Analisis Statistik untuk Prediksi Timbulnya Sampah Berdasarkan Proyeksi Pertumbuhan Penduduk Tangerang: Perspektif Lingkungan

Statistical Analysis for Waste Generation Prediction based on Tangerang's Population Growth Projections: An Environmental Perspective

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ABSTRACT

Tangerang is counted among Indonesia's fastest-growing industries and population since it is located near the capital. By the current population growth rate, the population in 2035 is expected to reach more than 2 million by applying the geometric method. Rapid population growth has severe environmental damage. A simple linear regression calculation was used to predict the Tangerang waste generation, and its expected value is 0.63 million tons by 2035. The correlation established a positive correlation between population and waste generation. The increase in the amount of waste can affect the formation of leachate, a toxic byproduct of waste decomposition, produced by Tangerang's open dumping system at the Rawa Kucing landfill. Increased waste creates more leachate, potentially contaminating groundwater and harming human health. Therefore, this study aims to forecast waste generation in Tangerang based on the population projection. Accurate waste predictions are crucial as inadequate leachate management poses environmental and public health risks through groundwater contamination. The findings presented here can guide stakeholders in formulating strategies to prevent and mitigate the dangers of groundwater contamination in Tangerang.

Keywords: Statistical analysis, Environmental perspective, Contamination, Population growth, Waste generation

INTRODUCTION

Tangerang is one of the cities in Banten Province, with an average population growth rate that increases yearly. Tangerang is divided into thirteen districts, with the most

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significant population density in Ciledug (Tangerang Central Bureau of Statistics, 2022). As a part of this study, a digital map of Tangerang is prepared by implementing a Geographic Information System (GIS), as shown in Figure 1. Tangerang has a population of over 1.5 million within an area of 184.23 km^2 (Tangerang Central Bureau of Statistics, 2020). Situated on the western border of the Indonesian capital city, Tangerang has become an area with rapid growth. Tangerang is considered very strategic in supporting the capital's economy, especially in the industrial sector, and it makes Tangerang known as the city of a thousand industries (Pradana, 2020).

The rapid development of population growth and industries in Tangerang have contributed to environmental quality degradation, that is, the intensification of waste generation. This relation has been observed by several authors (Weber & Sciubba, 2019; Ahmed et al., 2022; Ilham, 2021). Based on National Waste Management Information System's data from Indonesian Ministry of Environment and Forestry, the Tangerang's average amount of waste generation in 2021 is 1850 tons per day (Indonesian Ministry of Environment and Forestry, 2022). As the amount of waste generation has increased, waste has become a major problem in Tangerang, coupled with the capacity of the Rawa Kucing landfill, which is the largest landfill in Tangerang is almost full.

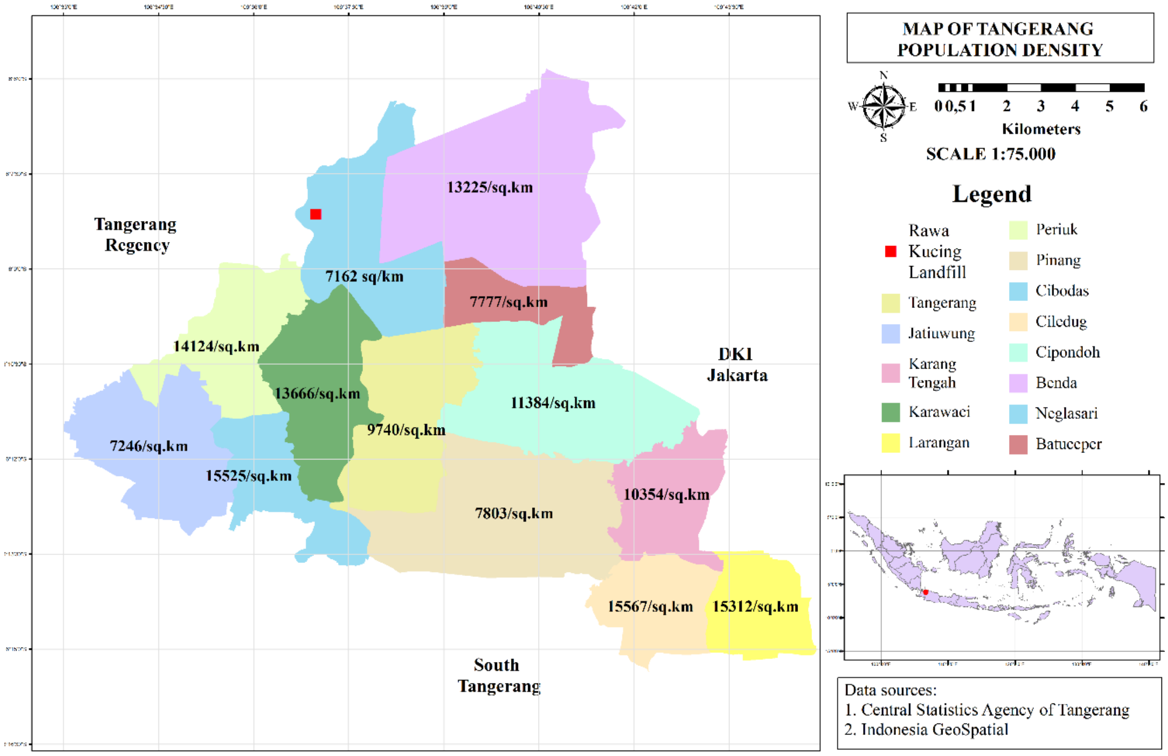

Figure 1. Map of Tangerang and the information on its population density

Rawa Kucing landfill, located in Neglasari district and adjacent to the Cisadane river, is Tangerang's main landfill. Rawa Kucing landfill implements an open dumping system in its waste management. An open dumping system is a typical Indonesian landfill constructed to meet the city's needs but offers little or no environmental protection. In open dumping sites, waste is piled and disposed of in a manner that is not environmentally friendly, increasing the risk of fires and trash avalanches (Priatna et al., 2019). One of the negative impacts of the open dumping system at the Rawa Kucing landfill is the potential for leachate to enter the soil around the landfill. Leachate is a contaminated fluid generated on account of the infiltration of water into landfills and its percolation through waste, containing several dissolved and suspended materials (T. George & Frank, 2022). Leachates may contain toxic organic matter, ammonia nitrogen compounds, heavy metals, sulfide, hardness acidity, phosphate, alkalinity, chlorinated organic and inorganic salts, and other toxicants (Youcai, 2019). The complexity of these characteristics makes the leachate more challenging to manage and is known as the major source of groundwater contamination.

Most local communities around the Rawa Kucing landfill rely on groundwater for daily living, although the aquifers are vulnerable to leachate contamination. Luczaj & Masarik (2015), suggest that groundwater quality and quantity must be guaranteed. Thus, it can be used for the daily living needs of the community following water quality standards. Water quality can significantly impact health through waterborne disease outbreaks and contribute to background disease rates. The contamination of these groundwater sources around the Rawa Kucing landfill by leachate would render them unwholesome for consumption and may be costly and difficult to treat.

Based on this background, waste generation in Tangerang is primarily a function of population factors. Therefore, the objective of the present study is to estimate the amount of waste generated in Tangerang municipalities based on census data. Accurate forecasting of waste generation plays a key role since inadequate leachate management poses an environmental and public health risk from surface or groundwater contamination, affecting water supply to local populations and damaging the local flora/fauna (Intharathirat et al., 2015). The result of this study can become a consideration for stakeholders for decision-making in the future in the context of preventing and mitigating the dangers of groundwater contamination in Tangerang.

RESEARCH METHODS

Study Area

Geographically, Tangerang is located between 6^0 06' – 60 13' S and 106^0 36' – 106^0 42' E with an altitude between 10 - 18 meters above sea level (m asl) and a slope of 0 - 3%. Tangerang's climate is considered a tropical rainforest, where the average annual rainfall is around 171 mm (Tangerang Central Bureau of Statistics, 2022). In 2021, Tangerang's daily wastes were more than 1850 tons. National Waste Management Information System’s data reported that the main fraction of Tangerang waste composition is organic matter (64%). In comparison, the other components are plastics (11%), papers (9%), fabrics (4%), metals (2%), glasses (2%), and others (8%) (Figure 2). This study focused on the Rawa Kucing landfill at the northern border of Tangerang, which has been operating since 1992. The total area of the landfill is about 350000 m^2. According to Tangerang Environmental Agency (2022), the landfill receives around 1500 tons of waste annually from 13 districts in Tangerang.

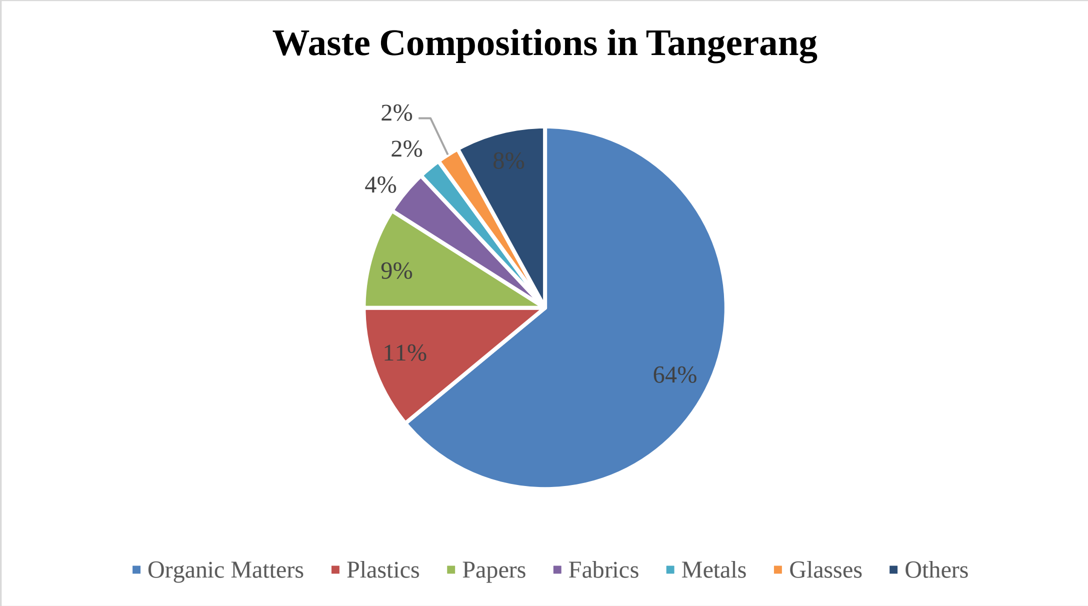

Figure 2. Waste compositions in Tangerang

Data and Method

The data sources used in this research were obtained from literature studies that support the research, population data obtained from the Central Statistics Agency of Tangerang and data of the amount of waste generation obtained from the Tangerang Environmental Agency and from National Waste Management Information System. In this study, to estimate the waste generation in Tangerang until 2035 as a function of population, the projection of population in Tangerang is calculated using the geometric method. This study used a simple linear regression to analyze the correlation between two variables; *x* represents the population and *y* represents the amount of waste generation. The correlation analysis was evaluated using the IBM SPSS 23 statistics software. In this statistical test procedure, the p-values are generated to promote the credibility of this study. The correlation between the two variables was considered statistically significant if the significance was .05 or less. Table 1 shows the interpretation of the correlation coefficient.

Table 1. Range of correlation coefficient and the corresponding levels of correlation

Coefficient Intervals (Positive)	Correlation
0.00 – 0.199	Negligible correlation
0.20 – 0.399	Weak correlation
0.40 – 0.599	Medium correlation
0.60 – 0.799	Strong correlation
0.80 – 1.000	Robust correlation

Source: (Meghanathan, 2016)

In addition to the result of waste estimation, the Rawa Kucing leachate quality testing was also carried out in this study. Leachate samples were acquired from two locations that consistently produce new leachate using the grab sampling method. The grab sampling method collected leachate samples once from a predetermined location. The acquired samples were subjected to evaluating leachate quality criteria such as pH, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), detergent and fat, oil and grease (FOG). pH was analyzed in situ using a digital pH meter, while the other parameters were analyzed in the laboratory. The TSS was measured using method 2540C, BOD using Winkler, COD using the titrimetric reflux, detergent using a spectrophotometer, and FOG using the Gravimetric method.

A simple mathematical model for the calculation of annual leachate volume from the Department of the Environment, Water, Heritage, and the Arts, Australian Government, was presented in this study (Ibrahim et al., 2017). Parameters used include annual rainfall and the surface area of the landfill. As more water flows through the solid wastes, more pollutants are leached. Therefore, it is essential to know methods that can be used to estimate the amount of leachate generation at a landfill site (Kamaruddin et al., 2015). These calculations are presented as an illustration of the impact of waste generation in Tangerang.

RESULTS AND DISCUSSIONS

Projections of Population Growth

The population of Tangerang is the key element in assessing the quantities of solid waste generated and leachate volume. One method for forecasting population growth is using the geometric method (Equation 1).

$$P_n = P_o(1 + r)^n \quad (1)$$

Pn is the population for *n* years to come, *Po* is the population at the end of the period, *r* is the average population growth per year, and *n* is the projection period (Sutikno, 2016). The geometric method assumes that the population will increase geometrically, with the growth rate being considered the same for each year (Samosir & Sri, 2010). The research results from Hartati et al., 2019 state that the geometric method is an estimation method of the population projection closest to the actual data compared to other methods. Table 2 shows the population of Tangerang in 2017 – 2023. However, there was a declination on population in 2020 due to COVID-19.

Table 2. The population of Tangerang in 2017 – 2023

Year	Population (People)
2017	2139891
2018	2185304
2019	2229000
2020	1895486*
2021	1911000
2022	1930556
2023	1957584

* A decline in population due to COVID-19 pandemic era. Source: (Tangerang Central Bureau of Statistics, 2022)

Based on the data from Tangerang Central Bureau of Statistics, the average population growth rate (*r*) is 0.014. Using the geometric method, this growth rate is then used to predict the population in Tangerang from 2024 - 2035. The calculation results for population projections until 2035 can be seen in Table 3. The following is an example of the calculation of the population in 2024.

$$P_{2024} = P_{2023}(1 + r)^n$$
$$= 1957584\,(1 + 0.014)^1$$
$$= 1984990 \text{ people}$$

Table 3. Projections of population in Tangerang

Year	Population (People)
2024	1984990
2025	2012780
2026	2040959
2027	2069532
2028	2098506
2029	2127885
2030	2157675
2031	2187883
2032	2218513
2033	2249572
2034	2281066
2035	2313001

Predictions of Waste Generation

The amount of waste generated in the last eight years in Tangerang based on Tangerang Environmental Agency's data is shown in Table 4.

Table 4. Tangerang's waste generation

No	Year	Waste Generation (Ton)
1	2012	194675
2	2013	216305
3	2014	302799
4	2015	333079
5	2016	373648
6	2017	421545
7	2018	459484
8	2019	578038

Table 4 shows that every year there is an increase in the amount of waste generation in Tangerang. Based on data from the National Waste Management Information System, organic matters hold the highest waste composition in Tangerang, with 64 percent. Based on these percentages and the data in Table 4, Table 5 shows the results of the calculation of the amount of organic waste in the last eight years in Tangerang.

Table 5. Tangerang's organic waste generation

Year	Waste Generation (Ton)	Organic Waste Generation (Ton)
2012	194675	124592
2013	216305	138435
2014	302799	193791
2015	333079	213171
2016	373648	239135
2017	421545	269789
2018	459484	294070
2019	578038	369944

Corresponding to the amount of waste generated in the last eight years and the data on the population of Tangerang, forecasting the generation of waste in Tangerang can be done for the next few years. In this study, the data for 2020 – 2023 was not included in the regression calculations, considering there were COVID-19 anomalies in that period. This anomaly is considered to cause the regression model obtained to be inaccurate. High mortality and other factors such as social restrictions and lockdowns can cause significant changes in waste generated. Forecasting the amount of waste generation can be done using a simple linear regression method (Equation 2). Simple linear regression is a statistical method to test the causal relationship between variables *x* and *y* (Katemba & Djoh, 2017).

$$Y = a + bX \tag{2}$$

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{n(\Sigma x^2) - (\Sigma x)^2} \tag{3}$$

$$b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2} \tag{4}$$

where the causal factor is denoted by *x* as the independent variable, *y* is the dependent variable or the response variable, *a* is a constant, *b* is the regression coefficient, and *n* is the amount of data.

The Classical Assumption Test

The classical assumption test is a series of important tests before a simple linear regression analysis to ensure that the resulting regression model is valid and reliable. Several assumptions must be met so that the conclusions from the test results are not biased. The assumptions include the normality test, linearity test, and heteroscedasticity test (Udin, 2021).

a. Normality Test

The normality test in simple linear regression is a statistical test to determine whether the residual (the difference between the actual and predicted values) in the regression model is normally distributed. In this study, the normality test was carried out using the Shapiro-Wilk test since the number of data tested is < 50 (n = 8). Interpretation of the test results states that the residuals are normally distributed if the significance is > .05. The normality test result for this study is shown in Figure 3.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Unstandardized Residual	.173	8	.200*	.959	8	.796

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 3. Result of the normality test

In Figure 3, the result of the Shapiro-Wilk inform that the residual data is normally distributed, considering the significance value is > .05 where [*W*(8) = .959, p = .796]. The significance value is marked with red box.

b. Linearity Test

The linearity test in simple linear regression is a statistical test to determine whether the relationship between the independent and dependent variables is linear. The linearity test is carried out to ensure the regression model is appropriate and accurate. In this research, the linearity test was carried out using a visual test obtained from scatterplot graphs and looking at the Sig Deviation from Linearity value. The results of the sig deviation from the linearity value show that there is a linear relationship between the independent variable (*x*) and the dependent variable (*y*) if the significance value is > .05. The pattern in Figure 4 shows a linear relationship between the population variable (*x*) and the waste generation (*y*). This scatter plot pattern is also strengthened by the Sig Deviation from Linearity value obtained at .879 (> .05), which shows that there is a linear relationship between population (*x*) and waste generation (*y*) (Figure 5).

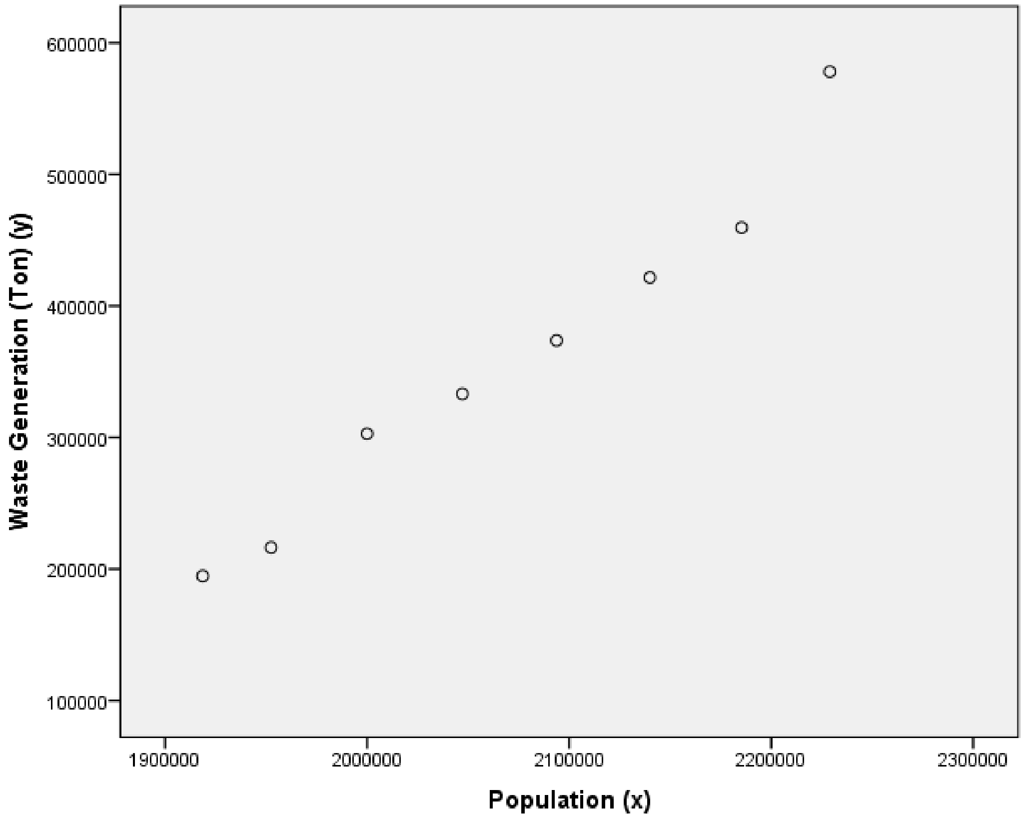

Figure 4. Scatter plot of linearity test between population variable (*x*) and waste generation variable (*y*)

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Waste Generation (Ton) (y) * Population (x)	Between Groups	(Combined)	1.045E+11	3	3.485E+10	15.717	.011
		Linearity	1.039E+11	1	1.039E+11	46.885	.002
		Deviation from Linearity	590006680.3	2	295003340.2	.133	.879
	Within Groups		8866954413	4	2216738603		
	Total		1.134E+11	7			

Figure 5. Results of the linearity test between variables *x* and *y* that are seen from the significance value

c. Heteroscedasticity Test

The heteroscedasticity aims to test a regression model in order to determine whether variance and residuals are unequal from one observation to another. A good regression should have no heteroscedasticity. In this study, Spearman's rho test was carried out to accurately detect symptoms of heteroscedasticity by correlating the independent variable (population) with the residual. Symptoms of heteroscedasticity occur if the 2-tailed Sig value is $< .05$, whereas if $> .05$, then no symptoms of heteroscedasticity are detected. Figure 6 shows that the 2-tailed Sig value obtained is .610 ($> .05$), thus it can be concluded that there are no symptoms of heteroscedasticity since the significance value obtained is greater than .05.

Correlations

			Population (x)	Unstandardized Residual
Spearman's rho	Population (x)	Correlation Coefficient	1.000	-.214
		Sig. (2-tailed)	.	.610
		N	8	8
	Unstandardized Residual	Correlation Coefficient	-.214	1.000
		Sig. (2-tailed)	.610	.
		N	8	8

Figure 6. The test results to detect symptoms of heteroscedasticity using the Spearman's rho

A Simple Linear Regression

After the classical assumption test has been carried out, the next step is to determine the linear regression equation in order to predict the waste generation for the following years. Based on the result of the simple linear regression obtained, in this study, a significant regression equation was obtained [$F(1,6) = 186.846$, $p < .001$] with R^2 of .969 (Figure 7 and 8). Figure 7 shows the correlation value or level of relationship between variables (*R*) of .984, indicates a robust positive correlation, according to the explanation in Table 1. It means that when one variable changes, the other variable changes in the same direction, i.e., the more population, the more waste is generated in Tangerang. This study's result agrees with the study by another researcher that showed a robust positive relationship between population and waste generation (Bello, 2018; Omololu & Lawal, 2013; Supangkat & Herdiansyah, 2020). One variable increases (the population), and the other (waste generation) also tends to increase. In the other hand, a coefficient of determination was obtained is .969, which means that the influence of independent variable (population) on the dependent variable (waste generation) was 96.9%. The remaining 3.1% is caused by other factors.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.984[a]	.969	.964	24248.262

a. Predictors: (Constant), Population (x)

b. Dependent Variable: Waste Generation (Ton) (y)

Figure 7. Result of model summary that contain correlation value and coefficient of determination

Figure 8 is the output that is used to answer a simple regression hypothesis, which hypothesis is:

- H0: variable *x* (population) does not affect variable *y* (waste generation)
- H1: variable *x* influences variable *y*

The following are guidelines that can be used for decision-making:

- If the significance value (sig) is > .05, then H0 is accepted
- If the significance value (sig) < .05, then H0 is rejected

In this study, the sig value (.000) < .05 was obtained, furthermore H0 was rejected and it can be concluded that variable *x* (population) affects variable *y* (waste generation).

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.099E+11	1	1.099E+11	186.846	.000[b]
	Residual	3527869307	6	587978217.8		
	Total	1.134E+11	7			

a. Dependent Variable: Waste Generation (Ton) (y)

b. Predictors: (Constant), Population (x)

Figure 8. Result of hypothesis test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1977453.168	171213.013		-11.550	.000
	Population (x)	1.129	.083	.984	13.669	.000

a. Dependent Variable: Waste Generation (Ton) (y)

Figure 9. Coefficient values from linear regression

From Figure 9, the constant value of *a* is -1977453.168, while the regression coefficient (*b*) is 1.129. A simple regression equation can be written as $Y = a + bX$ (Equation 2). Based on the result, the equation for forecasting the amount of waste generated in Tangerang is $Y = -1977453.168 + 1.129X$. The constant value *a* is -1977453.163, indicating that when the population is 0, the predicted waste generation is -1977453.163. However, since the amount of waste cannot be negative, this value is interpreted as the minimum possible value of waste generation. The constant *b* or regression coefficient of 1.129 shows that for every additional one person in the population, the waste generation is predicted to increase by 1.129 tons.

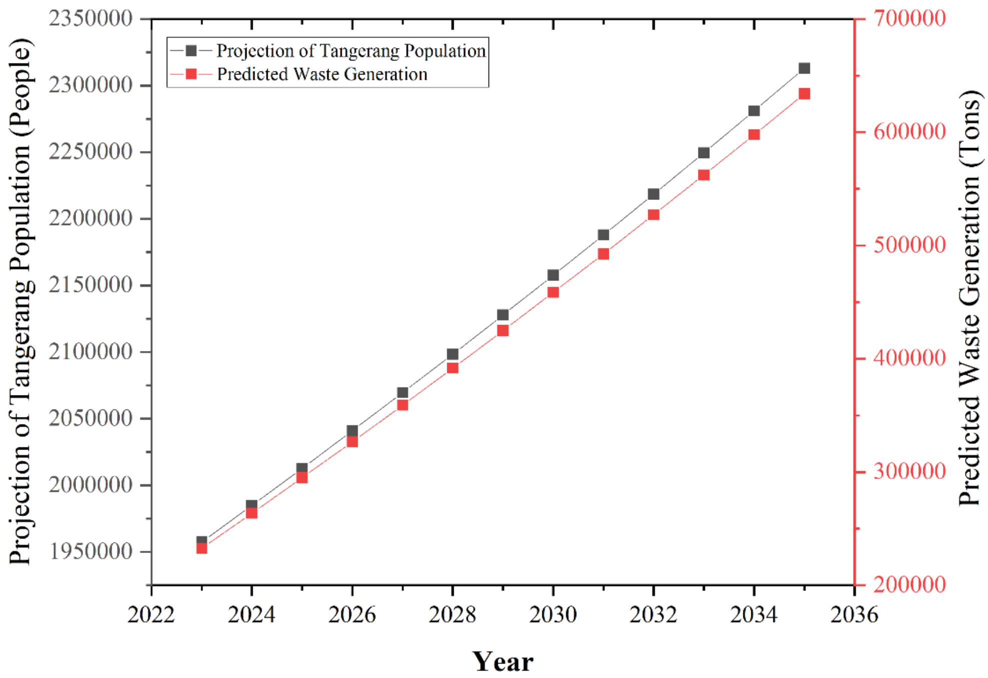

Figure 10. The correlation between projection of Tangerang population and predicted waste generation

Furthermore, the simple linear regression equation obtained can then be used to predict the waste generation (*Y*) until 2035 by entering data on the projected population of Tangerang (*X*) until 2035 (data in Table 3). Figure 10 describes forecasting the waste generation until 2035 in Tangerang. Based on the graph in Figure 10, it can be seen that the predicted waste generation until 2035 has increased every year in line with the increase in population. The graph shows that the predicted waste generation in 2035 is 633925 tons. As previously explained, the calculations did not include data for 2020 – 2023 due to the COVID-19 anomaly. However, despite this, it can be seen that the data before and after the anomaly period has a consistent trend (linear). Thus, it can be said that the regression model in this study can produce accurate predictions.

Estimation of Leachate Production

The amount of waste generated in Tangerang, which is increasing along with the increase in population, will impact decreasing environmental quality, especially regarding groundwater pollution by leachate produced by piles of garbage. Groundwater pollution will harm the people who live around the Rawa Kucing landfill. Most of the population still uses groundwater sources for their clean water needs. On the other hand, around the Rawa Kucing landfill, many agricultural lands utilize groundwater for irrigation. Neglasari sub-district, where the Rawa Kucing landfill is located, is famous for producing vegetables: spinach, water spinach, and mustard (Tangerang Central Bureau of Statistics, 2022). The irrigation system for land uses water sourced from groundwater. The hazardous leachate content can negatively influence agricultural products around the Rawa Kucing landfill.

The leachate quality test was carried out by measuring the concentration parameters of pH, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fat and oil, detergent, and total ammonia. The leachate taken is new. The following Table 6 shows the results of the leachate quality inspection.

Table 6. The leachate parameter test result

Parameter	Standard Max	Result	
		Sample 1	Sample 2
pH	6.0 – 9.0	6.7	6.5
TSS (mg/L)	50	179	124
BOD (mg/L)	85	157.8	462
COD (mg/L)	100	768	640
Fat, Oil, and Grease (FOG) (mg/L)	10	37.9	6.1
Detergent (mg/L)	2	0.402	0.052
Total Ammonia (mg/L)	10	28	27.25

Based on the leachate quality testing results, the pH values obtained for the two samples were 6.7 and 6.5. The pH at the Rawa Kucing landfill is still within the permitted pH quality standards range. The pH of the Rawa Kucing landfill can be classified as acidic, indicating that the leachate sample observed is leachate that comes from young waste, and the degradation process has not been carried out optimally. The leachate is also associated with carboxylic acids and bicarbonate ions. As waste ages, the pH of leachates changes from values corresponding to acidic to alkaline solutions (Wdowczyk & Szymańska-Pulikowska, 2021).

Total Suspended Solids (TSS) are the portion of fine particulate matter that remains suspended in water (Parwati & Purwanto, 2017). The presence of these solids causes turbidity in the water because these solids are not dissolved and cannot settle directly. This study's TSS value for two leachate samples exceeded the threshold standard. Suspended solids, especially organic ones with 64 presentations of Tangerang waste, are suspected of causing turbidity in the two leachate samples from the Rawa Kucing landfill. Biochemical Oxygen Demand (BOD) is the amount of oxygen required by bacteria in the decomposition of organic matter under aerobic conditions. The BOD value also describes the oxygen needed to stabilize carbon organic matter in biological processes in water bodies (Daroini & Arisandi, 2020). Organic matter contained in the water is the result of the decay of dead plants and animals and the result of waste from domestic and industrial waste. This study obtained a very high BOD value for both samples. The results obtained are the same as the leachate quality in Indonesia (Emalya et al., 2020). A high BOD value will cause low dissolved oxygen (DO) value, whereas the dissolved oxygen in the water is importantly used to oxidize organic material (Abdullahi et al., 2021). The low DO value indicates the poor water quality and it threatens the life of aquatic organisms, such as causing the death of aquatic organisms (Tarima et al., 2016). It will also result in aerobic bacteria's death and anaerobic bacteria's development.

Chemical Oxygen Demand (COD) is the oxygen needed to oxidize organic substances in water samples. The presence of organic matter in water generally comes from the activities of living things and humans that often throw domestic and industrial waste into the waters. In this study, the results of COD levels were very high and exceeded the threshold determined in both samples. This COD level indicates that non-biodegradable organic matter is the main waste composition in the Rawa Kucing landfill. Organic matter that cannot be decomposed will increase the level of COD in the water, causing the water to be oxidized, which results in lower levels of oxygen in the water (Noerfitriyani et al., 2018).

This study used the gravimetric method to determine fat, oil, and grease (FOG) in leachate. The result found that the oil and fat levels exceeded the standard threshold for sample 1, while sample 2 was below the predetermined threshold standard. The high oil content in sample 1 can be caused by the leachate sampling position that produces a new waste. Of course, the waste material may contain much FOG, and when exposed to rainwater, the leachate formed will contain the oil, which will then float and cover the surface of the leachate. High levels of FOG will be hazardous if it affects the subsurface aquifer system around the Rawa Kucing landfill since the high level of FOG can kill fauna in the water (Husain et al., 2014). Detergent parameters are almost undetected through the examination, based on spectrophotometer test results. The result indicates that the level of detergent leachate from the Rawa Kucing landfill still meets the quality standard.

This study showed that the ammonium content in the leachate of the Rawa Kucing landfill exceeds the regulatory threshold that has been set. Furthermore, the leachate of the Rawa Kucing landfill has the potential to pollute the environment, so it needs to be processed before being released into the environment. The concentration of ammonium in leachate tends to increase over time. Landfills with an operational life of >10 years tend to produce leachate with ammonium content above 1000 mg (Deng et al., 2022). Although the Rawa Kucing TPA has been operating for over 20 years, both samples did not show ammonia levels exceeding 500 mg. The leachate sample taken for this study was new and it could be the reason the ammonia levels stayed within the threshold, so the ammonia level was not too high. The ammonia content in the leachate of the Rawa Kucing landfill is thought to come from breaking down proteins in the waste.

As an illustration of the volume of leachate produced by the Rawa Kucing landfill, simple mathematical modeling for leachate volume calculation from the Department of the Environment, Water, Heritage, and the Arts Australian Government was used in this study. The leachate volume is expressed as follows (Equation 5).

$$V = 0.15 \; x \; R \; x \; A \quad (5)$$

where V is the leachate volume discharge in a year (m^3), R is the annual rainfall (m), and A is the surface area of the landfill (m^2). Rainfall data for the last five years were obtained from meteorological data of Tangerang station. The total area of the Rawa Kucing landfill is 34.8 hectares, with 30 hectares of waste cell area for the landfill. Figure 11 illustrates the amount of leachate production for the last six years (2017 – 2022) at the Rawa Kucing landfill. Based on the calculation results, the volume obtained by leachate varies from 4151 m^3/year to 8937 m^3/year. As expected, the volume of leachate will increase with rainfall every year. The highest rainfall in the last six years occurred in 2022, so in that year, the total volume of leachate produced became the highest among other years.

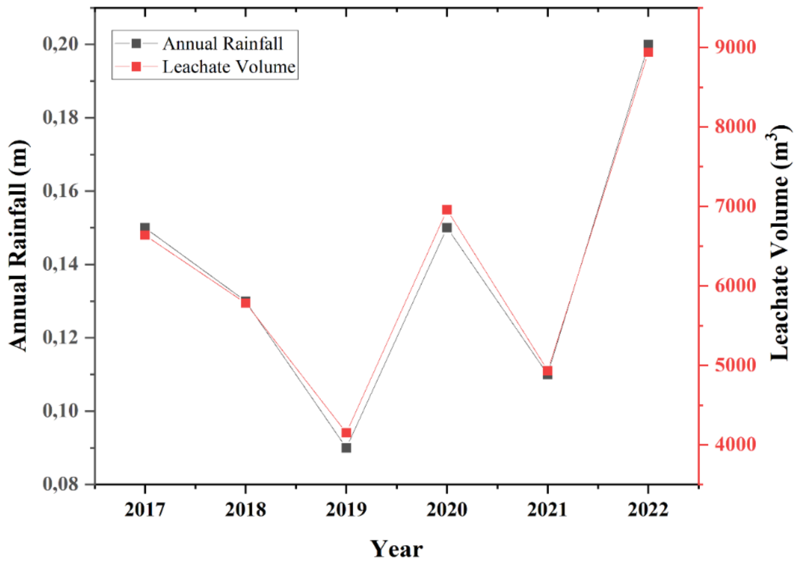

Figure 11. Relationship between leachate volume and annual rainfall

However, the leachate volume calculation in this study is a simple calculation of the volume of leachate generated per year based only on total area and rainfall data, not an accumulated leachate volume from year to year. To obtain leachate accumulation stored in the soil, it must consider the amount of precipitation and stormwater run-on and run-off, the volume of groundwater entering the waste-containing zone, and the waste's moisture content and absorbent capacity material (Nicholas, 1998). The calculation considering several important parameters will be more accurate and have an enormous total of leachate volume since it also considers the accumulation of leachate stored from previous years.

According to L. George (1994), Indonesia is included in tropical rain forests around the equator, about 15 degrees in the north and south. This climate is usually characterized by high precipitation and humidity, so Indonesia has high rainfall. Based on these facts, the high rain intensity will affect the leachate production in Rawa Kucing. The accumulation of garbage reaching 18 - 20 meters in Rawa Kucing will produce a massive volume of leachate when rainwater enters the waste pile. As a result of the relationship between population density variables and the amount of community waste generation, various influences arise and cause environmental quality to be polluted. As the population continues to increase, the production of waste generated by the community will continue to increase. The amount of waste generated causes various types of pollution, especially water pollution due to leachate. The large volume of leachate is hazardous, considering that the leachate test results at the Rawa Kucing landfill show that the leachate quality at the Rawa Kucing landfill does not meet the quality standards.

CONCLUSION

This study concerns the impact of population on the waste generation. A simple linear regression calculation was used to predict the Tangerang waste generation. Based on the result of the simple linear regression obtained, a significant regression equation and a significant positive correlation between population and waste generation in Tangerang was obtained. A determination coefficient of .969 was obtained, indicating the influence of population on the waste generation is 96.9%. As the population increased, the amount of waste generated also increased. The value of 0.63 million tons of Tangerang waste is expected in 2035 using the regression equation of Y = -1977453.168 + 1.129X. The increase in waste can affect the formation of leachate that containing highly toxic components. Based on the laboratory test results, the leachate quality at the Rawa Kucing landfill does not meet the quality standards. Accurate waste predictions are crucial as inadequate leachate management poses environmental and public health risks through groundwater contamination. The findings presented here can guide stakeholders in formulating strategies to prevent and mitigate the dangers of groundwater contamination in Tangerang.

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