeliana Kusumaningtiar
Address: *Department of Public Health, Faculty of Health Sciences, Universitas Esa Unggul, Jakarta, Indonesia.*
Phone: *+6285775955871*
E-mail: *deviangeliana@esaunggul.ac.id*

1. Introduction

Food waste can be edible that has not been consumed and is discarded for various reasons or left to rot [1-3]. According to Papargyropoulou et al., in the United States, food waste such as milk, vegetables, and fruit can increase 22% of greenhouse gases social and economic impacts [4]. Drawing on interviews with food waste specialists, this study construes the boundaries between food surplus and food waste, avoidable and unavoidable food waste, and between waste prevention and waste management. This study suggests that the first step towards a more sustainable resolution of the food waste issue is to adopt a sustainable production and consumption approach and tackle food surplus and waste throughout the global food supply chain. The authors examine the factors that give rise to food waste throughout the food supply chain, and propose a framework to identify and prioritize the most appropriate options for prevention and management of food waste. The proposed framework interprets and applies the waste hierarchy in the context of food waste. It considers the three dimensions of sustainability (environmental, economic, and social. Some studies show that reducing food waste can have a beneficial impact on climate change [5].

The limitations of waste management make the system uncontrollable. Public awareness and knowledge of sorting and processing waste is still significantly low. This is also due to the government's inadequate attention to environmental conditions and community sanitation, causing vast amounts of waste to accumulate in landfills in the village. Accordingly, there needs to be an approach from various aspects to determine a sustainable waste management system. Waste banks are one of the solutions to the waste management system in the community. The waste bank is waste management in public space to store community waste through deposits [6, 7].

Margajaya Village is part of the Bekasi City area, West Java, directly adjacent to DKI Jakarta. Margajaya Village is a sub-district of South Bekasi, which has an area of 14.96 km^2 with a population of 210 497 people. Waste handling in Margajaya Village already has a waste bank that manages organic/food and inorganic waste. Inorganic waste is managed at the village level, which is carried out once every two weeks, and people who donate their waste will get a savings book based on the volume in kg. In contrast, the mangosteen black soldier fly (BSF) technique manages organic waste. The scope is still in the house blocks and is collected daily by the janitor; however, some people come directly to the waste bank. The waste bank is a forum for processing waste for the community with the method of buying and selling waste and is managed by local stakeholders. Sustainable waste management is essential. In this study, waste management with the sustainability life cycle assessment (LCA) approach is one of the tools that can be used to calculate and analyze the potential environmental impacts of waste management, primarily to determine the possible effects of global warming if waste bank management is implemented within the village; accordingly, it can choose the most environmentally friendly waste management that can be used sustainably. LCA is a method to analyze environmental aspects or environmental impacts at all stages in a resource's life cycle, from the initial process of raw materials to disposal. With the sustainability LCA approach to waste management, it is hoped that it can provide an overview and solution for sustainable waste management by considering aspects of environmental impact and increasing products from waste management.

2. Methods

This was a cross-sectional study with hypothesis testing. The modeling and simulation were conducted to identify household food waste processing problems. The sampling technique was carried out by total sampling, resulting in 100 households willing to participate. The sustainability LCA model of household food waste processing was used to understand the concept of improving environmental quality in the future. To achieve the research outcome, it was necessary to process and analyze the data as follows: 1) Testing the hypothesis; 2) Sampling the generation and characteristics of household waste; 3) LCA based on ISO 14040:2006; and 4) Determination of waste management scenarios. The calculation of household waste generation refers to SNI 19-3694-1994, which was carried out for 8 consecutive days per sample, while the identification of household waste characteristics was based on SNI 19-2454-2002.

Scenario setting

The scenario setting of this research was to assess and compare the potential environmental impacts of waste processing before and after implementing the waste bank.

Life cycle assessment based on ISO 14040:2006

LCA calculations were carried out via the GaBi software, version 10.6.1 using inventory data from observations and analyses. The LCA calculation should have

data on the estimated amount of waste generation kg/day/householder and total waste generation tons/day in the Waste Bank. Waste composition consists of two types: Unsaleable waste and saleable waste. Commercial waste includes plastic bags, cups and bottles, buckets, paper, cardboard, books, slippers, cans, iron, rubber, and used fabrics. Non-saleable waste includes food waste, kitchen waste, and yard waste.

Data interpretation

The collected univariate and bivariate data were interpreted according to the study results. The data presentation can be in tables, garfish, bar charts, etc.

Conclusions and policy recommendations

The study results are expected to provide practical policy recommendations for managing sustainable household waste. Data analysis was conducted bivariately while bivariate analysis was used to analyze the relationship between household waste generation and community economic strata using the chi-square test with a P=0.05 considered the significance level.

3. Results

Table 1 shows that the high economic strata with the highest proportion of food waste generation is small at 83.8% (37 people). However, the middle economic strata with the highest proportion of food waste generation was 77.8% (63 people). Based on the results of statistical tests, the P of 0.641 with α=0.05 was obtained. The P is >α; therefore, no significant relationship exists between economic strata and household food waste management. The analysis received the value of PR=0.730 or 1.366. This shows that people with a middle economic strata are 1.366 times more likely to generate a lot of food waste than those with a high economic strata.

In this study, the potential environmental impact uses units of kg and eq. Based on the analysis of potential environmental impacts in processing organic waste with the BSF method, it produces the possible effects of global warming, eutrophication, acidification, and ozone depletion (Table 1).

The management of organic waste with the BSF method produces a global warming impact of 0.281 kg CO_2 eq, acidification of 2.37e-3 kg SO_2 eq, eutrophication of 6.43e-4 kg N eq, and ozone layer depletion of 7.65e-12 kg CFC 11 eq. The highest potential impact is the depletion of the ozone layer, resulting from the decay of waste, which will form methane gas (Table 2).

4. Discussion

Most urban areas in Indonesia have not sorted their solid waste according to waste composition. Only a few households in urban areas segregate waste, and even if they do, it is due to a waste bank that can be used to exchange segregated waste, such as bottles, glass, paper, organic, and others. Based on the study results, people with middle economic strata produce more food waste than individuals with high economic strata. According to Pariathamby (2014) [7], household waste management is the responsibility of wives at 54%, husbands at 23%, adult women at 20%, and the rest stated that it is the responsibility of adult men. The containerization pattern in this area is individual and communal containerization, where all communities do individual disposal first as temporary disposal in a particular container and then disposed of in collective disposal. However, some are also transported by waste bank officers to be collected in the waste bank, which later, if there is saleable waste, will be sold, and organic waste is processed as maggot feed.

The local cleanliness department carries out the condition of the temporary landfill in the neighborhood for no more than three days. This is because the landfill is not vastly big; therefore, it cannot accommodate too much waste for a long time. Neighboring communities that have the availability of facilities are good because they already have adequate facilities, and waste storage is no more than three days. This is due to the attitude or awareness of the community to have good facilities and economic factors playing a role in the availability of facilities. Such places require spending both for trash containers and the cost of monthly garbage that is transported by officers daily. With this problem, the policy suggestions that can be given to waste banks are as follows (Figure 1):

Managing organic waste with the BSF method impacts global warming, acidification, eutrophication, and ozone layer depletion. Of the four impacts, the most minor effect is global warming, with 0.281 kg CO_2 eq compared to other factors. With the processing of organic waste with maggot, BSF can reduce the impact on the environment. According to Anasstasia's research (2020) with LCA, the scenario of open landfilling waste processing and open waste burning can produce a more significant impact on global warming than waste processing in waste banks, where open dumping waste processing is 13,057 kg CO_2 eq and open waste burning is 10,850 kg CO_2 eq [8] Other research shows that open dumping is the highest form of waste management that has the potential to cause global warming impacts due to the

Table 1. Relationship between economic strata and household food waste generation

Economic Level	No. (%)			P	PR (95% CI)
	Food Waste Generation		Total		
	A Lot	A Little			
High	6(16.2)	31(83.8)	37(100)	0.641	0.730 (0.307-1.735)
Middle	14(22.2)	49(77.8)	63(100)		

Table 2. Potential impacts of organic waste treatment scenarios with the black soldier fly method

Scenario	Global Warming	Acidification	Eutrophication	Ozone Depleting
Processing organic waste using the black soldier fly (BSF) method	0.281 kg CO_2 eq	2.37e-3 kg SO_2 eq	6.43e-4 kg N eq	7.65e-12 kg CFC 11 eq

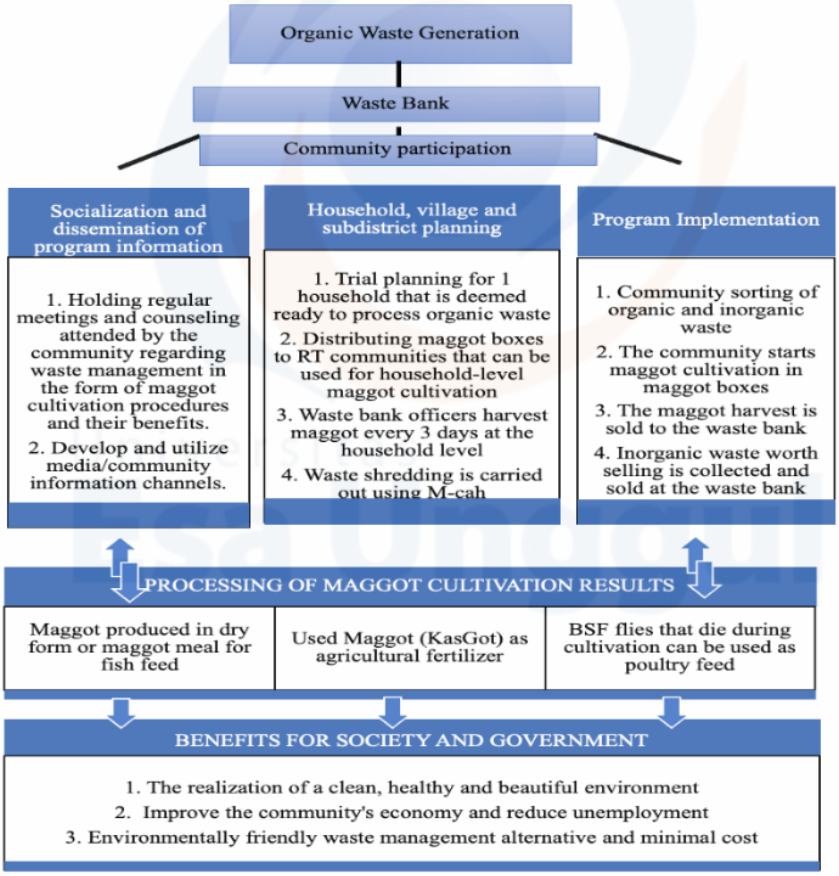

Figure 1. Organic and inorganic waste treatment policy

absence of gas handling from the waste decomposition process and leachate processing [9, 10]. The gas produced from the decomposition of waste will pollute the air, while the leachate produced will contaminate the soil and groundwater.

Based on the scenario of processing organic waste with the BSF method, the most significant impact still felt in the environment is the ozone layer depletion by 7.65e-12 kg CFC 11 eq. The lack of the ozone layer can be caused by an increase in CFC and CO_2 gases, which can cause ozone bonds to break loose and thin out and can cause the greenhouse effect and an increase in UV-B radiation, which has an impact on the vulnerability of resistance in humans, animals, and plants. The environmental impact will be even more significant if organic waste is not processed. Food waste is an inevitable part (34%-53%) of total household waste [11]. More than 30% of food produced is estimated to be wasted globally [12] landfilling, incineration, and composting, nearly 1.6 billion tons per year [13]. Accordingly, efforts need to process organic waste, especially food waste, in a sustainable manner. Every 1 kg of waste managed by a waste bank can produce a lower potential environmental impact compared to waste that is not processed.

5. Conclusion

Calculating potential environmental impacts on waste banks by processing organic waste with the BSF method can reduce the effects of global warming when compared to the findings of the open dumping environmental assessment, which has the highest potential impact in the impact categories of global warming, ozone depletion, and others. It was also found that the middle-income community generated more food waste than the high-income community.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Universitas Esa Unggul (Code: 0923-02.072/DPKE-KEP/FINAL-EA/UEU/II/2023).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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