Determination Of Tariffs For Managing Toxic And Hazardous Waste To Improve The Quality Of The Tourism City Semarang, Indonesia

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Abstract.

The garbage problem is never solved in various cities across Indonesia. This research focuses on specific waste, including toxic and hazardous waste. The study aims to determine the investment value and toll fees for the tourism area in Semarang, Central Java, Indonesia. So far, there is no proper mechanism because, according to government regulations, the government has the obligation to be the main responsible party. This study was conducted to find appropriate alternative treatments that are more implementable and can be carried out immediately. The survey was conducted in 16 districts within the city area, involving waste management communities or relevant agencies. Based on calculations at the household level, it was found that toxic and hazardous waste generation is 1006.25 tons per year. Per household, this ranges from 20 kg to 118 kg per year. This amount is very dangerous in increasing environmental, water, and soil pollution. Considering waste management practices, the required investment value is USD 1.46 million. Based on the polluter pays principle, the established collection fee per household is only USD 1.61 per kilogram per year, or IDR 26,571. This amount is very large if the government bears the entire cost, but through a participatory management system, the handling of toxic and hazardous waste will become easier

Keywords: *Toxic ; hazardous waste; waste management. and sustainable city.*

I. INTRODUCTION

Waste management has always been a problem in various major cities around the world, and this issue is never resolved [1-3]. Every country has its own rules for waste management, but the principle is the same: it starts with the community, at the community and household levels [4]. Waste classification also varies from households to regions, industries, commerce, hotels-cafés-restaurants, and tourism [5]. Besides the polluter aspect, waste is also categorized by type: non-toxic waste and toxic and hazardous waste [6-8]. Hazardous and toxic waste urgently requires special handling on a regular basis, from sorting at the polluter level to transportation, processing, and final disposal, so that it does not cause environmental effects/pollution or other undesirable consequences.[9, 10]. The problem is that not all countries or regions have good waste management strategies [11], One of them is Semarang City, Indonesia. Although it is a large city, it still lacks a specific strategy for waste management, especially for toxic and hazardous waste.

Semarang is one of the major cities located in the central part of Java Island, with an area of 13.6 square kilometers. It is a densely populated city with 1.7 million people and consists of 17 districts. Besides being an industrial center and port city, Semarang is also one of the popular tourist destinations in Indonesia. There are many tourist attractions in this area, such as Thousand Islands tourism, the ancient city of Kota Lama, temples for Chinese religious worship, modern shopping, the central traditional food market, and various other urban tourism options.As a tourist destination, Semarang City plans to improve its environmental quality through waste management. The waste in this city can be divided into domestic waste and specific waste, which includes a group of toxic and hazardous materials. Unlike regular domestic waste, which can now be managed quite well, specific toxic and hazardous waste remain completely unmanaged. Significant investment is required for the management of toxic and hazardous waste, while also measuring community contribution through the calculation of retribution based on ability to pay (ATP) and willingness to pay (WTP).

II. PROBLEM STATEMENT

1. How much investment is needed and what are the cost components?
2. What about ability to pay (ATP) and willingness to pay (WTP) as forms of community participation?

III. BENEFIT OF RESEARCH

1. For local governments, it will be able to determine the investment budget for waste management.
2. Mapping the potential volume of toxic and hazardous waste generation in each district so that the potential and waste management can be known based on waste production per district. At this stage, the supply of basic infrastructure needs per district will also be mapped.
3. To determine the ATP and WTP of the community in accordance with the polluter pays principle.
4. To raise public awareness of toxic and hazardous waste.
5. To serve as a policy basis for improving the quality of urban life.

IV. METHODS

The research method is conducted using a direct field research model, not based on theory but on phenomena and needs in the field. The needs assessment was conducted by directly observing and counting the waste generated from a survey of residents in 16 districts using a purposive quota sampling system (10% x household per District) over a period of 1 year (throughout 2024). The sample percentage is relatively small because, considering the potential for toxic and hazardous waste generation, it is relatively less than domestic waste for households, in addition to time and cost reasons, which are entirely the government's burden. Based on the results of this survey, it is known what types of toxic and hazardous waste exist, and the amount of waste generated per district will also be mapped, along with the appropriate handling plans.

Table 1. Samples Population for Each District

Tourism District	Number of Citizend Year 2024	Number of House Hold	Sample of House Hold	Representativeness of Sample
Tembalang	198.862	49.715,5	4.971,55	10,00%
Pedurungan	196.526	49.131,5	4.913,15	10,00%
Semarang Barat	149.326	37.331,5	3.733,15	10,00%
Ngaliyan	145.495	36.373,8	3.637,38	10,00%
Banyumanik	143.433	35.858,3	3.585,83	10,00%
Genuk	132.473	33.118,3	3.311,83	10,00%
Semarang Utara	117.887	29.471,8	2.947,18	10,00%
Gunungpati	100.752	25.188,0	2.518,80	10,00%
Mijen	89.948	22.487,0	2.248,70	10,00%
Candisari	75.614	18.903,5	1.890,35	10,00%
Gayamsari	70.409	17.602,3	1.760,23	10,00%
Semarang Timur	66.481	16.620,3	1.662,03	10,00%
Semarang Selatan	62.179	15.544,8	1.554,48	10,00%
Gajahmungkur	56.350	14.087,5	1.408,75	10,00%
Semarang Tengah	55.213	13.803,3	1.380,33	10,00%
Tugu	33.795	8.448,8	844,88	10,00%
All Semarang City	**1.694.743**	**423.685,8**	42.368,6	10,00%

V. REVIEW POLICY ON TOXIC AND HAZARDOUS WASTE

1. In Indonesia, there is already government regulation Number 27 Year 2020 about specific waste management, which defines toxic and hazardous waste as substances, energy, and/or other components that, due to their nature, concentration, and/or quantity, either directly or indirectly, can pollute and/or damage the environment, and/or endanger the environment, health, and the survival of humans and other living beings.
2. Waste containing B3 waste is waste originating from households and areas containing B3 waste, such as commercial areas, industrial areas, residential areas, social facilities, and other public facilities.

3. The management of Hazardous and Toxic Materials (B3) waste is temporarily stored before being transported to authorized collectors, processors, and final disposal sites.
4. The forms of hazardous and toxic waste include household products, used product packaging, and used electronic equipment.
5. The provision of Hazardous and Toxic Materials (B3) Waste Management facilities is the responsibility of the government, both local and central, and may involve third parties (private companies).
6. According to Law Number 38 Of 2009 concerning waste management, management fee levies can be imposed on the central government; regional governments; and the public. Local governments impose this fee for the service of providing infrastructure, transportation, processing, and final disposal of waste. The fee rate is determined by considering the ability of the fee payer and the costs incurred in providing waste management services.

Table 2. Handling of Toxic and Hazardous Waste According to the Government

Sorting	Collection	Transportation	Processing	Final Disposal
Sorting is done by the community, sorted according to their groups	Providing waste sorting containers placed at waste management facilities such as drop boxes, containers, or similar + Operator	Supported by Transportation Unit	Special waste processing machines, waste disposal machines such as incinerators	Waste disposal area or landfill or can also collaborate with third parties (private company)

VI. RESULT AND DISCUSSION

Types of Waste and Potential Generation Rates per District for Toxic and Hazardous Waste

Based on observations of 501 respondents purposively selected from 16 districts, representing approximately 12% of the population in each district, it was found that toxic and hazardous waste in Semarang City consists of:

1. Electronics, with an average generation rate of 5 kg per household per year (53%), is the largest volume category of hazardous waste. Household product waste contains hazardous waste with an average generation rate of 1.5 kg per household per year (16%). Used product packaging waste contains hazardous waste with an average generation rate of 2.5 kg per household per year (26%), and expired hazardous waste is 0.5 kg per household per year (5%) (Fig 1).

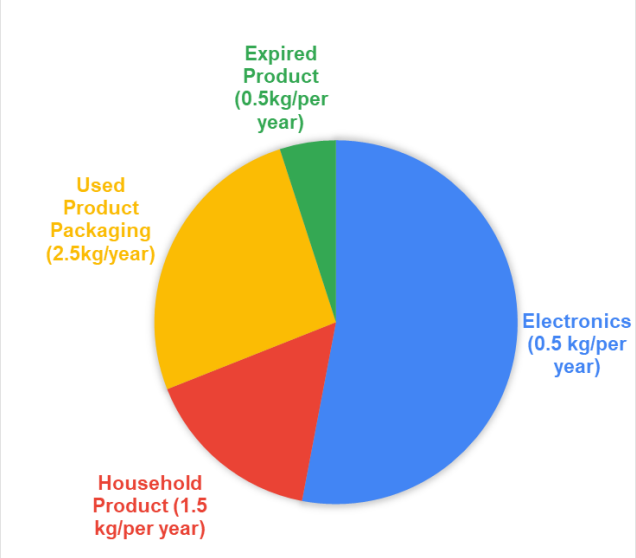

Fig 1. Estimated Weight per Type of Household Waste Containing Hazardous Waste

2. Waste Generation by Type (Kg) and the largest per sub-district are in Pedurungan, Tembalang, Semarang Barat, Banyumanik, and Ngaliyan sub-districts. Several other sub-districts have lower average waste generation volumes (Fig 2).

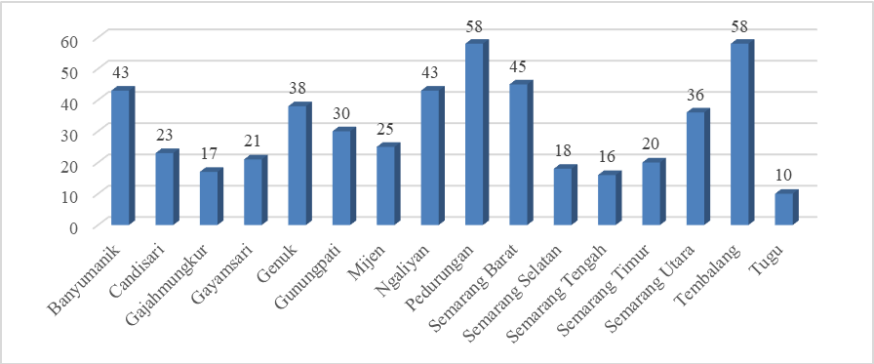

Fig 2. Estimated Average Waste Generation per District (kg)

3. Districts with high population density tend to generate more waste. For example, the Pedurungan and Tembalang sub-districts have dense residential areas and commercial zones that contribute to a higher volume of waste. Districts like Semarang Barat and Banyumanik are centers of economic and trade activity, resulting in more waste from both the industrial and commercial sectors. Districts with a high volume of toxic and hazardous waste have the potential to become locations for developing temporary storage or final disposal sites.
4. Using an estimated waste generation rate of 2.375 kg per household per year, the projected waste generation per district can be broken down as follows.

Table 2. Waste Generation Estimation Per District Based on Number of Households

District	Household	Hazardous Waste Generator (kg) per year	Hazardous Waste (Ton) Per Year	Hazardous Waste (Ton) Per Months
Tembalang	49,715.5	118.074,3	118,07	9,84
Pedurungan	49,131.5	116.687,3	116,69	9,72
Semarang Barat	37,331.5	88.662,3	88,66	7,39
Ngaliyan	36,373.8	86.387,7	86,39	7,20
Banyumanik	35,858.3	85.163,3	85,16	7,10
Genuk	33,118.3	78.655,8	78,66	6,55
Semarang Utara	29,471.8	69.995,4	70,00	5,83
Gunungpati	25,188.0	59.821,5	59,82	4,99
Mijen	22,487.0	53.406,6	53,41	4,45
Candisari	18,903.5	44.895,8	44,90	3,74
Gayamsari	17,602.3	41.805,3	41,81	3,48
Semarang Timur	16,620.3	39.473,1	39,47	3,29
Semarang Selatan	15,544.8	36.918,8	36,92	3,08
Gajahmungkur	14,087.5	33.457,8	33,46	2,79
Semarang Tengah	13,803.3	32.782,7	32,78	2,73
Tugu	8,448.8	20.065,8	20,07	1,67
Semarang City	**423,685.8**	**1.006.253,7**	**1.006,25**	**83,85**

Infrastructure Investment Needs Assessment for Hazardous Waste Management

A. Valuation Assumption

a. Population	:	1.694.743	People
b. Household	:	423.686	Household
c. Annual Waste Generation	:	974.477	kg/year
d. Daily Waster Generation	:	2669,8	kg/day
e. Inflation	:	3,01	%
f. Rate of Bank Interest	:	5,81	%
g. Technical Lifespan of Traditional Transportation Unit	:	2	Year
h. Technical Lifespan of Motorized Transportation Unit	:	5	Year
i. Technical Lifespan Open Bed-Truck	:	5	Year

j. Technical Lifespan of Building	:	30	Year
k. Technical Lifespan Garbage Disposal Tool	:	5	Year
l. Technical Lifespan of Dump Truck	:	8	Year
m. Reference Cost Based on Government Regulation			
▪ Investment Cost of Landfill Capacity 328.000 kg/Day	:	IDR. 44.444.739.073	/Year
▪ Operational Cost of Landfill 328.000 kg/Day	:	IDR. 170.974.176.456	/Year

B. Sorting and Containerization

Sorting and Containerization The required capacity is 120 L per container, and four containers are needed for one set:

	Trash Can	IDR. 1.200.000	/Unit	22	set	IDR. 105.600.000	/Year
	Amount						IDR. 105.600.000

Total Cost for Containerization IDR**.** 105.600.000, - **(F1)**

C. Transportation

At least three modes of transportation are needed: carts (traditional vehicles), motorized carts, and pickup trucks:

1	**Carts Capacity**		1	m3			
			3	laps/day			
			40	kg/day/unit			
	Waste Generation Served		194.895,45	kg/year			
1	Carts	IDR. 3.500.000	/Unit	14	unit	IDR. 26.703.746	/Year
2	Uniform/PPE	IDR. 350.000	/Unit	14	Person	IDR. 4.900.000	/Year
3	Operator's Salary	IDR. 3.250.000	/person/months	168	Person/ Year	IDR. 546.000.000	/Year
4	Maintenance	5%	/Year	14	/unit/ year	IDR. 2.450.000	/Year
	Amount						IDR. 580.053.746

2	**Motorized Carts**		1,5	m3			
			3	laps/day			
			90	kg/day/unit			
	Waste Generation Served		389.790,89	kg/year			
1	Motorized Carts	IDR. 45.000.000	/Unit	12	unit	IDR 117.714.471	/Year
2	Uniform/PPE	IDR. 350.000	/Unit	24	Person	IDR. 8.400.000	/Year
3	Operator's Salary	IDR. 3.250.000	/person/ months			IDR. 1.872.000.000	/Year
4	Gasoline	IDR. 10.000	/Liter			IDR. 18.396.000	/Year
5	Tax	IDR. 450.000	/Year	12	unit	IDR. 5.400.000	
6	Maintenance	5%	/Year	12	unit	IDR. 27.000.000	
	Amount						IDR. 2.048.910.471

3	**Pickup Truck**		4	m^3			
			2	laps/day			
			240	kg/day/unit			
	Waste Generation Served		389.790,89	kg/year			
1	Pickup	IDR.	/Unit	5	uni	IDR.	/Ye

		175.000.000			t	190.741.042	ar
2	Uniform/PPE	IDR. 350.000	/Unit	15	Person	IDR. 5.250.000	/Year
3	Operator's Salary	IDR. 3.250.000	/person/month			IDR. 1.755.000.000	/Year
4	Gasoline	IDR. 10.000	/Liter			IDR. 12.775.000	/Year
5	Tax	IDR. 2.000.000	/Year			IDR. 10.000.000	
6	Maintenance	5%	/Year			IDR. 43.750.000	
	Amount					IDR. 2.017.516.042	

Total Cost for waste sort & collecting IDR 4.646.480.259 **(F2)**

D. Temporary Disposal

	Capacity	270	kg/day/temporary disposal (TD)			
	80% Waste Generation Per Day	2135,84	kg/day			
	Needs of Temporary Disposal	8	unit			
	Waste Generation Served	779.581,78	kg/TD/Year			
1	Land Acquisition Costs	IDR. 5.000.000	/m^2	100 m^2/unit	IDR. 4.000.000.000	
2	Building Costs	IDR. 3.000.000	/m^2	50 m^2	IDR. 43.597.952	/Year
3	Container Cost	IDR. 35.000.000	/Unit	4 item/unit	IDR. 244.148.533	/Year
4	Container Chassis Cost	IDR. 25.000.000	/Unit	4 item/unit	IDR. 43.597.952	/Year
5	Cost of Waste Transfer Equipment	IDR. 50.000.000	/Unit		IDR. 87.195.905	/Year
	Amount				IDR. 4.331.344.438	

Total Cost for Temporary Disposal IDR. 4.331.344.438 **(F3)**

E. Transportation to Final Disposal

	Dump Truck	6	m^3			
		1	laps/day			
		270	kg/day/unit			
1	*Dump Truck*	IDR. 400.000.000	/Unit	8 unit	IDR. 435.979.524	/Year
2	Uniform/PPE	IDR. 350.000	/Unit	40 people	IDR. 14.000.000	unit/ year
3	Operator's Salary	IDR. 3.250.000	/person/months		IDR. 7.800.000.000	/Year
4	Gasoline	IDR. 10.000	/Liter		IDR. 438.000.000	/Year
5	Tax	IDR. 2.000.000	/Year		IDR. 16.000.000	/Year
6	Maintenance	5%	/Year		IDR. 160.000.000	/Year
7	Tire Change	IDR. 4.000.000	/Unit		IDR. 233.600.000	/Year
8	Vehicle Inspection Cost	IDR. 2.000.000	/Year		IDR. 16.000.000	/Year
	Amount					IDR. 9.113.579.524

Total Cost for Transportation to Final Disposal IDR. 9.113.579.524 **(F4)**

F. Final Disposal (Landfill)

	Waste Generation Served Per Year	389.790,89	kg/Final Disposal/Year			
	Waste Generation Served Per Day	1.067,92	kg/ Final Disposal /Day			
	Final Disposal Capacity in 5 Years	32.482,57	m^3			
1	Land Acquisition Costs	IDR. 5.000.000	/m^2	1000 m2/unit	IDR. 5.000.000.000	
2	Building Cost	IDR. 3.000.000	/m^2	700 m^2	IDR. 76.296.417	/Year
3	Investment Cost *	IDR. 35.000.000	/Unit	4 items/unit	IDR. 144.705.600	/Year
4	Operational Cost*	IDR. 25.000.000	/Unit	4 items/unit	IDR. 556.667.026	/Year
	*0,33% based on govt. regulation					
	Amount				IDR. 5.777.669.043	

Total Cost for Final Disposal IDR 5.777.669.043 **(F5)**

Total Financing and Fee Requirements

Based on the breakdown of management financing needs explained above, the government's investment needs for hazardous waste treatment equipment are F1 + F2 + F3 + F4 + F5, which can be seen in the following table:

Table 3. Total Investment for Hazardous Waste Treatment Infrastructure

F1	F2	F3	F4	F5
105.600.000	4.646.480.259	4.331.344.438	9.113.579.524	5.777.669.043
TOTAL = IDR. 23.974.673.264 or about 1.46 million USD				

Retribution Cost Per Household

Based on these results, the following fees can be established:

Cost Per Kg		:	IDR. 24.603	/kg/Year
Fixed Contribution	8%	:	IDR. 1.968	/kg/Year
Retribution (Cost Per Kg + Fixed Contribution)		:	IDR. 26.571	/kg/Year
Retribution Cost Charged to The Community		:	IDR. 2.214	/kg/Months

Ability to Pay (ATP) dan Willingness to Pay (WTP)

A. Ability to Pay (ATP)

The people of Semarang City have an average monthly household income of IDR 2,500,000 - IDR 3,500,000, and have been paying monthly waste fees of IDR 15,000 - IDR 50,000. Based on this data, the community certainly has the ability to afford waste fees, including for poisonous hazardous waste.

B. Willingness to Pay (WTP)

Based on the survey, the community has a fairly good awareness of toxic and hazardous waste, which has been widely socialized by environmental preservation movement communities and non-governmental organizations working in the field of waste management. In some areas, there are even community groups focused on educating the public about specific types of waste, including hazardous waste, and on educating them about sorting and containment. Each neighborhood has a coordinator who will collect the accumulated hazardous waste and take it to the village office for further transportation and processing. Regarding willingness to pay, in accordance with the general principle of the Polluter Pays Principle, the community is generally willing to pay waste disposal fees as they have been doing so far.

VII. CONCLUSION

Specific waste of toxic and hazardous materials is waste that, due to its nature, concentration, and/or volume, requires special management because it can pose a risk to human health and the environment.

Semarang City is one of the cities in Indonesia with the potential for toxic and hazardous waste, which is actually relatively small compared to other major cities in Indonesia such as Jakarta and Surabaya, with an estimated 1,006,253.7 kg/year or about 2.375 kg/household/year. Of that amount, the largest waste generation is in several districts. Electronic waste is the largest waste category at 53%, followed by used product packaging waste at 26%, household product waste at 16%, and expired waste at 5%. Optimal waste management can be achieved through two scenario models: either entirely managed by local government or through collaboration between the government and the community. Final management can be outsourced to a third party. The best option to avoid being a complete burden on the government is to involve the community, especially in the sorting and containment process, which is separate from regular (non-toxic) domestic waste. Additionally, in accordance with the polluter pays principle, the community is willing to pay fees both in terms of ability to pay and willingness to pay, due to increasing awareness of toxic and hazardous waste. The government only needs to invest in transportation, processing, and final disposal, which can be done in collaboration with third parties, namely those who are already professional in the disposal of toxic and hazardous waste.

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