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Impact of recycling on the feedstock sustainability of waste to energy plant in Kuala Lumpur

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Abstract. Malaysian government proposed to construct Waste to Energy (WtE) plant to solve the waste management problem in Kuala Lumpur. Recent implementation of compulsory separation at source (SAS) program might disrupt the sustainability of the waste supply. Sufficient feed rate of waste is required to achieve the designated temperature and autothermic combustion. Results of the study showed that, the annual average daily generation rate was reduced by 105 tonnes/day or 5.5% after the implementation of separation at source program. The estimated maximum recycling rate from the program was 13.8%. The annual average daily collection of recyclable materials was only about 1.3 tonnes/day, which might be due to illegal collection by recycling vendors, poor enforcement by the authority and selling of the recyclable materials by residents directly to vendors. 3 regression models were proposed to describe the overall correlation behaviour between waste generation and population density. The waste generation rate was forecasted to be in increasing trend after 2018 and reach 3072 tonnes/day or 1.4 kg/capita/day in 2043. Thus, the waste supply was expected to be sustainable even after the program implementation.

1. Introduction

Kuala Lumpur had faced a problem with high generation of waste. Currently, there is no available area in the city for the waste disposal. The waste is sent to Bukit Tagar Sanitary Landfill in Selangor via Taman Beringin Transfer Station, the only operating waste management facility within the city. The station received solid waste from residential, commercial, industrial, and institutional areas; excluding bulky and construction wastes. The government proposed to develop Waste to Energy (WtE) plant to solve the current issue.

The selection of WtE plant capacity requires the understanding of local waste generation trend to ensure the sustainability of the plant feedstock. Sufficient feed rate of waste is required to achieve the designated temperature and autothermic combustion in the WtE furnace [1]. The furnace needs to be designed in such a way that the flue gas emitted is raised to a temperature of at least 850 °C for at least two seconds to achieve the desired pollutants destruction [2][3]. The volume of the furnace was based on the desired temperature and the expected heat input from the waste combustion process. The latter is contributed by the amount and calorific value of the combusted waste. If the feeding rate is too low from the expected supply, the desired temperature could not be achieved as the heat input is reduced while the radiation loss remains the same [4]. Under this condition, autothermic or thermally self-sustained combustion could not be achieved due to flame instability. Hence, more auxiliary fuel is required to maintain the high temperature combustion process, which might not economical for WtE operation. Neglecting the assessment on the feedstock supply sustainability could cause problem to WtE project.

Starting from September 2015, Malaysian government implemented separation at source program for several states and federal territories including Kuala Lumpur to achieve the national targets of 40% landfill diversion and 22% recycling rate by 2020. This program obligated the residents to separate their wastes into recyclable and non-recyclable materials [5][6]. The separated recyclable materials were sent to recycling facilities. This program might affect the sustainability of the waste supply for the WtE project. This research aimed to analyze the impact of this program on the local waste generation rate. This research also accessed the impact of this program on the correlations between waste generation rate with gross domestic product (GDP) and population density. The established correlations were modelled and used to forecast the future trend of waste generation rate.

2. Methodology

Figure 1 shows the overall methodology of the research. It started with the data collection and validation of the Kuala Lumpur waste generation rate, population, gross domestic product and recyclable material collection rate from SAS program. Then, the collected data were analysed with the aim to determine the impact of the program on the waste generation rate and its correlations with per capita gross domestic product and population density.

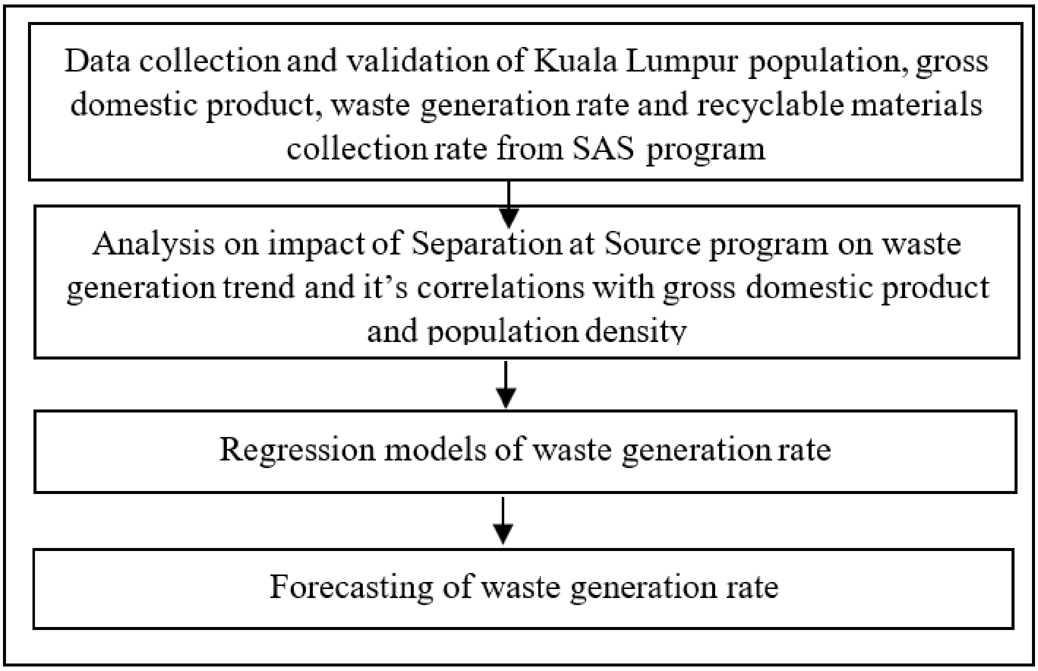

Figure 1. Overall Research Methodology

2.1. Data Collection and Validation

All datasets were collected at range between 2009 to 2018, except the recyclable material collection rate from SAS program that only available from 1st September 2015. Kuala Lumpur solid waste generation data was based on the amount of waste received at Taman Beringin Transfer station excluding bulky materials, which was measured through the facility weighbridge. The weighbridge data was obtained from National Solid Waste Management Department, Solid Waste Corporation, and the facility operator, Alam Flora Sdn Bhd. This research then proceeded to verify the collected waste data in terms of its accuracy and representativeness. Verification of data representativeness was due to the possibility of the collection services did not cover all areas within the city and the diversion of the collected waste to

Selangor, the neighbour state of Kuala Lumpur. At the same time, the transfer station might also receive waste from Selangor. The validation processes were conducted through interviews with the authority officers, contractor manager, sub-contractors and collection workers. It also included crosschecking of the waste data and map analysis of waste collection service area. Waste generation data from other states i.e. Penang and Melaka were also collected respectively from Majlis Bandaraya Pulau Penang and SWcorp for comparative purposes

Data of recyclable materials collection rate from SAS program in Kuala Lumpur were obtained from SWCorp and Alam Flora. Verification process was conducted through interviews and site visits. The collection rate data from other states that adopted SAS program were also collected for comparative purpose.

Data of Kuala Lumpur population and per capita GDP were obtained from Department of Statistics Malaysia (DOSM). The population in 2010 was based on the conducted national census while the population number for the following years were updated based on the reported birth, death, and net-migration numbers [7].

GDP data was based on the constant 2010 price. The use of constant price (real) GDP rather than the current price (nominal) GDP was to eliminate the impact of price changes and only focus on the volume change in GDP [8]. Some of real GDP data was not reported by DOSM in constant 2010 price. For instance, data in year 2009 and 2015-2018 period were respectively reported in constant 2005 and 2015 prices. The constant price GDP (base year 2010) data in these periods were then estimated using equation 1.

$$Constant\ price\ GDP\ (base\ year\ 2010)\ in\ year\ X = \frac{Current\ price\ GDP\ in\ year\ X}{GDP\ deflator\ (base\ year\ 2010)} \qquad eq\ 1$$

Current price GDP from 2009 to 2018 were available from DOSM. GDP deflator (base year 2010) was varied for different year. For instance, as the base year was 2010, the GDP deflator in 2010 was 1.00 while the deflator value in 2011 was 1.02. This indicates that the inflation rate in 2011 was 2%. The GDP deflator (base year 2010) was calculated by dividing the current price GDP with constant price GDP (base year 2010). As the constant price GDP (base year 2010) only available from 2010 to 2014, the GDP deflator for the other years were estimated from the average growth rate of GDP deflator in 2010-2014 period.

2.2. Data Analysis

The impact of SAS program was accessed through the analysis of solid waste generation trend and recyclable collection rate. This research also evaluated the impact of the program on the correlations between waste generation, per capita GDP and population density. Pearson correlation test was used to quantify the correlations strength. The critical point of Pearson correlation coefficient was based on table provided by Fisher and Yales [9] where the values varied for different levels of significance and degrees of freedom. For instance, the correlation coefficient of two tailed test must exceed 0.669 to be significant for the case of 5 degrees of freedom and 0.05 significance level

Correlation coefficient value was calculated only based on the sample data. The addition of a new data might give a different coefficient value. In order to draw conclusion on the real population, t-test was conducted. This test came out with a null hypothesis, suggested that there was no correlation between the examined variables (zero coefficient value) and the obtained r value from samples merely occurred by chance. Confidence level on the null hypothesis was examined based on the probability (p value) of the obtained r value to occur during the sampling in the case of the null hypothesis was true. Low probability indicated that the null hypothesis could be rejected, thus, proved that the correlation between the examined variables existed in real population. The probability was calculated from

Student's t-distribution with n-2 degrees of freedom. The test statistic (t*) value was calculated using the following equation [10]

$$t* = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \qquad eq\ 2$$

There were arguments on p-value significance level. Conventionally, the null hypothesis could be rejected if the p-value was less than 0.05. Conservative researchers claimed that the null hypothesis was false only when the p value was less than 0.01 [11].

2.3. Data Modelling
The relationships between solid waste generation rate and the influencing factors were then modelled through regression analysis. In regression analysis, the data of dependent and manipulated variables were plotted on the graph. Best-fitted regression line was drawn through the points on the scatter plot to summarize the relationship between the variables. Then, the equation was developed based on the regression line, which can be either linear or non-linear.

2.4. Forecasting
The forecasting of waste generation trend was conducted based on the developed model and the future projections of population and per capita GDP. The two projections were conducted using Exponential Smoothing Algorithm.

3. Results and Discussions

3.1. Current Trends of Population and Gross Domestic Product in Kuala Lumpur
Figure 2 represent the trends of population and per capita gross domestic product in Kuala Lumpur from 2009 to 2018. Kuala Lumpur population showed an increasing trend with an average annual growth rate of 0.9%/year. Significant annual growth rate (2.5%/year) was observed from 2014 to 2015. From 2015 to 2018, the growth rate reduced from 0.5%/year to 0.2%/year that might be contributed by the 6% decrease of annual live births and 12% increase of annual deaths number [7].

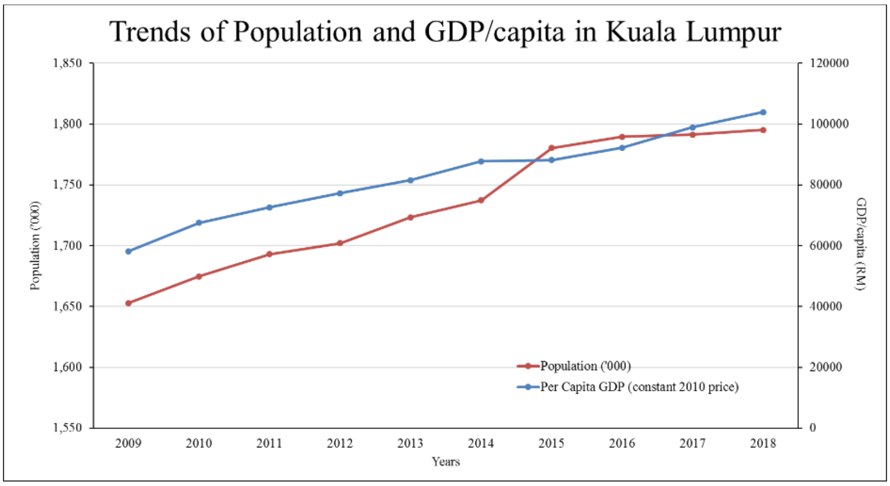

Figure 2. Trends of Population and Per Capita Gross Domestic Product in Kuala Lumpur from 2009 until 2018

The data of GDP/capita showed an upward linear trend with an average annual growth rate of 7%/year. It had increased by 79% from RM 58171/capita in 2009 to RM 103985/capita in 2018. The increase of GDP/capita might be attributed to the increase of population and urbanization in Kuala Lumpur. Becker et al. [12] suggested that the rise of population in urbanized area might increase the income growth as a result of increasing return from greater specialization. Specialization was when a business focused on producing a specific type of goods or services that would enhance the productivity of workers [13]. Friebel and Yilmaz [14]; and Bucci [15] also agreed upon this positive impact of specialization on productivity.

3.2. Current Trends of Waste Generation Rate

Figure 3 represents the yearly average of daily solid waste generation rate in Kuala Lumpur from 2009 to 2018, in total and on per capita bases. From 2009 to 2014, the solid waste generation rate had increased by 14% from an average of 1685 tonnes per day (tpd) in 2009 to an average of 1914 tpd in 2014. This was correlated with the population rise in Kuala Lumpur. Fluctuation trend was observed afterwards. The generation rate declined by 5.5% to 1808 tpd in 2015 before it increased to 1823 tpd in 2016. Then, it dropped by 1.83% to 1790 tpd in 2017 and rose again afterwards by 0.97% to 1808 tpd in 2018. This fluctuation trend is discussed in more details later in this section.

Similar trend was observed for per capita basis. The per capita generation rate increased by 8% from 1.02 kg/capita/day in 2009 to 1.10 kg/capita/day in 2014. This was expected due to the increase of per capita gross domestic product (GDP) in Kuala Lumpur. This was explained by the fact that higher GDP indicates the increases of consumer activities and business expansion. Thus, increases waste generation [12]. The 0.4% reduction during 2010 to 2011 period was due to the higher growth of population (1.1%) as compared to 0.7% increment of the average daily waste tonnage. From 2014, the per capita generation then dropped by 7.8% to 1.02 kg/capita/day in 2015 and continued to fluctuate until it reached 1.00 kg/capita/day in 2018.

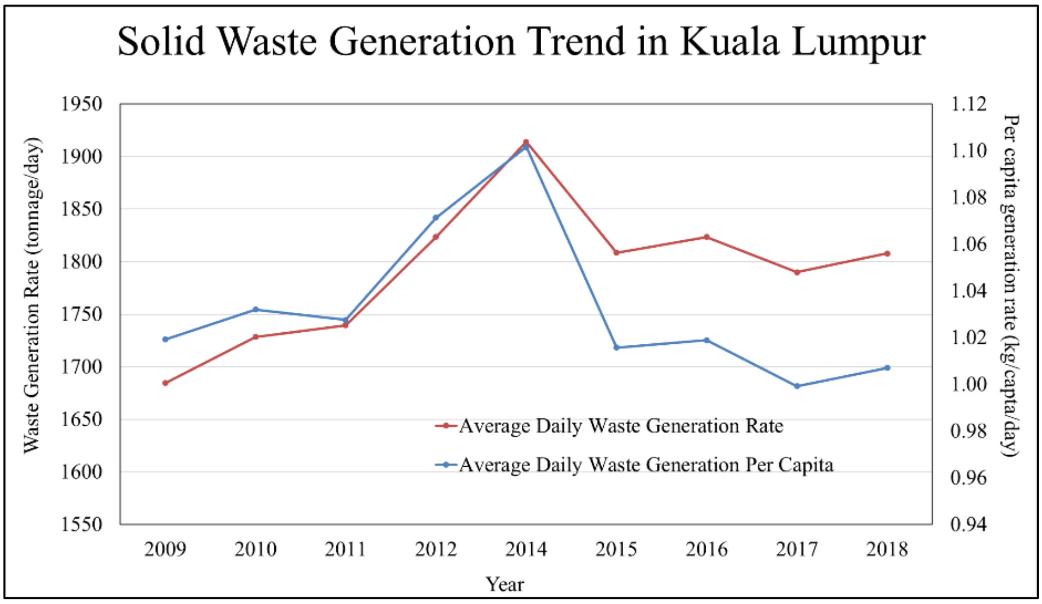

Figure 3. Solid Waste Generation Rate Trend in Kuala Lumpur from 2009 until 2018

The fluctuation trends observed in both waste generation bases might be due to the implementation of SAS program, which became effective on 1st September 2015. Further analysis showed that the downtrend was only occurred for the waste tonnage collected by Alam Flora company, which mostly came from residential areas. This strengthened the theory of the impact of SAS program as the rule only applied to household wastes.

In overall, the yearly average of daily waste disposal rate in Kuala Lumpur, after the program was implemented (2015-2018 period), were reduced by 4.8% to 6.5% from the yearly average of daily disposal tonnage of 1914 tpd in 2014. The authority did not set any specific reduction target for the program. The national targets for recycling and waste diversion from landfill were respectively 22% and 40% by 2020 [17]. The waste reduction rate could be increased by enhancing public awareness of the program. Based on the survey conducted by Noor [18], 56.2% of the respondents did not aware of the program implementation in their municipality.

Penang, the states that has a similar development level with Kuala Lumpur also showed a similar trend. Based on Figure 4, the solid waste disposal rate decreased in 2016 due to the higher increment of recycling rate compared to the increment of yearly average of daily as-generated waste (AGW). AGW is the summation of disposed solid waste and collected recyclable materials. From 2015 to 2016, the yearly average of daily AGW increased by 99 tpd (0.04 kg/capita/day) from 2819 tpd (1.66 kg/capita/day) to 2918 tpd (1.70 kg/capita/day) while the recycling tonnage inclined by 114 tpd (0.06 kg/capita/day) from 1006 tpd (0.59 kg/capita/day) to 1120 tpd (0.65 kg/capita/day). From 2016 to 2017, the increment of AGW generation rate (196 tpd or 0.09 kg/capita/day) was higher than the increase of recycling tonnage (101 tpd or 0.05 kg/capita/day), which caused the increment trend of the disposal tonnage. The graph also shows that the increase of recycling rate had reduced the increment of waste disposal rate from 2012 to 2015.

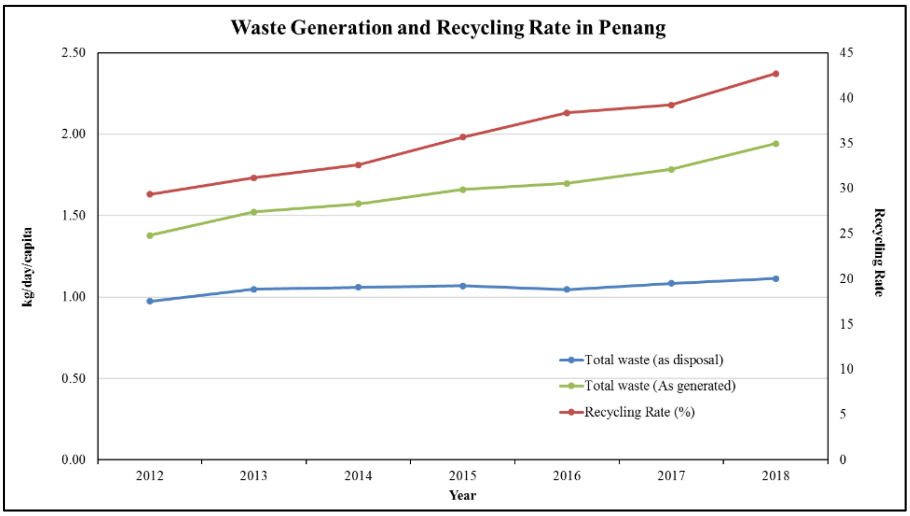

Figure 4. Trends of Solid Waste Generation and Recycling Rates in Penang

High recycling rate in Penang might be contributed by the recycling enforcement on Joint Management Body (JMB) of high-rise properties. JMB was tasked with the responsibilities of informing the residents to separate their waste, providing the recycling container, and assigning contractor to collect the recyclable materials. Separation at Source programme that was launched in 1st June 2016 and enforced in a year later, could be one of the reason for high recycling rate in 2018 [19].

Melaka, the state that also implemented SAS program also showed reduction trend of solid waste disposal after 2015. Based on Figure 5, the quarterly average of daily solid waste generation in Melaka was reduced by 12% from 946 tpd or 1.06 kg/day/capita in Q2 2015 to 830 tpd or 0.91 0.02 kg/capita/day in Q2 2017. Similar to KL, the reduction trend might also due to the obligatory separation program. The increase of solid waste generation rate from Q4 2015 to Q1 2016 might due to the higher increment of AGW generation rate compared to the inclination tonnage of the recycled materials.

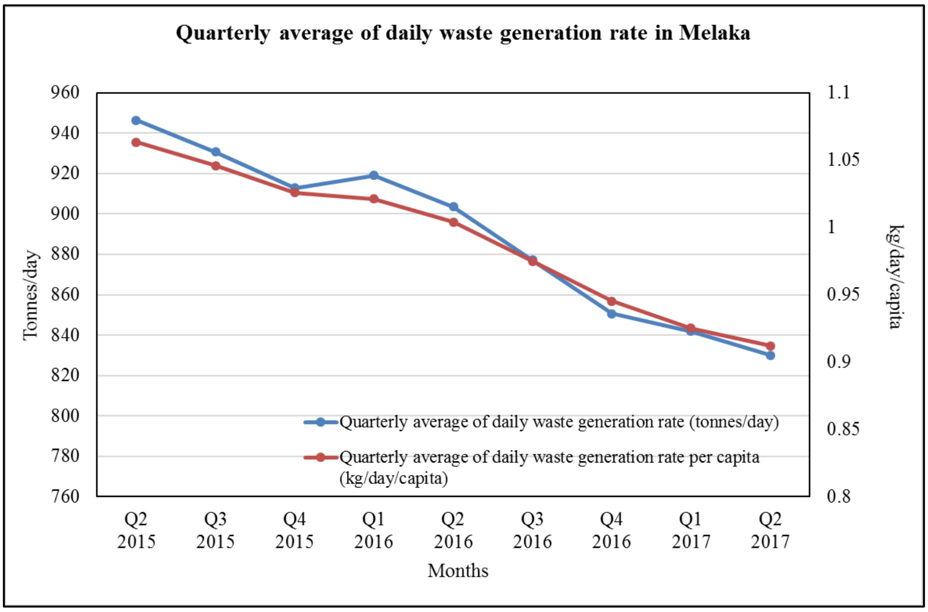

Figure 5. Quarterly Average of Daily Solid Waste Generation in Melaka

3.3. *Recyclable Material Collection Rate from SAS Program*

The collection rate of recyclable materials from the SAS program in Kuala Lumpur was low, which did not tally the with reduction amount of solid waste that has been discussed before. Figure 6 shows that the monthly average of daily tonnage from September 2015 to December 2018 were ranged between 0.3-2.0 tpd. Based on the discussion with the authority [19], low recycling rate from the program might be due to illegal collection by scavengers and street collectors, poor enforcement of by the authorities and selling of the recyclable materials by the residents directly to the vendors

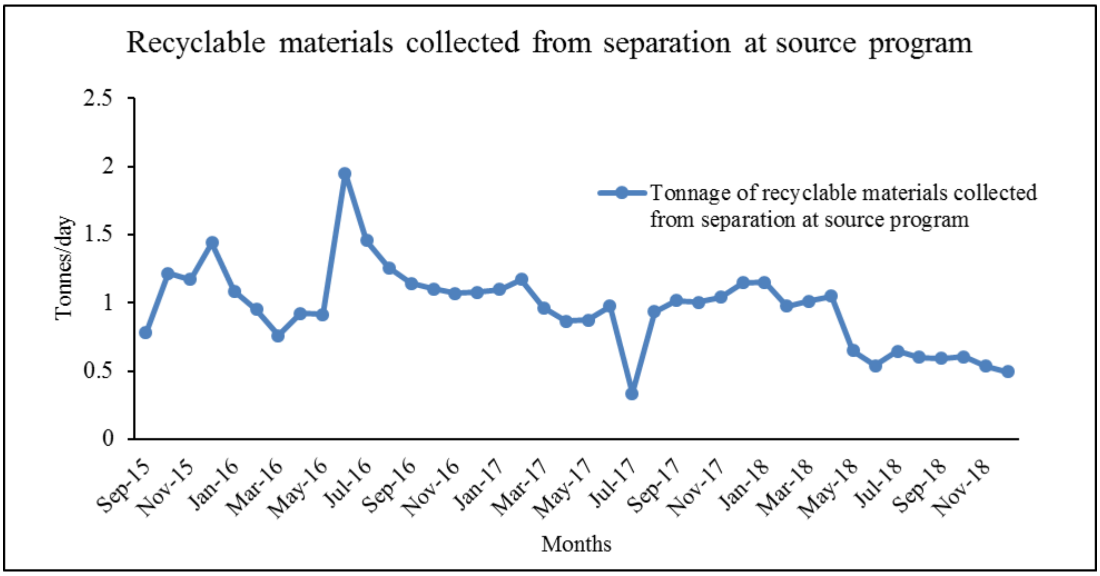

Figure 6. Monthly Average of Daily Tonnage of Collected Recyclable Materials from Separation at Source Program in Kuala Lumpur

Other states that implemented SAS program also showed low recyclable materials collection rate. Based on the yearly tonnage data of recyclables materials collected from SAS program in 2016, the highest collection rate was observed in Putrajaya with 1.10 kg/capita/year while the lowest collection rate was recorded in Perlis with 0.03 kg/capita year.

In the same year, similar collection rate between Kuala Lumpur (0.25 kg/capita/year) and Pahang (0.24 kg/capita/year) was observed. This similarity provided the basis for the claims on the illegal collection and direct selling of the recyclable materials in Kuala Lumpur. As Pahang per capita GDP (RM 30,754/capita) was lower than Kuala Lumpur per capita GDP (RM 97,060/capita), lower collection rate was expected for Pahang. This is based on Hoornweg & Bhada-Tata [20] that concluded positive correlation between country income level with recycling rate. Similar recycling rate between the two states might be due to higher number of recycling centres in KL. This might increase the rate of illegal collection and direct selling of recyclable materials, thus, reduced the collection rate by the authority.

3.4. *Correlation Tests*

This section discusses the impact of SAS program on the correlations between per capita waste generation rate, per capita GDP and population density. Table 1 shows the changes in correlations coefficient after the program implementation.

Table 1. Pearson Correlation between waste generation, population density and GDP

	Per capita Waste Generation	Population Density	Per capita Gross Domestic Product
Per capita Waste Generation rate	R: 1		
Population Density	2009-2014; R: 0.92 2014-2018; R:-0.98	R: 1	
Per capita Gross Domestic Product	2009-2014; R: 0.92 2014-2018; R:-0.62	R: 0.96	R: 1

Note: R = Pearson correlation coefficient

In the period of 2009-2014, positive correlation was observed between population density and waste generation rate with the correlation coefficient (r) of 0.92, sample numbers (N) of 5, and calculated probability (P) value of 0.03. The P-value indicates that the probability of null hypothesis to be true was 3%. As the probability was less 5%, the hypothesis was rejected and the correlation was considered significant. This positive correlation was tallied with the conducted studies by many researchers [21][22][23][24][25]. As the impact of SAS program was included, negative correlation between population and waste generation rate was observed with r and p values of -0.99 and 0.004 respectively. This was tallied with the recent study by Liu et al [26] that found the negative correlation between population density and the total waste generation in China provinces. Similar finding was observed by Garcia et al [27] whom conducted the study for various municipalities in Biscay. The observed negative impact might be due to the policy implementation, which in favour of waste reduction, in municipalities with high population density.

For the impact of per capita GDP, high correlation between the economic variable and per capita waste generation rate was observed in 2009-2014 period with r and p values of 0.92 and 0.03 respectively. This was a typical correlation between the two variables as reported by Diacon and Maha [28], Khajuria et al [29], Alajmi [30] and Kaza et al [31]. In 2015-2018 period, negative correlation between the variables was observed with r and p values of -0.62 and 0.27 respectively. This was tallied with Sjostrom and Ostblom [32]; and Alajmi [30] whom suggested that policy measures could inverse the positive relationship between waste generation rate and economic growth. Grazdani [33], Gu et al [34] and Yi et al [35] also agreed on the significant impact of policy measures that related with instrumental motivators such as fees, charges, and subsidies on waste reduction performance.

3.5. *Model Development*

The regression model of waste generation rate only considered population density as manipulated variable due to the collinearity between the variable with per capita GDP, which would lead to unstable estimates of regression coefficients in the model [36]. This claim on the collinearity was based on the high Pearson correlation coefficient (0.96) between per capita GDP and population density. Dohoo et al [36] claimed that the collinearity was almost certain to be problematic if correlation coefficient was above 0.9. The collinearity between population and per capita GDP in urbanized area like Kuala Lumpur was expected due to the increasing return from greater specialization [16].

Figure 7 shows the scatterplot of per capita waste generation rate versus per capita GDP. For 2009-2014 period, the correlation behaviour could be described as linear regression model. The coefficient of determination (R2) value of the model was 0.84, which indicates that 84% of the variation in waste generation data was explained by the regression line equation. For 2014-2018 period, the waste generation rate showed the initial sharp decline that might indicate the significant recycling activities in Kuala Lumpur during the first year of the program implementation. As the recycling rate was limited due to the fact that not all waste materials could be recycled, subsequent slower decline or flattened pattern was observed. This correlation behaviour could be described by polynomial regression model. The coefficient of determination (R2) value of the model was 0.97.

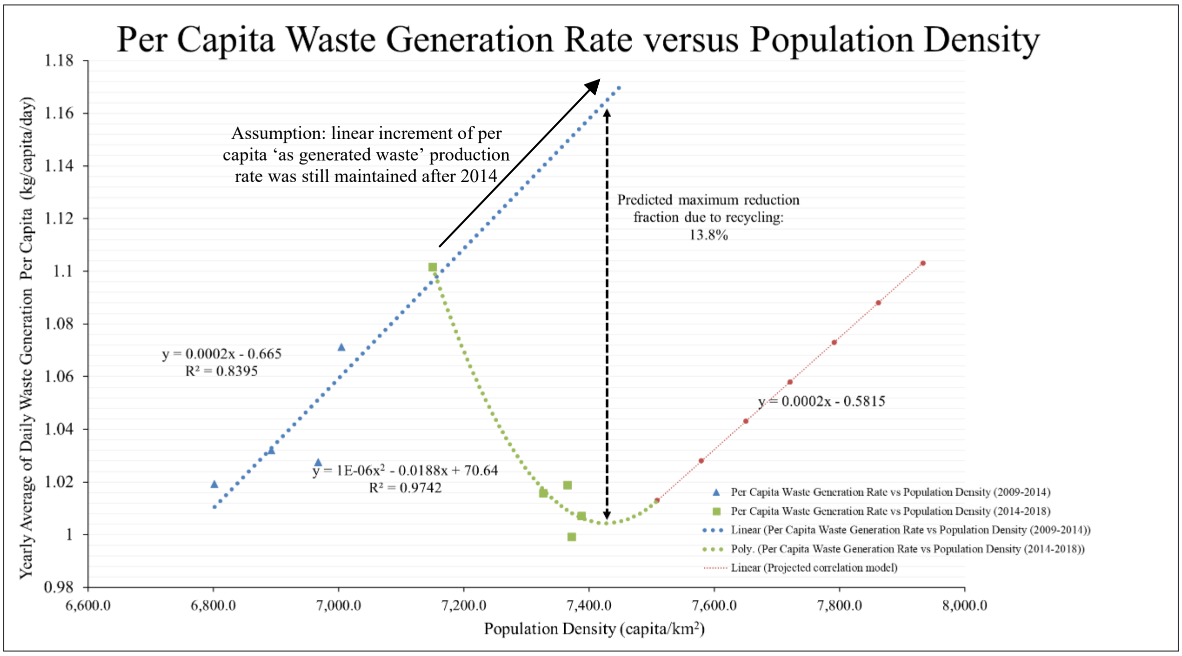

Figure 7. Per Capita Waste Generation Rate versus Population Density

It was expected that the waste generation rate reached the maximum reduction in 2018 where the population density was about 7450 capita/km^2. By assuming that the linear increment of as-generated waste tonnage was maintained after the program implementation, the maximum recycling rate was estimated based on the difference between the lowest waste generation rate rate after the program implementation, which was in 2018, and the amount of as-generated waste in the respective year. Thus, the maximum recycling rate achieved by the program was estimated to be 13.8%. Then, the per capita waste generation rate was expected to continue the similar linear correlation with population density as in 2009-2014 period. Thus, similar linear regression model was proposed to describe the correlation behavior after 2018. The manipulated variable coefficient of the model was corrected by considering the 13.8% recycling rate

3.6. *Forecasting of Waste Generation Data*

Figure 8 shows the future projection of population density in Kuala Lumpur. It was expected that population density in Kuala Lumpur will reach around 9200 person/km^2. Based on developed model and population density projection, the waste generation data were forecasted. As shown in Figure 9, the waste generation rate was predicted to be 3072 tonnes/day or 1.4 kg/capita/day in 2043.

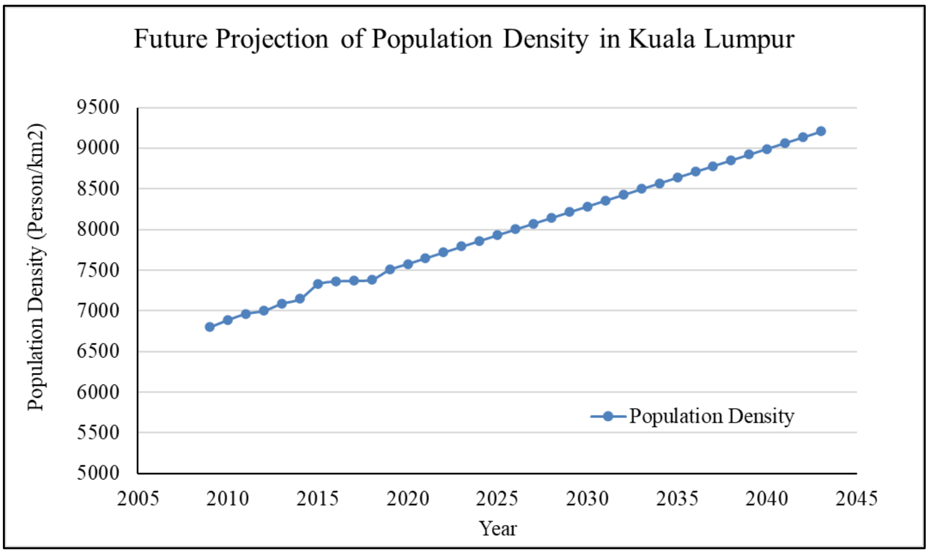

Figure 8. Future Projections of Population Density in Kuala Lumpur

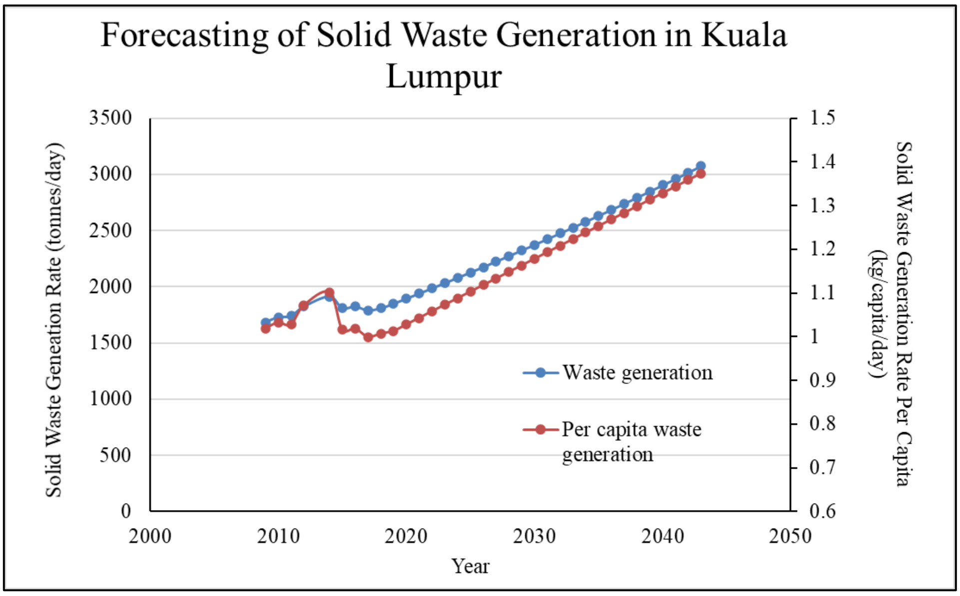

Figure 9. Future Projection of Solid Waste Generation Rate in Kuala Lumpur

4. Conclusions

Results of the study showed that, the annual average daily generation rate was reduced by 105 tonnes/day or 5.5% after the implementation of separation at source program. The estimated maximum recycling rate contributed by SAS program was 13.8%. 3 regression models were proposed to describe the overall correlation behaviour between waste generation and population density. The waste generation rate was forecasted to be 3072 tonnes/day or 1.4 kg/capita/day in 2043. Based on the current prediction, it was expected that solid waste supply for WtE project in Kuala Lumpur is sustainable even after the implementation of SAS program. However, more waste generation data collection was recommended in future studies to improve the reliability of the prediction model.

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References

[1] an Heerden C. 1953 Autothermic Processes *Industrial & Engineering Chemistry* **45**(6) 1242-7.
[2] Wienchol P, Szlęk A, Ditaranto M. 2020 Waste-to-energy technology integrated with carbon capture – Challenges and opportunities *Energy* **198** 117352.
[3] European Union (2010). Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)
[4] Meissner HG. 1961 Incinerator Furnace Temperature *Journal of the Air Pollution Control Association* **11**(10) 479-82.
[5] Moh Y, Abd Manaf L. 2017 Solid waste management transformation and future challenges of source separation and recycling practice in Malaysia *Resources, Conservation and Recycling* **116** 1-14.
[6] Prime Minister's Department of Malaysia (2015). Solid Waste Management Lab 2015. Final Lab Report.
[7] Department of Statistics Malaysia (2018). Current Population Estimates, Malaysia 2018. Yearly Report. Retrieved on 7/12/2020 from https://www.dosm.gov.my/v1/
[8] Statistical Office of the European Union (2020). EUROSTAT: Real GDP Growth Rate-Volume. Luxembourg: Eurostat. Retrieved on 8/12/2020 from: https://ec.europa.eu/eurostat/databrowser/view/tec00115/default/table?lang=en
[9] Toutenburg H, Fisher RA, Yates F 1971 Statistical tables for biological, agricultural and medical research *Biom Z* **13**(4) 285-285.
[10] Lumen Learning (2020). Introduction to Statistics. Retrieved March 3, 2021, from: https://courses.lumenlearning.com/introstats1/
[11] Lane, D. (2021, January 11). Logic of Hypothesis Testing. Retrieved March 3, 2021, from https://chem.libretexts.org/@go/page/2151
[12] Becker GS, Glaeser EL, Murphy KM. 1999 Population and Economic Growth *American Economic Review* **89**(2) 145-9.
[13] Powell SG. 2000 Specialization, teamwork, and production efficiency *International Journal of Production Economics* **67**(3) 205-18.
[14] Friebel, Guido & Yilmaz, Levent. (2016). Flexibility, Specialization and Individual Productivity: Evidence from Call Center Data. SSRN Electronic Journal. 10.2139/ssrn.2916042.
[15] Bucci A. 2015 Product Proliferation, Population, and Economic Growth *Journal of Human Capital* **9**(2) 170-97.
[16] Mazars, 2003. Dublin City Council Waste Management Plan Review Report, Mazars Ltd., Dublin, Ireland.
[17] Pauze (2020). Former Deputy Chief Executive Officer, Solid Waste and Public Cleansing Corporation. Personal Communication.
[18] Noor, Z. Z. (2016). Towards Sustainable Household Waste Management in Urban Areas: Determinants That Hindered The Recycling Activities in The City of Johor Bahru, Malaysia. Malaysia Sustainable Cities Program, 1–20.
[19] Kuan (2019). Head of Solid Waste Management Unit, Penang Island City Council. Personal Communication.
[20] *Hoornweg, Daniel; Bhada-Tata, Perinaz. 2012. What a Waste : A Global Review of Solid Waste Management. Urban development series;knowledge papers no. 15. World Bank, Washington, DC.*

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[21] Dohoo IR, Ducrot C, Fourichon C, Donald A, Hurnik D. 1997 An overview of techniques for dealing with large numbers of independent variables in epidemiologic studies *Prev Vet Med* **29**(3) 221-39.
[22] Dangi MB, Pretz CR, Urynowicz MA, Gerow KG, Reddy JM. 2011 Municipal solid waste generation in Kathmandu, Nepal *J Environ Manage* **92**(1) 240-9.
[23] Senzige J, Makinde O, Karoli N, Njau K, Nkansah-Gyeke Y, Petro J, et al. 2014 Factors Influencing Solid Waste Generation and Composition in Urban Areas of Tanzania: The Case of Dar-es-Salaam *American Journal of Environmental Protection 2328-5699* **3** 172-8.
[24] Bureecam C and Chaisomphob T 2015 Models of municipal solid waste generation and collection costs applicable to all municipalities in Thailand *J. Sci. Technol.* **37**(4) 449-454.
[25] Thanh NP, Matsui Y, Fujiwara T. 2010 Household solid waste generation and characteristic in a Mekong Delta city, Vietnam *J Environ Manage* **91**(11) 2307-21.
[26] Liu J, Li Q, Gu W, Wang C. 2019 The Impact of Consumption Patterns on the Generation of Municipal Solid Waste in China: Evidences from Provincial Data *International Journal of Environmental Research and Public Health* **16**(10) 1717.
[27] Oribe-Garcia I, Kamara-Esteban O, Martin C, Macarulla-Arenaza AM, Alonso-Vicario A. 2015 Identification of influencing municipal characteristics regarding household waste generation and their forecasting ability in Biscay *Waste Manage (Oxford)* **39** 26-34.
[28] Diacon P-E, Maha L-G. 2015 The Relationship between Income, Consumption and GDP: A Time Series, Cross-Country Analysis *Procedia Economics and Finance* **23** 1535-43.
[29] Khajuria A, Yamamoto Y, Morioka T. 2010 Estimation of municipal solid waste generation and landfill area in Asian developing countries *Journal of environmental biology* **31**(5) 649-54.
[30] Alajmi R G 2016 The Relationship between Economic Growth and Municipal Solid Waste & Testing the EKC Hypothesis: Analysis for Saudi Arabia *Journal of International Business Research and Marketing* **1**(5) 20–25.
[31] Kaza S, Yao LC, Bhada-Tata P, van Woerden F. What a Waste 2.0: A global Snapshot of Solid Waste Management to 2050. Washington, DC, 2018 (accessed November 13, 2018).
[32] Sjöström M, Östblom G. 2010 Decoupling waste generation from economic growth — A CGE analysis of the Swedish case *Ecological Economics* **69**(7) 1545-52.
[33] Grazhdani D. 2016 Assessing the variables affecting on the rate of solid waste generation and recycling: An empirical analysis in Prespa Park *Waste Manage (Oxford)* **48** 3-13.
[34] Gu B, Wang H, Chen Z, Jiang S, Zhu W, Liu M, et al. 2015 Characterization, quantification and management of household solid waste: A case study in China *Resources, Conservation and Recycling* **98** 67-75.
[35] Yi Y, Hartloff SL, Meyer PB. 1999 Factors affecting household-level environmental decision making: A three-country comparison of the determinants of household recycling *Urban Ecosystems* **3**(2) 149-61.
[36] Dohoo IR, Ducrot C, Fourichon C, Donald A, Hurnik D. 1997 An overview of techniques for dealing with large numbers of independent variables in epidemiologic studies *Prev Vet Med* **29**(3) 221-39.