Comparison of Solid Waste Generation During and Before Pandemic Covid-19 in Indonesia Border Island (Riau Islands Province, Indonesia)

by Mega Mutiara Sari

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ABSTRACT

Waste in the archipelagic border area must be appropriately managed to maintain diplomatic relations. Indonesia's Riau Islands Province is an archipelagic region in Indonesia with limited solid waste infrastructure development. The capacity of the waste infrastructure depends on the rate of waste generation and is influenced by the socioeconomic conditions of the community. This study aims to study the model for estimating the rate of waste generation in the Riau Islands. This study uses data before and during the Covid-19 pandemic in 2019 and 2020. The estimation model uses a multiple linear regression model with independent variables such as gross regional domestic product, access sanitation, total population, and human development index. The fixed variable is the incidence of waste generation rate. During the pandemic Covid-19, the generation and composition of waste in the Riau Islands Archipelago did not experience significant changes, so the waste generation and composition characteristics are the same. However, the variable human development index (0.053) and the population (0.012) significantly increase the waste generation rate. The gross regional domestic product (0.017) negatively correlates, reducing the waste generation rate. The Riau Islands, which has an ocean area of 96%, is a source of life and significant to manage because the waste can be released into the ocean. Therefore, management from sources through policies considering the gross regional domestic product, total population, and human development index needs to be considered to reduce waste generation in the archipelago.

Keywords: Archipelago, waste generation, comparison, socio-economic analysis, multiple linear regression, pandemic Covid-19.

INTRODUCTION

Riau Islands Province, Indonesia, is an archipelago with many islands determined to become one of the centers of the national economy but still has waste problems [Zainul Ikhwan et al., 2021]. Many areas in the Riau Islands have not maintained environmental cleanliness [Jocom et al., 2021], so the current waste problem cannot be adequately handled. Many losses are felt starting

from the health of humans or other creatures and can help the environment. Many waste piles are caused by a lack of awareness and understanding of humans or the community in managing waste [Kedzierski et al., 2020; Koko et al., 2022; Phelan et al., 2020; Suryawan et al., 2022]. Waste management can be done by sorting or separating waste based on waste, namely organic and non-organic waste [Sutama, 2021]. So if the community carries out waste sorting, it can at least reduce the pile of waste in the area and make it easier for officers to process waste destruction and processing [Widayat et al., 2021].

Riau Islands Province has 19 leading islands directly connected to neighboring countries [Setiawan & Mahadiansar, 2020]. However, regional development with neighboring countries is not yet optimal. Several things that need attention are the welfare of the people in the border area [Nengsih & Setyadiharja, 2017]. One of the crucial ones is the generation of marine debris carried by currents and borders to border areas in Indonesia [Purba et al., 2021]. Internally, this situation is caused by the lack of availability of collection facilities and infrastructure, the little fleet of personnel, and the difficulty of finding non-governmental organizations that can be carried out with the government in handling waste properly in the archipelago. There is limited land that can be used as a landfill because it is increasingly difficult to obtain appropriate space and the distance is further from the city center. Furthermore, the need for significant funds to demand landfill land is an external factor affecting the waste problem [Seow Ta Wee et al., 2022]. The above conditions encourage better archipelagic waste management efforts to handle waste as early as possible, as close to the source, and reuse waste as much as possible [Brotosusilo et al., 2020]. Through this research that focuses on social and economic aspects, it is hoped that the causes of increasing the amount of waste in the archipelago can be found.

Gross regional domestic product is the amount of added value for goods and services produced by various production units in the territory of a country within a certain period [Magdalena & Suhatman, 2020; Suarmanayasa et al., 2019]. Household consumption expenditure includes various household final expenditures on goods and services to directly meet individual or group needs. Household expenses here include food and beverages other than restaurants; clothing, footwear, and maintenance services; housing

and household equipment; health and education; transportation and communication; restaurants and hotels and more [Mien & Said, 2018]. The higher the Gross regional domestic product, the higher the consumption pattern of the community and indirectly increases the rate of waste generation [Gui et al., 2019].

In addition, another challenge faced in developing a solid waste management system in Indonesia is the low level of access to solid waste services [Andriani & Atmaja, 2019; Khair et al., 2019; Kubota et al., 2020]. Based on the 2015-2019 RPJMN, the Government of Indonesia has set a universal access target in the sanitation sector, namely increasing population access to proper sanitation (domestic wastewater, solid waste, and environmental drainage) to 100% at the level of basic needs [Kerstens et al., 2016; Nalle et al., 2019]. Increasing access to sanitation will reduce the rate of a waste generation because it is difficult for residents to handle and reduce the waste they produce. Research conducted in India, Bangladesh, Nepal, Sri Lanka, and Pakistan showed that waste generation in these five countries increased from 0.2 to 1.4 kg/day, in line with the increase in population in their respective settlements [Khajuria et al., 2008]. Apart from the increasing population, the human development index influences waste management [Namlis & Komilis, 2019]. However, in terms of waste, the human development index is a composite index based on three indicators: life expectancy at birth, adult literacy rate and the average length of schooling, and purchasing power [Lind, 2004].

Knowing the waste generation in the archipelago can be used as a policy and strategy to build a new paradigm that focuses on local and central government services in the Riau Islands Province as a border area in Indonesia. This study aims to study the model for estimating the rate of waste generation in the Riau Islands based on gross regional domestic product, access sanitation, total population, and human development index.

METHOD

The location of this research was carried out in the Riau Islands Province (Figure 1). The Riau Islands Province was chosen as the location of this research because Riau Province has experienced relatively fast growth and development and has quite a lot of natural resources. In

addition, the area of the Riau Islands Province has very open accessibility in various directions to create development opportunities to improve the welfare and prosperity of the community and regional development.

The data needed in this study is waste generation data by region in the Riau Islands Province in sorting waste by province obtained from an official website https://sipsn.menlhk.go.id/sipsn/ [Kementerian Lingkungan Hidup dan Kehutanan, 2021] and the Indonesian statistical center agency [BPS, 2021] (Table 1). The data collected is from community behavior data on waste generation from 2019 to 2020. This study has four independent variables: gross regional domestic product, access to sanitation, population, and human development index, and one dependent variable is the waste generation rate. The research data was collected from secondary data in Table 1, and then the data were analyzed using Multiple Regression Analysis (MRA). Multicollinearity test is used to test whether there is a correlation between the independent variables in the regression model. If there is a correlation, it is called a multicollinearity problem. A good regression model should not have a correlation between the independent variables. If it is proven that there is multicollinearity, it is better if one of the existing independents is removed from the model, then the regression model is made again. An autocorrelation test is a test where the dependent variable is not correlated with the value of the variable itself, both the

value of the previous period and the value of the period after. The regression models in this study are following equation 1.

$$Y = \beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 + e \qquad (1)$$

where: Y – waste generation, $X1$ – regional domestic product, $X2$ – sanitation access, $X3$ – total population, $X4$ – human development index.

Regression results are determined by the coefficient of determination, in essence, measuring how far the ability of a model to explain the variation of the dependent variable. The value of the coefficient of determination is between 0 and 1. A small matter of R^2 means a minimal interpretation of the dependent variable. A value close to 1 means that the independent variables can provide all the information needed to predict the dependent variable.

RESULT AND DISCUSSION

The distribution of waste generation rates in the Riau Archipelago Province is very different from one region to another (Figure 1). The Covid-19 pandemic is like the closure of teaching and learning activities in schools and universities. The impact of the Covid-19 pandemic requires the world's population to carry out social and physical distancing, causing changes in human life. The community must work from home by implementing WFH (Work from Home) for workers

Table 1. Secondary data used in model analysis in determining waste generation in Riau Islands Province

Year	Region	Gross regional domestic product[1]	Access sanitation[1]	Total population[1]	Human development index[1]	Waste generation (tons/day)[2]	Waste generation rate (kg/person·day)
2019	Kota Tanjung Pinang	20,167	87	211,583	79	143.53	0.68
2019	Kota Batam	164,490	95	1,376,009	81	1,332.39	0.97
2019	Kab. Lingga	4,274	60	89,781	65	27.28	0.30
2019	Kab. Kepulauan Anambas	17,440	26	42,309	68	12.73	0.30
2019	Kab. Karimun	13,544	95	232,797	71	175.36	0.75
2019	Kab. Bintan	21,303	81	159,403	74	51.30	0.32
2020	Kota Tanjung Pinang	19,665	86	227,663	79	149.06	0.65
2020	Kota Batam	161,364	96	1,196,396	81	837.48	0.70
2020	Kab. Lingga	4,292	59	98,633	65	27.83	0.28
2020	Kab. Kepulauan Anambas	14,454	24	47,402	69	12.88	0.27
2020	Kab. Karimun	13,311	90	253,457	71	177.20	0.70
2020	Kab. Bintan	20,744	77	159,518	74	53.42	0.33

Note: [1] BPS, 2021; [2] Kementerian Lingkungan Hidup dan Kehutanan, 2021.

and SFH (School from Home) for students [Ali-yyah et al., 2020; Suyadi & Selvi, 2022].

The comparison results of the generation and composition of household waste before and during the Covid-19 pandemic are different. It was found that there was an increase in the household waste generation of up to 38.32% in Batam City (Figure 2). While other areas also showed a downward trend in waste generation, while Kab. Bintan experienced an increase of only 3.9%. This is influenced by the need to look at the waste composition data. However, there was a decrease in waste generation in unit volume as controlled by the dominant type of plastic waste generated during the Covid-19 pandemic, namely plastic bags with a smaller volume [Patrício Silva et al., 2021; Sari, Inoue, Septiariva, et al., 2022; Septiariva et al., 2022; Torres & De-la-Torre, 2021]. In addition to the types of plastic waste, cardboard, Styrofoam, and masks, which are commonly used for daily activities, have increased during the pandemic [Cordova et al., 2021; Sari, Yosafaat, et al., 2022].

To see the overall effect of the pandemic, the grouping of waste generation data before and during the pandemic shows that the average is not significantly different. For example, table 2 shows the significance of (0.67). This concludes that the generation of waste in the archipelago has not changed

significantly. However, some researchers also mention that a pandemic can cause different effects on waste generation for each area depending on the social and economic conditions of the community [Piras et al., 2021; Suryawan et al., 2021].

Figure 3 shows trends in the composition of waste in the Riau Islands. There is no significant difference between household waste composition before and during the Covid-19 pandemic (Table 3). Food waste and plastic waste are the most common types of waste generated in Riau Islands [Nasution et al., 2021; Yodi et al., 2020; Zainul Ikhwan et al., 2021]. Online shopping for most Indonesian residents tends to increase during pandemic Covid-19 [IRIANI et al., 2021; Khoirunurrofik et al., 2022]. The packages were wrapped with plastic materials, especially tape, plastic wrap, and bubble wrap [Fasake et al., 2021]. This causes plastic waste and the burden on landfills to increase during the pandemic [Vanapalli et al., 2021]. In addition, plastic has a significant contribution to global warming and marine debris [Chu et al., 2022; Sari, Inoue, Harryes, et al., 2022; Septiariva et al., 2022]. From the production process to the disposal and management stage, plastics emit many greenhouse gases into the atmosphere. Even though there is no change in waste composition, the Covid-19 pandemic has changed people's habits and lives with new
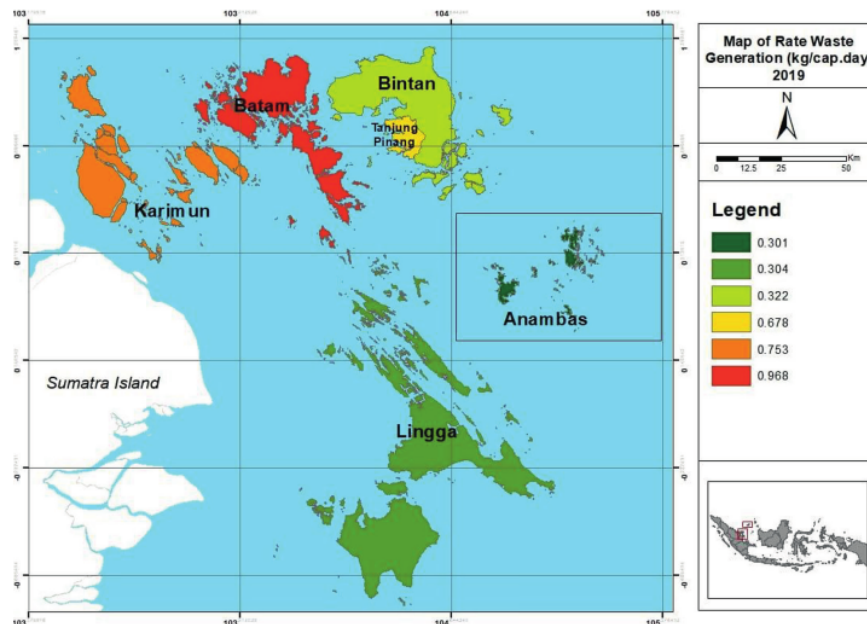

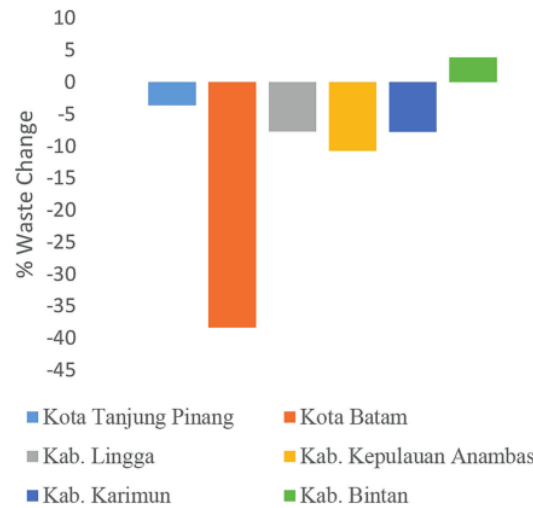**Figure 1.** Waste generation rate in Riau Islands Province in 2019

Figure 2. Changes in waste generation during 2019 and 2020 in Riau Islands Province

Table 2. ANOVA analysis changes in waste generation during 2019 and 2020 in Riau Islands Province

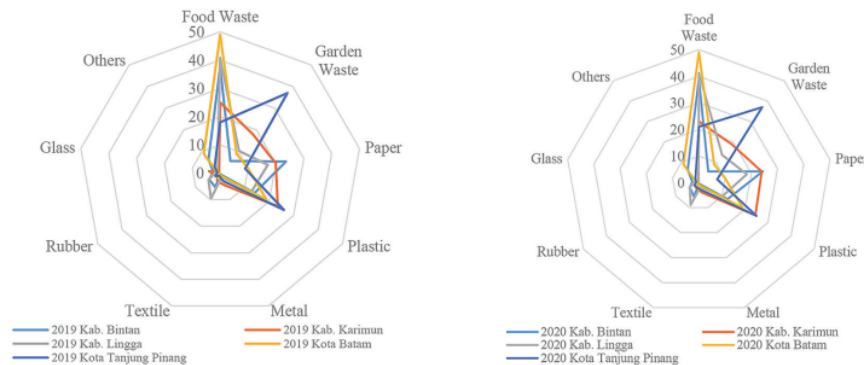| Descriptiion	Sum of squares	df	Mean square	F	Sig.
Between groups	0.012	1	0.012	0.193	0.67
Within groups	0.637	10	0.064		
Total	0.650	11			

Figure 3. Trends in the composition of waste in the Riau Islands (a) 2019, (b) 2020

lifestyles. During the pandemic, various changes have emerged, such as all digital activities, work from home, virtual meetings, online shopping, and non-cash transactions that change all people's perspectives [Akata, 2022]. However, this does not apply to changes in the composition of waste in the Riau Archipelago which shows no change in groups. The ANOVA test for waste composition tends to be above 0.05, which means no change in the average composition of waste during and before the pandemic. Pearson correlation is a statistical analysis tool used to see the close linear relationship between 2 variables whose data scale is interval or ratio. The positive and negative signs on the correlation coefficient indicate the direction of the relationship. The correlation coefficient is positive, meaning that the relationship is directly proportional, where the higher the value of one variable, the higher the value of the other variables. It can be seen in Table 4 that the correlation between

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Table 3. ANOVA analysis changes in waste composition during 2019 and 2020 in Riau Islands Province

Descriptiion		Sum of squares	df	Mean square	F	Sig.
Food waste	Between groups	0.729	1	0.729	0.005	0.946
	Within groups	1208.552	8	151.069		
	Total	1209.281	9			
Garden waste	Between groups	1.764	1	1.764	0.011	0.918
	Within groups	1246.296	8	155.787		
	Total	1248.06	9			
Paper	Between groups	1.6	1	1.6	0.031	0.865
	Within groups	414.064	8	51.758		
	Total	415.664	9			
Plastic	Between groups	1.849	1	1.849	0.047	0.834
	Within groups	315.876	8	39.485		
	Total	317.725	9			
Metal	Between groups	0.016	1	0.016	0.007	0.936
	Within groups	18.544	8	2.318		
	Total	18.56	9			
Textile	Between groups	0.004	1	0.004	0	0.985
	Within groups	81.94	8	10.243		
	Total	81.944	9			
Rubber	Between groups	0.196	1	0.196	0.056	0.819
	Within groups	28.124	8	3.516		
	Total	28.32	9			
Glass	Between groups	0.625	1	0.625	0.613	0.456
	Within groups	8.156	8	1.019		
	Total	8.781	9			
Others	Between groups	0.625	1	0.625	0.045	0.838
	Within groups	112.1	8	14.013		

variables is directly proportional. A multiple linear regression test was conducted to determine the effect of the independent variable on the dependent variable. Table 5 shows the regression model estimating waste generation in the Riau Islands Province. The influence of independent variables in this study is significant on gross domestic product, population, and human development index. Meanwhile, access to sanitation does not significantly affect the model. The coefficient on the variable human development index and the population is significant; namely, the waste generation rate will increase when the human development index increases and the population increases. Meanwhile, the gross regional domestic product has a negative correlation, where an increase in the gross regional domestic product can reduce the waste generation rate. This is in line with Khajuria [Khajuria et al., 2008], which states that in addition to urbanization factors and Gross Regional Domestic Product, one

more factor affects waste generation, namely the illiteracy factor (level of public awareness).

To achieve the universal access target, appropriate policies and strategies are needed by involving the active role of the community and development partners [Leal Filho et al., 2019], including the private sector and donors from abroad, to obtain alternative sources of financing [Appiah-Effah et al., 2019; Taghizadeh-Hesary & Yoshino, 2020]. However, in making this estimation model, it is not suitable to be used. Besides, it also shows that the low significance and the value of the coefficient B close to zero will not significantly change the quantity of waste generation rate to the prediction. For this reason, the recommendations given in the estimation only pay attention to three main points, namely gross regional domestic product, total population, and human development index.

The autocorrelation test is used to determine whether in the regression model, there is a

Table 4. Pearson correlation

Parameter	Waste generation rate	Gross regional domestic product	Access sanitation	Total population	Human development index
Pearson Correlation					
Waste generation rate	1	0.62	0.764	0.719	0.72
Gross regional domestic product	0.62	1	0.43	0.985	0.69
Access sanitation	0.764	0.43	1	0.54	0.668
Total population	0.719	0.985	0.54	1	0.701
Human development index	0.72	0.69	0.668	0.701	1
Sig. (1-tailed)					
Waste generation rate	.	0.016	0.002	0.004	0.004
Gross regional domestic product	0.016	.	0.082	0	0.006
Access sanitation	0.002	0.082	.	0.035	0.009
Total population	0.004	0	0.035	.	0.006
Human development index	0.004	0.006	0.009	0.006	.

Table 5. Model multiple regression for estimating waste generation in Riau Islands

Model	Unstandardized coefficients	Std. error	Standardized coefficients	t	Sig.
	B		Beta		
(Constant)	-1.173	0.614		-1.909	0.098
Gross regional domestic product	-1.61E-05	0	-3.822	-3.109	0.017
Access sanitation	-0.002	0.003	-0.251	-0.87	0.413
Total population	2.30E-06	0	4.221	3.36	0.012
Human development index	0.024	0.01	0.567	2.331	0.053

correlation between the confounding error in period t and the confounding error in the previous period (t-1). One way to test the autocorrelation is to analyze the Durbin-Watson value. Based on the table above, it can be interpreted that there is no autocorrelation symptom. The analysis of the autocorrelation test can be seen in Table 6. Durbin Watson's value in this study was 2.056, which is in the range of 2.0 to 4.0, indicating a negative autocorrelation. The coefficient of determination (R^2) shows how significant all independent variables' contribution influences the dependent variable simultaneously. Based on the table above, the value of R^2 is 0.8885. All independent variables simultaneously affect the waste generation rate; other variables outside the model influence the rest. The higher the value of R^2, the better or the contribution of all independent variables in explaining the dependent variable is higher. The ANOVA test method tests the population's mean undergoing estimating waste generation in Riau Islands. The waste generation model has a

Table 6. Autocorrelation analysis for model multiple regression for estimating waste generation in Riau Islands

| Model		Value
R		0.941
R^2		0.885
Adjusted R^2		0.82
Std. error of the estimate		0.10364
Change statistics	R square change	0.885
	F change	13.511
	df1	4
	df2	7
	Sig. F change	0.002
Durbin-Watson		2.056

significance of 0.002 (Table 7), which means that the linear model influences the waste generation rate in the Riau Islands region.

The Riau Islands, which has an ocean area of 96%, is the source of life [F, 1967]. When a lot of

Table 7. ANOVA analysis for model multiple regression for estimating waste generation in Riau Islands

Model	Sum of squares	df	Mean square	F	Sig.
Regression	0.581	4	0.145	13.511	0.002
Residual	0.075	7	0.011		
Total	0.656	11			
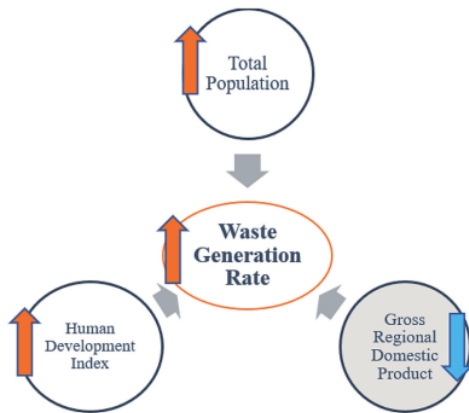
Figure 4. Framework for estimating waste generation in Riau Islands

waste generation, the tourism sector will also be disturbed, so let's keep the ocean clean from waste. Marine debris and land burning are two aspects that characterize [Abidin & Steven, 2021] the fishing-farming communities in the archipelago, including on Riau Island. Whether we realize it or not, local people often enter this conservation area to fulfil their everyday and economic conditions for their daily needs. Indonesia is a country that continues to experience population growth accompanied by increased community activities which have implications for increasing the amount of waste. Based on the results of this study, three key factors in increasing the rate of waste generation can be seen in the framework of Figure 4. There are several efforts to manage waste by reducing waste and forming a community group for processing waste in line with the factors of increasing human development and population. Therefore, these two factors are closely related and must be supported by planning and socialization and involvement carried out by the local government. Improvements in waste management need to be carried out so that waste can have value because the sub-management of waste, waste and recycling is currently still not done commercially. A lot of the waste produced by households is dumped in pits/burnt, in the trash and then transported, so that there is still waste that is not managed or recycled first, it is directly dumped in rivers/irrigation streams or other. Therefore, it is necessary to change the paradigm of waste management that is not useful to be of economic value and needs to be done to increase the gross regional product of the country.

CONCLUSION

The gross regional domestic product (0.017) negatively correlates, reducing the waste generation rate. The Riau Islands, which has an ocean area of 96%, is the source of life and significant to manage because the waste can be released into the ocean. Therefore, management from sources through policies considering the gross regional domestic product, total population, and human development index needs to be considered to reduce the waste generation in the archipelago.

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