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Solid Waste Management

Evaluation Existing Condition of Waste Generated Based on Population and Population Density in Batam City

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A B S T R A C T

Population and population density affect the production of waste generated. The increasing of population and population density in Batam caused by the economic growth. The development of Batam not only led into the increasing of population but also waste generated. Therefore, the aims of this research is to evaluate the existing condition of waste generated based on population and population density in Batam with descriptive analysis. Descriptive statistical analysis was conducted in order to know range value, mean and standard deviation of waste generated, population and population density. The result shows waste generated in Batam has increased into 4.81% from 2021 to 2022. Batam Centre District supplies the most amount waste generated (23%), whereas Nongsa District supplies the less amount of waste generated (4,86%). The Daily waste generation rate in Lubuk Baja is higher than daily waste generated based on SNI. Another specific variable in population might be given impact to waste generated, which is ratio comparation of population based on gender. Descriptive analysis's result stated that waste generated has range value 12,478,650 – 60,336.220 with standard deviation 14,542,363.712 and mean 28,998,778.89. Population range value is 61,497–226,040 with standard deviation and mean respectively 57,227.43 dan 135,304.22. Last, population density has range value 295 – 6,406 with standard deviation 1,907.59 and mean 2,550.89.

1. INTRODUCTION

Increased population growth will affect the amount of waste generated. Population growth is the change in population over time. The results showed that population growth in Gili Trawangan has increased every year with an average growth rate of 1.09%. This will certainly have an impact on waste management efforts to overcome waste problems and preserve the environment [1]. In addition to the increase in population, there are other factors that affect the amount of urban waste generation. According to Prajati and Pesurnay (2019), population density has a significant influence on the increase in municipal solid waste generation [2].

One of the causes of increased population growth in an area is people who come to the area for certain purposes. Research conducted in Gili Trawangan states that population growth is caused by tourists who come to travel [1]. Another purpose for which people move is for education or work. This type of movement or urbanization is also known as circular mobility. Circular migrants do not settle in their destination but are highly active and contribute to an increase in the amount of waste generated in the area [3].

Batam City is one of the cities with high economic growth in Indonesia. The Central Bureau of Statistics recorded that Batam City has experienced an economic increase over the last three years (2020-2023) [4]. The impact of the development of Batam City is not only on the increase in population, but also on waste generation. This can be seen from the Batam City Environment Agency Report for 2023 which shows that the total waste generation is 260,989,010 kg [5].

Based on the problems described, this research aims to evaluate the existing condition of waste generation based on population and population density in Batam City. This research uses descriptive statistical analysis to evaluate.

2. LITERATURE REVIEW

2.1. Waste Generation

Waste generation is waste generated from waste sources. Waste sources include residential and non-residential areas. Residential areas consist of permanent houses, semi-permanent houses and non-permanent houses. Meanwhile, non-residential areas consist of offices, shops, markets, schools, places of worship, roads, hotels, restaurants, industries, hospitals, and other public facilities [6].

Waste management is determined by differences in the composition of waste generation. In addition, the determination of waste management also depends on the nature of the waste. Waste composition consists of various types of materials from different material sources. A study of waste generation and composition found that 50% of the waste composition on campus is organic waste. Based on this, an effort was made to utilize waste by implementing composting [7].

Municipal waste is defined as waste generated from household, commercial and construction activities that is collected, transferred, managed and disposed of by the relevant local agencies. In recent years, the issue of waste generation has received considerable attention due to its increasing volume [8]. More than 2 trillion tons of municipal waste generated worldwide per year [9].

2.2 Factors that affect waste generation

2.2.1 Total population

Suparmoko (1997) explains that the relationship between population and environment has two consequences. First, positive effects in the form of the availability of goods and services in the economy. Second, it causes negative effects in the form of residual products as a result of production and consumption activities [10].

The growth boundary theory explains that an increase in population results in an increase in pollution levels. This can be interpreted as a decrease in the quality of the living environment. In addition, economic development that is not followed by the utilization and preservation of the environment will cause problems in the health, social, economic, environmental and other fields [11].

The amount of household waste increases as the population increases. The increase in population can be caused by the high birth rate or the movement of people into an area or region.The low level of public awareness, as well as the lack of ability of the community to manage household waste, also results in an increase in the amount of household waste generated [12].

The results of a study (Zambrano-Monserrate et al., 2021) of 173 countries show that an increase in a country's population affects urban waste production. This effect occurs in all countries that are the object of research.Further research found that although the same effect occurs, the rate of increase in waste differs between countries. In low-income countries, 1% population growth only results in an increase in waste of 0.5921%, while in high-income countries, 1% population growth can result in waste growth of 1.16% [9].

2.2.2 Population density

According to the Ministry of Education and Culture of the Republic of Indonesia, population distribution or spread is a form of population distribution that is either evenly distributed or not in an area. The occurrence of population distribution can be known from population density. Population density is a value or measure that shows how many people live in one square kilometer of area.Population density is also an indicator of the difference in resources owned by an area compared to other areas. Areas that have better resources, both natural and human resources, will tend to be densely populated [13].

The results of the study (Prajati and Pesurnay, 2019) showed that the most influential factor on waste generation in nine provincial capitals of Sumatra is population density. [2]. Hasil yang sama juga didukung oleh penelitian (Qurrota dan Lavany, 2022). The results showed that the population density variable had a positive and significant influence on waste generation. The consequences of population density growth also affect waste management, with less space available for waste management facilities. There is a scarcity of land resources for waste management [10].

The level of urban population density also affects the amount of waste production in a country. This effect occurs in middle and upper income countries. Zambrano-Monserrate et al. (2021) estimated that every 1% increase in population density will affect the increase in waste by 0.2928%. The population density that occurs is not only from the number of residents but also from the number of visitors or tourists who come at certain times. Special protocols to control waste generation during holidays or increased tourism must be made. The waste generation impact of this increase in tourists occurs more in countries with high or above average income. This may be due to the inflow of tourists to these countries compared to low-income countries. High-income countries have more luxurious and comfortable tourism facilities, higher levels of security, more shopping access and high-end accommodation and transportation, and more affordable communication/internet access [9].

3. METHOD

3.1. Research Location

The research was conducted in nine sub-districts located in the main land of Batam City. These sub-districts are Batam Kota sub-district, Batu Aji sub-district, Batu Ampar sub-district, Bengkong sub-district, Lubuk Baja sub-district, Nongsa sub-district, Sagulung sub-district, Sei Beduk sub-district, and Sekupang sub-district. Figure 1 showed the map of Batam City area [5].

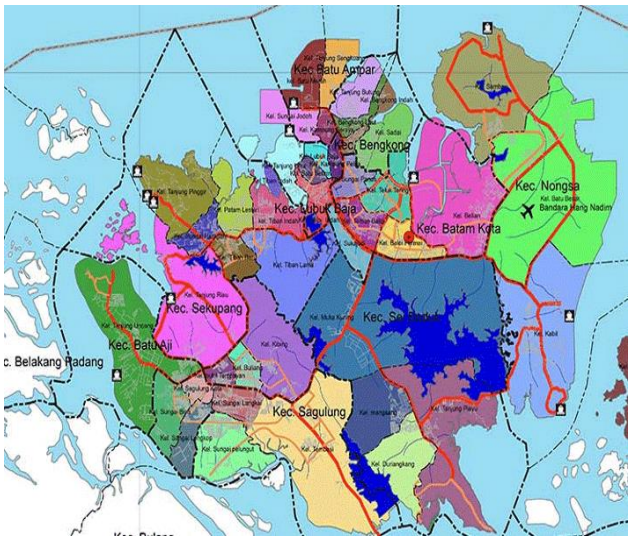

Figure 1. Administrative Map of Batam City

3.2 Data Type and Source

The research area is Batam City. The data taken is 2022 data. The type of data is secondary data taken from the Batam City Regional Environmental Management Performance Information Document (DIKPLHD) Year 2023.

3.3 Data Collection

The data required in this study were obtained from the Environmental Management Performance Information Document of Batam City Year 2023 published by the Environmental Agency of Batam City. The data taken from the report are:

a. Data of Household Waste Entering Punggur Landfill per Sub-district (Main Land) of Batam City in 2022,
b. Total Population in 2022,
c. Population Density in 2022.

3.4 Data Analysis

This research uses descriptive analysis. Descriptive analysis evaluates and explains research data in a form that is easier to understand and interpret. Tabulation presents a summary, organization, arrangement of data in numerical and graphic form. Descriptive analysis is used by researchers to provide information about the characteristics of research variables. Activities related to descriptive statistics such as calculating mean (average), maximum value, minimum value and deviation [14].

4. RESULTS AND DISCUSSION

Household waste referred to waste generated from daily activities in households, excluding feces and specific waste. Household waste originating from commercial areas, industrial areas, special zones, social facilities, public facilities, and/or other facilities was called household-like waste. Household waste and household-like waste were transported and disposed of at the landfill [5].

The Regional Regulation of Batam City Number 11 of 2013 covers waste management, which includes household waste and household-like waste. The management mentioned includes activities such as sorting, recycling, utilization, collection, transportation, processing, and final disposal of waste. The waste collection referred to in this regulation is carried out for waste originating from households, residential areas, commercial areas, industrial areas, special zones, public facilities, social facilities, and other facilities [5]. Based on this information, the study defines household waste data entering the landfill, obtained from the DLH Report, as household waste generated from activities in households as well as from commercial areas, industrial areas, special zones, social facilities, public facilities, and/or other facilities.

4.1 Existing Condition of Waste Generation in Batam City

The increase in the amount of waste entering the Punggur landfill from 2021 to 2022 was 4.86%. Figure 2 illustrates the rise in waste generation in Batam City from 2021 to 2022. Meanwhile, Figure 3 shows the increase in waste generation across nine sub-districts of Batam City from 2021 to 2022.

The sub-district contributing the most waste is Batam Kota Sub-district, with a total waste generation of 60,336,220 kg or 23% of the total waste in Batam City. The sub-district contributing the least amount of waste is Nongsa Sub-district, with a total waste generation of 12,478,650 kg or 4.78% of the total waste in Batam City. The highest increases in waste generation were observed in Sei Beduk Sub-district and Nongsa Sub-district, with increases of 21.9% and 14.6% from 2021 to 2022, respectively. In contrast, Lubuk Baja Sub-district experienced the lowest increase in waste generation, at 0.59%. The only sub-district that experienced a decrease in waste generation was Batu Aji Sub-district, which saw a reduction of 2.91% from the previous year [5].

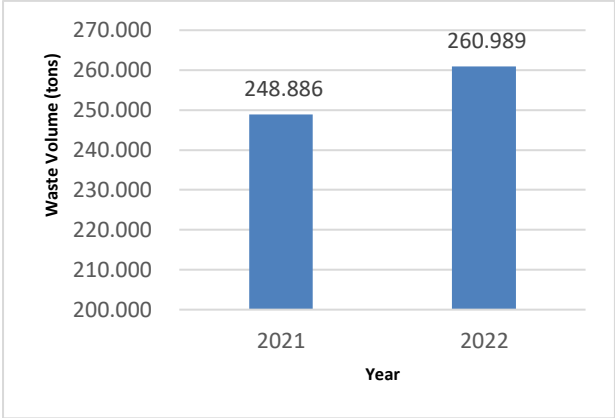

Figure 2. Increase in Waste Volume in Batam City 2021-2022

Source: Data processing results, 2024

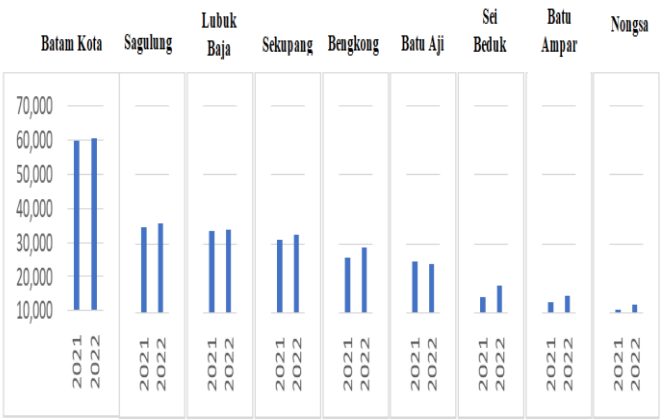

Figure 3. Increase in waste generation in each sub-district 2021-2022
Source: Data processing results, 2024

4.2 Existing Conditions of Waste Generation Based on Population and Population Density in Batam City

Data on household waste generation, population numbers, and population density by sub-district can be seen in Table 1. The total amount of household waste (mainland) entering the Punggur landfill in 2022 was 260,989 tons.

Table 1. Data on Waste Generation, Population and Population Density [5]

No	District	Waste volume (kg)	Total Population (people)	Population Density (people / km^2)
1	Batam Kota	60.336.220	208.965	4.345
2	Batu Aji	24.108.990	143.625	2.281
3	Batu Ampar	14.729.080	61.497	1.522
4	Bengkong	28.840.230	127.593	6.406
5	Lubuk Baja	34.038.780	86.277	2.360
6	Nongsa	12.478.650	90.626	295
7	Sagulung	35.839.290	226.040	3.401
8	Sei Beduk	17.895.770	100.768	814
9	Sekupang	32.722.000	172.347	1.534
	Total	**260.989.010**	**1.217.738**	**22.958**

Source: Data processing results, 2024

Figure 4 illustrates the comparison of the percentage of waste generation, population numbers, and population density. The sub-district with the highest waste generation is Batam Kota, with a waste generation percentage of 23.12%, followed by Sagulung Sub-district at 13.73%. Batam Kota has a higher female population ratio compared to Sagulung, which is indicated as a contributing factor to the higher waste produced by Batam Kota. Research conducted by Cantaragiu (2019) indicates that women tend to generate more food waste compared to men. Women also have a habit of cooking their own meals, which can lead to an increase in the amount of organic household waste [15].

Meanwhile, the sub-district with the lowest waste generation is Nongsa, with a percentage of 4.78%. This is because Nongsa has the lowest population density compared to other sub-districts. Population density has a significant and positive impact on waste generation. A study conducted in Java showed that an increase in population density significantly affects the amount of waste produced [16].

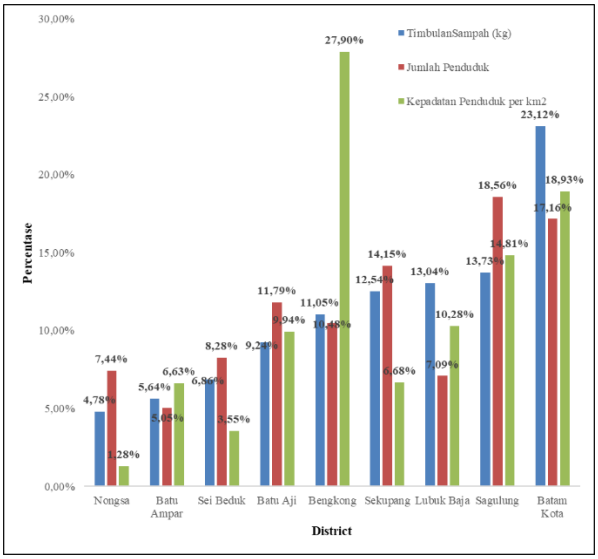

Figure 4. Comparison of waste generation, population and population density in nine sub-districts of Batam City.
Source: Data processing results, 2024

The amount of waste generation based on city classification in SNI 3983-1995 is used to calculate the total waste generation according to standardized measurements. The waste generation measurement used is the weight measurement for large city classification. A large city is defined as a city with a population ranging from 500,000 to 1,000,000 people [17].

Table 2 shows a comparison of waste generation amounts in the nine sub-districts of Batam City with the waste generation amounts in SNI 3983-1995 (0.7 – 0.8 kg/person/day). SNI 3983-1995 outlines that waste generation is derived from various waste source components, including permanent houses, semi-permanent houses, non-permanent houses, offices, shops, kiosks, schools, secondary arterial roads, secondary collector roads, local roads, and markets [18]. The sub-district with per capita waste generation exceeding the SNI standards is Lubuk Baja.

There may be specific variables influencing the population variable, such as the gender ratio of the population. Batam Kota and Lubuk Baja have a higher female-to-male population ratio compared to other sub-districts. Research by Talajaj and Walery (2015) indicates that areas with a higher female population ratio tend to generate more waste. This is because unmarried women and those managing households often have more time and resources to indulge themselves. Additionally, women are significant consumers with substantial spending in the economic environment [19].

Table 2. Comparison of waste generation based on SNI 3983-1995

No	District	Waste volume (kg/people. day)	SNI 3983-1995 (kg/people. day)	Conclusion
1	Nongsa	0,38	0,7 – 0,8	Does not exceed SNI
2	Batu Aji	0,46	0,7 – 0,8	Does not exceed SNI
3	Batu Ampar	0,66	0,7 – 0,8	Does not exceed SNI
4	Batam Kota	0,79	0,7 – 0,8	Does not exceed SNI

5	Sekupang	0,52	0,7 – 0,8	Does not exceed SNI
6	Bengkong	0,62	0,7 – 0,8	Does not exceed SNI
7	Sei Beduk	0,49	0,7 – 0,8	Does not exceed SNI
8	Sagulung	0,43	0,7 – 0,8	Does not exceed SNI
9	Lubuk Baja	1,08	0,7 – 0,8	Exceeds SNI

Source: Data processing results, 2024

Table 3 shows the basic statistical values of the available data. The waste generation variable has a range of values from 12,478,650 to 60,336,220, with a standard deviation of 14,542,363.712. The mean value for the waste generation variable is 28,998,778.89. The population variable has a range of values from 61,497 to 226,040, with a standard deviation and mean of 57,227.43 and 135,304.22, respectively. Meanwhile, the population density variable has a range of values from 295 to 6,406, with a standard deviation of 1,907.59. Based on the descriptive analysis results, the mean value for the population density variable is 2,550.89.

Table 3. Results of descriptive statistical analysis

Variable	Waste volume (kg)	Total Population (people)	Population Density (people / km^2)
N	9	9	9
Minimum	12.478.650,00	61.497,00	295,00
Maximum	60.336.220,00	226.040,00	6.406,00
Sum	260.989.010,00	1.217.738,00	22.958,00
Mean	28.998.778,89	135.304,22	2.550,89
Std.Dev.	14.542.363,71	57.227,43	1.907,59

Source: Data processing results, 2024

5. CONCLUSIONS

The following are the conclusions drawn from the study titled Evaluation of Existing Conditions of Waste Generation Based on Population Numbers and Population Density in Batam City: :

1. The waste generation entering Punggur Landfill from 2021 to 2022 increased by 4.86%. The sub-district that supplied the most waste was Batam Kota sub-district, with a total waste generation of 60,336,220 kg. The sub-district that supplied the least was Nongsa sub-district, with a waste generation of 12,478,650 kg. The highest increase was seen in waste generation in Sei Beduk and Nongsa sub-districts, with increases of 21.9% and 14.6%. Meanwhile, Lubuk Baja sub-district experienced the lowest increase in waste generation at 0.59%. The only sub-district that experienced a decrease in waste generation was Batu Aji, which amounted to 2.91%. The results of the calculation between population and the amount of waste generation showed that Lubuk Baja sub-district was the only sub-district that exceeded the SNI waste generation standard, which was 1.08 kg/person/day. There were other factors from the population variable that affected the amount of waste generation, namely the ratio of the population by gender.
2. The results of the descriptive statistical analysis showed that the waste generation variable had a value range of 12,478,650 - 60,336,220, with a standard deviation of 14,542,363.712 and a mean value of 28,998,778.89. The total population variable had a value range of 61,497 - 226,040. The standard deviation and mean of the total population variable were 57,227.43 and 135,304.22, respectively. Meanwhile, the population density variable had a value range of 295 - 6,406, with a standard deviation of 1,907.59 and a mean of 2,550.89.

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