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HAZARDOUS AND TOXIC WASTE MANAGEMENT SCENARIO FROM THE DOMESTIC AND OFFICE SECTORS IN SEMARANG CITY

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Abstract: The hazardous and toxic waste material from domestic and office sectors in Semarang is directly disposed of in the Jatibarang landfill without further processing. Therefore, appropriate management is needed as has been implemented in the medical sector. Therefore, this study aims to simulate the appropriate hazardous and toxic waste management in Semarang City from the domestic and office sectors. This research was conducted by analysing the existing conditions of hazardous and toxic waste management, followed by establishing a scenario of waste treatment through the projection of hazardous and toxic waste produced. The total waste generation of Semarang in 2031 is predicted to be 283.08 m^3/day. It is predicted that Semarang City will require 22 incinerators to treat all of the waste. The ash residue would then be dumped in a hazardous waste landfill covering 0.89 hectares. Hazardous and toxic waste management, specifically from the domestic and office sectors, is expected to prevent adverse impacts on human health and the environment.

Keywords: Hazardous and toxic waste, domestic, office, incineration, hoarded.

Introduction

Semarang is one of the largest cities in Indonesia with a population of 1,814,110, as recorded in the Semarang City Central Statistics (Central Statistics Agency, 2020) data in 2019, spread over 16 sub-districts. The rising number of residents will increase the amount of waste produced from various daily activities. This includes waste from hazardous and toxic materials, defined by Pichtel (2014) as waste that cannot be decomposed and is detrimental to human health or living organisms in the vicinity. According to Ichtiakhiri and Sudarmaji (2015), the contents of hazardous and toxic waste, such as heavy metals, affect human health, causing neurotoxicity, mental disorders, kidney and liver function damage and possible death.

The Semarang City Environment Service handles the management of hazardous and toxic waste in Semarang by formulating strategies and implementing technical solutions for waste treatment and management. Meanwhile, the Ministry of Environment oversees the handling of hazardous and toxic waste in all of Indonesia. The treatment of hazardous and toxic waste in Semarang has been carried out specifically for the hospital medical sector. However, waste management has not been applied in the domestic and office sectors. The treatment of hazardous, toxic medical waste resulting from hospital activities in Semarang is accomplished using incinerators either directly at the hospital or by third parties (Pertiwi *et al.,* 2017; Arumdani, 2021). On the other hand, hazardous and toxic waste from domestic and office sectors is directly disposed of in a landfill, which can cause pollution. The improper management of hazardous and toxic waste can harm the environment and human health.

Santosh Vani *et al.* (2017) reported that the quantity and composition of hazardous and toxic material waste affect the environmental impacts. Therefore, these negative impacts must be prevented by handling hazardous and toxic waste correctly and adequately. In addition, according to Jiang *et al.* (2019), the disposal of hazardous and toxic waste is a key factor for addressing environmental and health problems because long-term exposure can cause severe issues, such as cancer and risks of bioaccumulation in the environment. Ruslinda *et al.* (2018) suggested handling domestic hazardous and toxic waste in Padang City using incineration to destroy the toxic waste content. According to Qiu *et al.* (2016), the content of harmful substances in the waste can be damaged using incineration at high temperatures owing to pyrolysis and oxidation processes. In addition, handling by hoarding can be an option so that the hazardous and toxic content does not harm humans, but the effects of environmental pollution still need to be considered. Putra *et al.* (2019) conducted a similar study, calculating the volume and type of domestic hazardous and toxic waste and collecting data on waste management facilities in the Pasar Tais village, Sleman regency. The researchers obtained 0.8 L of liquid hazardous and toxic waste and 0.4 kg of solid hazardous and toxic waste weekly for eight weeks.

Waste handling requires a separate hazardous and toxic waste bin with a storage time limit of three months, which must be submitted to the official hazardous and toxic waste collector. Therefore, this study aims to simulate hazardous and toxic waste management in Semarang from two sectors, namely domestic and office. This research was conducted by analysing the existing conditions using household waste generation, composition collection and measurement methods. This analysis is followed by creating a waste management scenario that begins with population projections and office facility estimates to determine the hazardous and toxic waste generated. This study is expected to be a consideration for the government in treating hazardous and toxic waste from the two sectors in Semarang, preventing harmful impacts on the residents and environment.

Materials and Methods

The research was conducted in Semarang, Central Java Province, for four months consisting of three stages including (i) sampling by selecting three sub-district samples to represent high, medium and low population densities and a sample from the office sector (for eight consecutive days), (ii) data collection and (iii) data analysis. The SPSS application assists in the determination of high, medium and low population densities. The categorisation criteria are based on a study by Azwar (2012) where the assumption is that the subject population values are normally distributed; the categorical values are presented in Table 1. This study covers two sectors, namely domestic and office. These sectors were chosen because they produced hazardous and toxic wastes directly disposed of in landfills without initial treatment. Unlike those from other sectors, such as the medical or hospital sector, they are processed their waste in the incinerator.

Sampling Tool

Equipment used in taking samples comprises the following: garbage bags to contain samples, boxes to measure sample volume, gloves to protect hands from cuts and bacteria when gathering samples, scales to measure sample weight, masks to protect from odours and metre sticks to measure sample heights in the measuring box.

Sampling Method

The sampling was conducted per SNI 19-3964-1994 concerning Collection and Measurement Methods of Generation and Composition Samples of Urban Waste (Anonymous, 1994) with the formula presented in table 1.

Data Collection

A desk study was used to describe the existing hazardous and toxic waste management conditions in Semarang City. The literature was obtained from Semarang Central Statistics Agency, Local Government Agency, Environment Service, Meteorology Climatology and Geophysics Agency Semarang City. The detail of the desk study includes 1. Population, 2. Map of Semarang City Spatial Planning, 3. Population Density, 4. Gross Regional Domestic Product Per capita, Agriculture and Industry, 5. Waste Retribution, 6. Data on Location of Village, 7. Rainfall Data, 8. Geographical

Table 1: Sampling method

Calculation	Formula or Method	Result
Number of Surface Samples	$K = \frac{S}{N}$ Information: K = Number of samples S = Number of samples (people) N = Number of people per family = 5	Population Density (sample) Height = 122 Medium = 103 Low = 46

District Population Density Sample	Processed using SPSS
	low category = X < 5.178;
	medium = 5.178 < X < 9.307;
	high = 9.307 < X
		Low Category District = Tugu
		Medium Category District = Banyumanik
		High Category District = Gayamsari

Office Sample	S=Cd√(T_s) S = number of samples for each type of non-residential building Cd = Coefficient of non-residential buildings Non-residential Cd = 1 Ts = Number of non-residential buildings	18 Samples
Waste Generation Measurement and Calculation	Put the collected waste into a 40 Liters transport container and weigh it for 8 days.	

Condition Data for Jatibarang Landfill and 9. Waste Management Master Plan.

Data Analysis

Existing Condition Analysis

The existing condition analysis involves the study of the population, physical requirements and facilities for managing hazardous and toxic waste. The population density is required because it affects the generation of hazardous and toxic waste produced.

Calculation of Projected Population and Number of Office Facilities

Population projections calculated in the next ten years were selected using three population projection methods according to the Regulation of the Minister of Public Works Number 3 of 2013 concerning the Implementation of Waste Infrastructure and Facilities in the Handling of Household Waste and Similar Household Waste (Anonymous, 2013), namely the arithmetic, geometric, or least-square methods. The choice of method is based on the smallest standard deviation. The results of the calculations include population projections in terms of the percentage of the population growth rate factor per year and the projection of office facilities. Furthermore, the results of office projections will be multiplied by the number of Semarang City employees, as shown in Eq. (1). The results will be used in determining the required hazardous and toxic waste treatment facilities.

$$\frac{Number\ of\ Office_{n-1}}{Number\ of\ Residents_{n-1}} x Number\ of\ Residents_{n} \tag{1}$$

Calculation of Projected Community Consumption Patterns

The pattern of public consumption can be determined based on the magnitude of the GRDP (Gross Regional Domestic Product) per capita at constant prices because the increase in regional income is influenced by economic growth.

Calculation of Hazardous Waste Generation

Based on the sampling results, the type and composition of hazardous and toxic waste can be calculated based on SNI 19-3964-1994 (Anonymous, 1994) with the following formula:

$$\text{Waste Generation} = \text{Weight x Number waste generating units} \qquad \textbf{(2)}$$

$$\%\ \text{Composition of Waste}\ \% = \frac{\text{Weight composition of waste}}{\text{Total weight}}\ x100\% \qquad \textbf{(3)}$$

where *Weight* refers to the weight of daily waste (kg) per unit (resident/employee).

After obtaining the results of the generation and composition of the waste, the hazardous and toxic waste projection is calculated by taking into account population growth and GRDP using the equation (4):

$$\boldsymbol{Q_n = Q_t(1 + C_s)n}$$

$$\boldsymbol{Cs = \frac{[1+(Ci+Cp+Cqn)/3]}{1+P}} \qquad \textbf{(4)}$$

Where Qn refers to the waste generation in the next n years (kg); Qt is the waste generation in the first year of calculation; Cs is the city improvement/growth; Ci is the growth rate of the industrial sector; Cp is the agricultural sector growth rate; Cqn represents the rate of increase in per capita income; and P is the population growth rate.

Incinerator Calculation

The number of incinerators that may be used to treat all hazardous and toxic waste follows the equation (5).

$$\text{Number of Incinerator needs} = \frac{\text{Hazardous waste volume}}{\text{Incinerator Capacity}} \qquad \textbf{(5)}$$

where the numerator and denominator are in units of m^3/day.

Calculation of the Volume of Burning Ash, Yuliani (2016)

$$\text{Ash Volume} = \text{Hazardous Waste Volume x 20\%} \qquad \textbf{(6)}$$

$$\text{Waste Density} = \frac{\text{Waste Mass } (\frac{\text{kg}}{\text{day}})}{\text{waste volume } (\frac{\text{m3}}{\text{day}})} \qquad \textbf{(7)}$$

$$\text{Combustion Mass} = \text{Incinerator Capacity x Waste Density} \qquad \textbf{(8)}$$

Table 2 presents a summary of the requirements used in this study.

Table 2: Sampling method

Requirements	Utility
SNI 19-3964-1994	Collection and Measurement Methods of Generation and Composition Samples of Urban Waste, Calculation of Hazardous Waste Generation
Minister of Public Works Number 3 of 2013	Calculation of the population projection
Minister of Public Works Number 12 of 2014	Rainfall analysis
SNI 19-2454-2000	Determine the Types of Hazardous Waste Generation
Standardisation of the Ministry of Environment and Forestry with register number: 038/TRL/Reg-1/KLHK, No. P.56/MenLHK-Setjen/2015	Incinerator Qualification
Decree of the Head of the Environmental Impact Management Agency Number Kep-04/Bapedal/09/1995, Government Regulation Number 27 of 2020	Determine the Hoarding Location

Results and Discussion

The Existing Condition of Semarang City Hazardous Waste Treatment

Total Population and GRDP

Based on the Central Statistics Agency of Semarang City in 2019, Semarang City reached a population of 1,814,110 with a GRDP of Rp140,209.39M (million rupiahs) in 2019. The most significant contributor to the GRDP was in the manufacturing sector with a value of Rp35,950.86M, while the smallest GRDP contributor was in the water supply, waste management and recycling sectors with a value of Rp120.68M. From 2016 to 2109, Semarang experienced an increase in GRDP, which describes the level of economic growth, regional income levels, per capita income, changes or shifts in the economic structure, inflation rates and the welfare or prosperity of the residents. Table 3 presents the GRDP of business services and the economic growth rate of Semarang in the 2010 series in 2015–2019.

Table 3: Population, GRDP of business services and economic growth rate of Semarang from 2015–2019

Description	2015	2016	2017	2018	2019
Total Population (Soul)	1,701,114	1,729,083	1,757,686	1,786,114	1,814,110
Based on current price (million rupiah)	134,205.84	147,049.32	159,622.73	174,649.26	191,547.22
Based on the constant price (million rupiah)	109,110.69	115,542.56	123,107.02	131,137.26	140,326.26
Growth rate (%)	5.82	5.89	6.55	6.52	6.86

Hazardous and Toxic Waste Generation in Domestic and Office Sectors

The existing condition of waste generation in this study was obtained by sampling for eight consecutive days in the Gayamsari District, Banyumanik District and Tugu District. Meanwhile, hazardous waste from offices in Semarang was sampled from 18 random samples with 247 employees. Details of the amount of waste generated are listed in Table 4, which shows the average waste generation in high-, medium- and low-density sub-districts and the office sector.

Based on SNI 19-2454-2000 (Anonymous, 2002), the types of hazardous waste generation in Semarang are toxic, corrosive, flammable and infectious. This study uses a sample of toxic waste: used detergent packaging, used dish cleaning packaging, used floor cleaner packaging, used hand sanitiser packaging, used beauty product packaging, used hair oil packaging, medicine packaging, used lamps, corrosive waste, used fabric softener, used batteries, flammable waste includes; aerosols, used ink containers and cartridges. The last is infectious waste such as masks, sanitary napkins and diapers.

The percentage composition of the toxic wastes is presented in Figures 1 and 2. The results show that the composition of the most hazardous waste generated from the domestic sector is solid waste of the infectious type with a percentage of 83%. This type is generated from waste such as sanitary napkins, diapers and masks. This situation may have happened because, during the COVID-19 pandemic, people were required to wear masks, causing infectious types of hazardous waste to increase. In the office sector, the most hazardous waste produced was the corrosive type with a composition of 45%, mostly from used batteries. The different office and domestic activities can cause these results. Hazardous and toxic waste in Semarang is still mixed with other waste because no segregation from the source exists. The waste is transported by a janitor from the waste collection point directly to the landfill without any pre-treatments. The landfill location in Semarang is explained further in the following section.

Landfill Site

Semarang has one landfill site in Kedungpane Village, Mijen District, Semarang, namely Jatibarang landfill. The area is 46,183 hectares (60%), which includes the buried area of 27,7098 hectares and 40% is for leachate treatment plant 18,4732. Jatibarang landfill is located in a hilly and bumpy area with a more than 24% slope. The altitude varies from 63 to 200 meters above sea level. With these conditions, Jatibarang can accommodate incoming waste 3,750 m / 750 – 800 tons per day). Figure 3 presents the layout of the Jatibarang landfill.

Table 4: Results of hazardous and toxic waste sampling for domestic and offices

Description	Average Waste Generation(Volume/day)		Average Waste Generation(Volume/person/day)	
	Weight (kg)	Volume (l)	Weight (kg)	Volume (l)
Domestic Sector				
High	11.242	67.042	0.008	0.0498
Medium	9.944	52.954	0.007	0.0393
Low	1.531	18.010	0.001	0.0134
Average	7.572	46.002	0.0053	0.0341
Office Sector	1.666	6.607	0.0067	0.0267

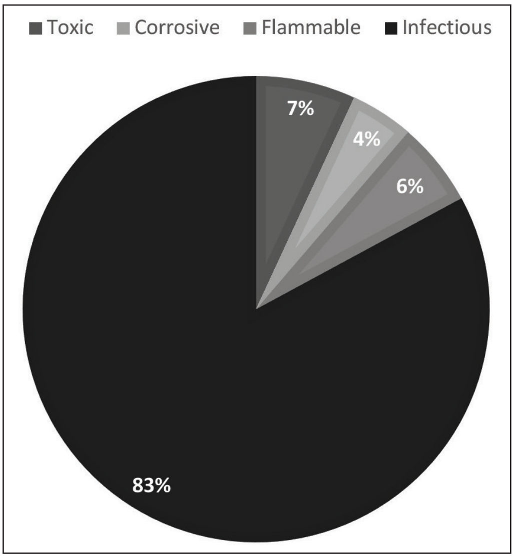

Figure 1: Hazardous and toxic waste composition for the domestic sector

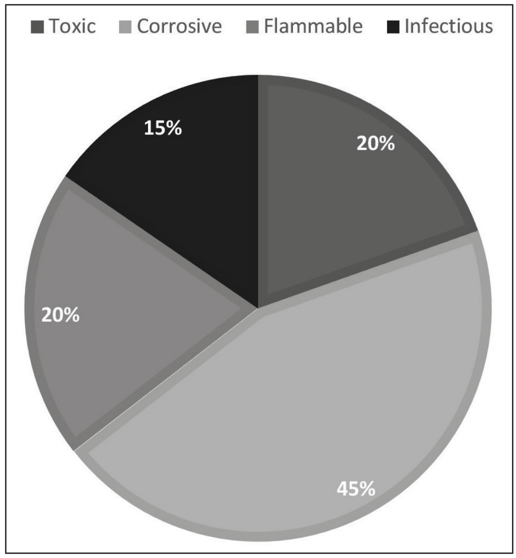

Figure 2: Hazardous and toxic waste composition for the office sector

Figure 3: Jatibarang landfill layout

Hazardous Waste Treatment Scenario of Semarang City

Population and GRDP Projections

This calculation aims to predict population growth at the end of the scenario in the year 2031. The arithmetic method was chosen from three population projection methods with the smallest standard deviation of 39,950 people. The analysed GRDP includes the GRDP per capita and industrial GRDP in Semarang with the geometry method, while the agricultural GRDP was obtained with the arithmetic chosen. This calculation was carried out because the amount of waste generated is influenced by the consumption pattern of the community and regional economic growth, which can be seen from the value of GRDP. The projection results are presented in Table 5.

Table 5: Population and GRDP projection

Population and GRDP Projection (Million Rupiah)				
Year	Population (Soul)	GRDP Per Capita	Industrial GRDP	Agricultural GRDP
2020	1,842,359	113.57	38,024,766.21	1,105,642.40
2021	1,870,608	122.16	40,218,305.35	1,121,716.18
2022	1,898,857	131,39	42,538,383.44	1,137,789.96
2023	1,927,106	141.33	44,992,300.14	1,153,863.74
2024	1,955,355	152.01	47,587,776.22	1,169,937.52
2025	1,983,604	163.50	50,332,977.83	1,186,011.30
2026	2,011,853	175.87	53,236,542.21	1,202,085.08
2027	2,040,102	189.16	56,307,604.84	1,218,158.86
2028	2,068,351	203.46	59,555,828.23	1,234,232.64
2029	2,096,600	218.84	62,991,432.26	1,250,306.42
2030	2,124,849	235.39	66,625,226.38	1,266,380.20
2031	2,153,098	253.18	70,468,643.60	1,282,453.98

Projection of Office Facilities

Population growth will adjust and affect the development of office facilities. Initially, the number of offices in 2020 was 407, which would increase to 468 in 2031. Details of the calculation results are shown in Table 6.

Projection of Hazardous Waste Generation

The projection of waste generation in Semarang was carried out until 2031 using the field sampling measurements in the previous section, considering the population growth factor P and the growth rates of agricultural sector Cp, industrial sector Ci and community per capita Can. The results indicated that in 2031 Semarang produced as much as 0.131 L/person/day of hazardous and toxic waste for the domestic sector and 0.031 L/person/day in the office sector. The total waste generation of Semarang in 2031 is predicted to be 283 m^3/day, the details

Table 6: Office facility projection

Year	Total Population	Number of Offices
2020	1,842,359	407
2021	1,870,608	413
2022	1,898,857	419
2023	1,927,106	426
2024	1,955,355	432
2025	1,983,604	438
2026	2,011,853	444
2027	2,040,102	451
2028	2,068,351	457
2029	2,096,600	463
2030	2,124,849	469
2031	2,153,098	468

of which are shown in Table 7. The overall composition of waste in 2031 is presented in Figure 4, with the highest percentage of 59% generated from organic waste. Hazardous and toxic waste occupies the fourth position at 6%.

Scenario of Hazardous and Toxic Material Waste Processing

Incineration

The projected amount of waste generation through 2031, as calculated above, was used to

Table 7: Projection of hazardous waste generation for domestic and office sector

Year	Waste Generation							
	Domestic Sector				Office Sector			
	kg/day	kg/person/ day	L/day	L/person/ day	kg/day	kg/person/ day	L/day	L/person/ day
2021	31,548	0.017	191,652	0.102	32.94	0.0067	130.64	0.027
2022	32,780	0.017	199,135	0.105	34.46	0.0068	136.65	0.027
2023	34,064	0.018	206,939	0.107	36.02	0.0069	142.84	0.028
2024	35,404	0.018	215,080	0.110	37.63	0.0071	149.21	0.028
2025	36,802	0.019	223,573	0.113	39.28	0.0072	155.77	0.028
2026	38,261	0.019	232,433	0.116	40.98	0.0073	162.52	0.029
2027	39,783	0.020	241,679	0.118	42.73	0.0074	169.46	0.029
2028	41,371	0.020	251,327	0.122	44.53	0.0075	176.60	0.030
2029	43,029	0.021	261,397	0.125	46.38	0.0076	183.94	0.030
2030	44,759	0.021	271,908	0.128	48.28	0.0077	191.47	0.030
2031	46,565	0.022	282,881	0.131	50.23	0.0078	199.21	0.031

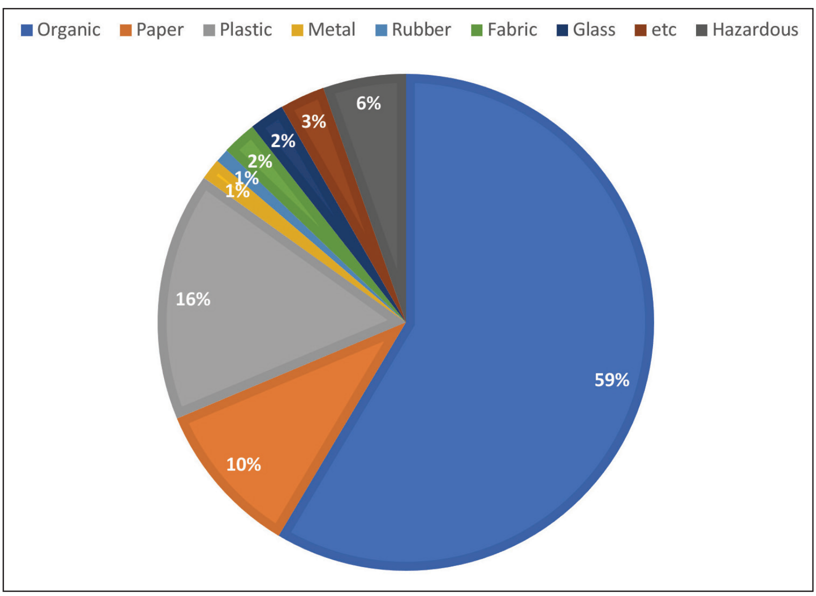

Figure 4: Waste composition of Semarang city

establish a hazardous waste management scenario using incineration as a treatment procedure. The selection of waste treatment using an incinerator is according to PermenLHK Number 6 of 2021 concerning 'Procedures and Requirements for Management of Hazardous and Toxic Waste', the technology allowed is incineration. Allowed wastes to be incinerated are non-explosive, non-mercury and non-radioactive (< 1 Bq/cm2). Hazardous waste treatment using incineration is an effective method with a faster processing time than other methods such as reduction, stockpiling and recycling (Visvanathan, 1996). This treatment was chosen to destroy the physical properties and characteristics of hazardous and toxic waste in Semarang, which produces infectious, corrosive, explosive and toxic waste. Waste from the domestic sector is dominated by infectious composition, while corrosive products dominate waste produced from the office sector. According to Ruslinda *et al.* (2018), incineration can reduce the hazardous characteristics of the waste produced and reduce the waste mass.

The selected incinerator for the scenario was an incinerator with a capacity of 4 m^3/h, adjusted to the standardisation of the Ministry of Environment and Forestry with register number: 038/TRL/Reg-1/KLHK (Center of Forestry and Environment Standardization, 2018). The incinerators chosen have to have environmental-friendly claims of energy savings for large capacity (average of 100 kg/h and continuous), 30% heat recovery and emissions not exceeding exhaust emission-quality standards following the Regulation of the Minister of the Environment Num. P.56/MenLHK-Setjen/2015 (Anonymous, 2015) The incinerators should be equipped with a wet scrubber for air pollution control and can accommodate a maximum capacity of 400 kg. Operators must exhibit waste handling skills, attend incinerator operation training and understand occupational health and safety in waste treatment.

Most of the available incinerators in the market could be used for five years with the manufacturer's availability of spare parts, so the scenario is arranged every five years, as presented in Table 8. In 2022–2026, Semarang needs nine incinerators plus one backup incinerator to accommodate the volume of waste produced at 232.60 m^3/day. In 2027–2031, at 283.08 m^3/day of waste, 11 incinerators plus one backup incinerator are needed. The incinerator capacity is 28 m^3/day for 7 h. Meanwhile, the solid waste density is 164.67 kg/m^3. The total mass of combustion for 7 h is 419.17 kg/incinerator and the volume of ash from combustion produced is 56,616 m^3/day, which will be hoarded in a hazardous waste landfill. Pictures of the incinerator material balance are presented in Figure 5.

Table 8: Details of treatment scenario with incinerator projection of hazardous waste generation for the domestic and office sectors

Description	Value
Hazardous Waste Volume in 2026	232.60 m^3/day
Hazardous Waste Volume in 2031	283.08 m^3/day
Incinerator Needs in 2022 - 2026	10 incinerators
Incinerator Needs in 2027-2031	12 incinerators
Incinerator Capacity	4 m^3/h
Incinerator Capacity per day	28 m^3/h
Incinerator Burn Percentage	20%
Ash Volume	56.616 m^3/day
Waste Density	164.67 kg/m^3
Combustion Mass	658.69 kg/h
Combustion Mass per Incinerator	419.17 kg

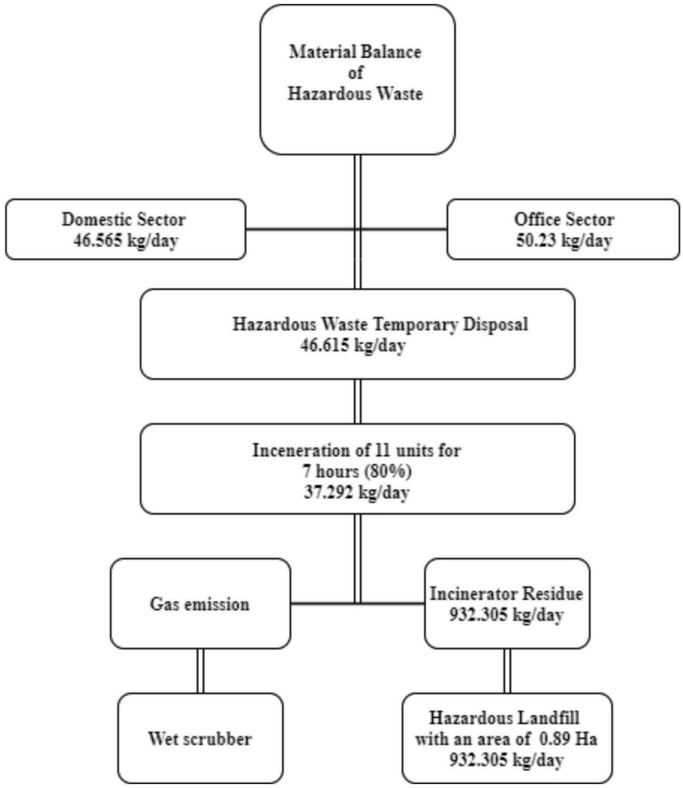

Figure 5: Material balance of hazardous waste

Hoarding

Hazardous and toxic waste characteristics meet the requirements for hoarding, such as non-explosive, non-flammable and non-reactive. This waste type does not cause infection after going through an incineration process. Combustion residue from incineration treatment is generated in landfills not to harm human health. Following the material balance, 0.89 hectares of land is required to store hazardous waste. The location determination is based on the Decree of the Head of the Environmental Impact Management Agency Number Kep-04/Bapedal/09/1995 (Environmental Impact Control Agency, 1995), Environmental Protection Agency (2011) and Government Regulation Number 27 of 2020 (Anonymous, 2020). The location criteria include the following: far from floods and natural disasters, not a water catchment area and not fertile, rainfall of at least 500 mm/year, stable soil structure and dominant wind direction to unpopulated or sparsely populated areas. The selected zone is the location of the former PT. Narpati company has an area of 4.2 hectares and can be reused to become a hazardous waste landfill. The location layout of the landfill is presented in Figure 6.

The hazardous waste landfill in the scenario has a liner system to prevent leachate or liquid waste material from flowing into groundwater. The liner system consists of a sub-base and a final cover. The sub-base, which comes from re-compacted clay, comprises thin layers 15–20 cm thick to support the layer above it. The thin layers include a secondary geomembrane, leak detection system, barrier soil liner, primary geomembrane, leachate collection and transfer system (SPPL) and operation cover. The final cover is pollution protection when the landfill is over capacity and consists of an intermediate soil cover, cap soil barrier, cap geomembrane, cap drainage layer, vegetative layer and vegetation.

The hazardous waste landfill must have a leachate management system to accommodate an estimated leachate discharge of 0.041 m/yr. A leachate line pipe with a 150–200 mm diameter is required. The leachate management must have leachate collection vessels or pits for water that comes in contact with hazardous waste around the landfill, such as water used for washing transport vehicles. A leachate collection vessel or pit has a roof in the form of a pond surrounded by a tank with a volume of 110% of the tank volume to accommodate leachate over one week.

In addition, the hazardous landfill must be equipped with a drainage system to drain rainwater that falls around the landfill. The rainfall analysis used the nearest rain station, Gunungpati Rain Post, referring to the Regulation of the Minister of Public Works Number 12 of 2014 (Anonymous, 2014). The most suitable method for the analysis was chosen because it has the least difference in distribution methods, namely the Type III Log Person Distribution Method. The results yielded a flow velocity of 1 m/s. Other complementary facilities include an administrative office with an area of 6×4 m, a place for vehicles and equipment with an area of 12×6 m, a guard post with an area of 3×3 m, 'emergency shower' equipment and other supplies for emergencies, waste collection equipment, such as bulldozers, personal safety equipment for workers and first-aid kits. The projected amount of waste generation until 2031, calculated previously, was used to evaluate the hazardous scenario.

Conclusion

This study aims to simulate hazardous waste management in Semarang from the domestic and office sectors. The sampling of waste generation showed that the average waste generation in high-, medium- and low-density sub-districts is 0.0341 L/person/day. Meanwhile, the average waste generated in the office sector is 0.0267 L/person/day. The projected waste generation in 2031 in the residential sector is 0.131 L/person/day and in the office sector is 0.031 L/person/day. The total waste generation of Semarang in 2031 is 283.08 m^3/day. The most hazardous waste projected to be generated from the domestic sector is the infectious type which dominates at 83%, while the office sector will produce the corrosive type with a composition of 45%. Incineration treatment was chosen because it was considered the most effective.

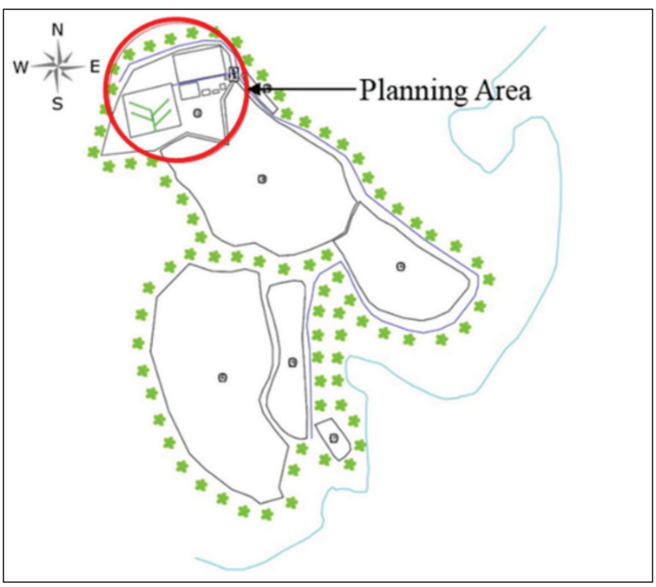

Figure 6: Hoarding location layout

The results of the scenario until 2031 require 22 incinerators to accommodate 283.08 m^3/day of waste volume, resulting in an ash volume of 56.616 m^3/day. The ash residue would then be hoarded in a hazardous waste landfill covering 0.89 hectares. Prevention of adverse effects on human health and the environment is expected to occur by treating toxic hazardous waste materials, especially from the domestic and office sectors, as well as landfills of hazardous and toxic materials equipped with liner systems, leachate treatment, drainage and other supporting facilities. Our research has limitations, the projected waste generation until 2031 is not separated between infectious waste, even though the waste may only be produced in large quantities during the pandemic period and may decrease in the following years. Therefore, future research is expected to consider projection scenarios with two different conditions.

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References

Anonymous. (1994). SNI 19-3964-1994 Concerning Collection and Measurement Methods of Generation and Composition Samples of Urban Waste.

Anonymous. (2002). SNI 19-2454-2002 Regarding Operational Technical Procedures for Urban Waste Management.

Anonymous. (2013). Regulation of the Minister of Public Works Num. 3 of 2013 concerning the Implementation of Waste Infrastructure and Facilities in the Handling of Household Waste and Similar Household Waste.

Anonymous. (2014). Regulation of the Minister of Public Works and Public Housing concerning the Implementation of Urban Drainage Systems number 12/PRT/M/2014.

Anonymous. (2015). Minister of Environment and Forestry Regulation No. P.56/MenLHK-Setjen/2015 concerning Procedures and Technical Requirements for Management of Hazardous and Toxic Waste from Health Service Facilities.

Anonymous. (2020). Government Regulation (PP) on Specific Waste Management No 27 of 2020.

Arumdani, I. S. (2021). Evaluation of solid medical waste management of hazardous and toxic materials at educational hospital in Semarang. *International Journal of Health, Education & Social (IJHES), 4*(4), 19-30.

Azwar, S. (2012). *Psychological scale preparation* (ed. 2). Yogyakarta: Pustaka Pelajar Publisher.

Center of Environment and Forestry Standardization. (2018). *Verified Eco-friendly Technology Register: Number 038/TRL/Reg-1/KLHK*. Ministry of Environment and Forestry Indonesia. http://standardisasi.menlhk.go.id/wp-content/uploads/2018/04/Incinerator-AJMTech.pdf.

Central Statistics Agency. (2020). *Semarang City in numbers*. Semarang: Central Statistics Agency of Semarang City.

Environmental Protection Agency. (2011). *Municipal solid waste generation, recycling and disposal in the United States: Facts and figures for 2010*. Washington DC: United States.

Head's Decision Environmental impact Control Agency. (1995). Num: KEP-04/BAPEDAL/09/1995 regarding Procedures and Requirements for Hoarding Results Processing, Requirements for Ex-Processing Locations and Location of Former Hoarding Hazardous and Toxic Waste.

Ichtiakhiri, T. H., & Sudarmaji, S. (2015). B3 Waste management and health workers complaint in Inka (Persero) Madiun City. *Jurnal Kesehatan Lingkungan Unair, 8*(1), 118-127.

Jiang, X., Li, Y., & Yan, J. (2019). Hazardous waste incineration in a rotary kiln: A review. *Waste Disposal & Sustainable Energy, 1*(1), 3-37.

Pertiwi, V., Joko, T., & Dangiran, H. L. (2017). Evaluation of hazardous and toxic waste management at Roemani Muhammadiyah Hospital Semarang. *Jurnal Kesehatan Masyarakat (Undip), 5*(3), 420-430.

Pichtel, J. (2014). *Waste management practices: Municipal, hazardous and industrial* (2nd ed.). Boca Raton: CRC Press.

Putra, T. I., Setyowati, N., & Apriyanto, E. (2019). Identification of types and management of household hazardous and toxic waste: A case study of Pasar Tais Village, Seluma District, Seluma Regency. *Naturalis: Jurnal Penelitian Pengelolaan Sumber Daya Alam dan Lingkungan, 8*(2), 49-61.

Qiu, M., Xu, B., Chen, L., & Qin, J. (2016). A brief discussion on the incineration technology of hazardous waste rotary kiln (in Chinese). *Jiangxi Chemical Industry*, 51-53.

Ruslinda, Y., Raharjo, S., & Putri, D. F. (2018). The study of hazardous and toxic household waste processing technology in Padang City. *Prosiding Semnastek*.

Santosh Vani, S., Bhaumik, S., Nandan, A., & Siddiqui, N. A. (2017). Hazardous waste-impact on health and Environment for sustainable development in India. *World Scientific News, 70*(2), 158-172.

Visvanathan, C. (1996). Hazardous waste disposal. *Resources, Conservation and Recycling, 16*(1-4), 201-212.

Yuliani, M. (2016). Incineration for municipal waste treatment. *Jurnal Rekayasa Lingkungan*. *Journal of Environmental Engineering*, *9*(2), 89-96.