science, engineering and health studies

Research Article

Science, Engineering and Health Studies
https://lio1.tci-thaijo.org/index.php/sehs
ISSN (Online): 2630-0087

Forecasting of plastic packaging waste in Thailand using economic index data application

Haritsalak Viriya[1], *Phongthon Saengchut*[2*], *and Nirun Kongritti*[1]

[1] Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima 30000, Thailand
[2] Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand

***Corresponding author**:
Phongthon Saengchut
p.saengchut@gmail.com

***Received**: 14 June 2023*
***Revised**: 3 April 2024*
***Accepted**: 19 April 2024*
***Published**: 2 December 2024*

***Citation**:
Viriya, H., Saengchut, P., and Kongritti, N. (2024). Forecasting of plastic packaging waste in Thailand using economic index data application. Science, Engineering and Health Studies, 18, 24020007.*

ABSTRACT

Population growth and urbanization used to be the only indicators of waste quantity in the past. This research forecasted plastic packaging waste with data from 2010 to 2022 using statistical methods for analysis and aimed to study 47 economic indexes that correlate with and influence the quantity of plastic packaging waste. The quantity of municipal solid waste is constantly increasing by approximately 25 million tons per year, with the quantity of plastic packaging waste having a similar proportion generated each year at 7.91–11.79%. This study observed that the quantity of plastic packaging waste had a Pearson correlation value with an economic index of more than 0.4 (R>0.4) at a significance level of 0.05. The economic index could additionally explain 52.2% of the changes in the quantity of plastic packaging waste, including the wholesale index for food, retail sales index for beverages, and sales index without a store, using the stepwise multiple regression method. The accurate forecasting of plastic packaging waste for use in the planning and design of management systems averaged 78.57%, including the fact that it could be forecasted simultaneously with forecasting economic index changes.

Keywords: plastic packaging waste; municipal solid waste; economic index; forecasting

1. INTRODUCTION

The quantity of municipal solid waste worldwide is more than 2,200 million tons per year, and one third of this is from countries with the highest income (Bueta et al., 2021). Indonesia, Thailand, Vietnam, the Philippines, and Malaysia are the top five Southeast Asian producing countries of municipal solid waste (UN Environment, 2017; Arumdani et al., 2021). The quantity of municipal solid waste has a direct relationship to economic, social, and environmental activities, as municipal solid waste primarily consists of food waste, followed by plastic waste (Letshwenyo and Kgetseyamore, 2020). When separating plastic waste, plastic packaging waste accounted to more than 50% (PlasticsEurope and EPRO, 2019), and 44.10% were observed to be of the single-use type (Horton et al., 2017; Praveena and Aris, 2021).

The planning and design of plastic packaging management systems require the accurate forecasting of plastic packaging waste. The published literature provides explanatory economic variables for forecasting the municipal solid waste rate, including the plastic packaging waste rate. Moreover, the waste generation and economic growth in all countries in EU-27 show a sharper and larger decrease (Inglezakis et al., 2012). These results are congruent with those of Saengchut et al. (2022), who observed that the leading economic index affected changes in the quantity of municipal solid waste and plastic packaging waste (Saengchut et al., 2021). Changes in waste rate, therefore, influenced the plastic packaging waste rate. Other economic factors such as employment, gross domestic product (GDP), education, or population could forecast general waste, such as waste generation in California, where employment was observed to be the

strongest predictor of waste and a good predictor of commercial waste (Hockett et al., 1995; Bach et al., 2004). The quantity of plastic packaging waste changes with the development of each country, where the economy is an important indicator (Pollution Control Department, 2023). Consequently, it is necessary to consider that the relationship between the economic index and data representative of consumption is associated with the quantity of plastic packaging waste as one of the key factors.

Plastic packaging waste is generated after the lifecycle of products or services. This study aimed to forecast plastic packaging waste in Thailand using the application of economic index data to study the correlation between economic index factors and plastic packaging waste quantity. The statistical method was used to analyze the quantities of plastic packaging waste and economic index data for correlation and multiple regression coefficients. Accordingly, plastic packaging waste was forecasted simultaneously with the economic index changes. Additionally, it involves efficient waste management and reflects changes in the economic index.

2. MATERIALS AND METHODS

2.1 Scope of data

This study analyzed a mathematical equation for forecasting plastic packaging waste in Thailand. All the data were selected to analyze changes in the quantity of plastic packaging waste from January 2010 to December 2022. The information was divided into three categories: quantity of plastic packaging production from the Office of Industrial Economics (The Office of Industrial Economics, 2023), population data from the Department of Provincial Administration (Department of Provincial Administration, 2003), and economic index from the Bank of Thailand (Bank of Thailand, 2023).

2.2 Data collection

The data collected comprised secondary data from online databases comprising monthly data, namely, the packaging industry database, the civil registration demographic statistics database, and economic indices and indicators. Plastic packaging is the quantity of production that replaces the initial amount of waste because the plastic packaging produced is almost all waste. A total of 47 economic indices were selected to create a mathematical equation for forecasting plastic packaging waste, as they are directly related to the use of packaging. The indices include one economic-leading index, 18 wholesale indices, and 28 retail sales indices.

2.3 Scope of data analysis

The selected data were analyzed using statistical analysis software to obtain an equation for forecasting changes in the quantity of plastic packaging waste. The data analysis was divided into three steps—the first step was a correlation test of plastic packaging waste quantity between population and economic index using Pearson's correlation at a significance level of 0.05. The second step was equation creation for forecasting using stepwise multiple regression, in which both steps used data from January 2010 to December 2017 (96 months). The final step was to calculate the validity of the forecasting equation using data from January 2018 to December 2022 (60 months).

3. RESULTS AND DISCUSSION

3.1 Trend of plastic packaging waste in Thailand

The results were compared with the quantity of municipal solid waste, comprising a high composition of municipal solid waste, followed by plastic waste (Letshwenyo and Kgetseyamore, 2020). Municipal solid waste constantly increased from 24.22 million tons in 2010 to 28.71 million tons in 2019, and the quantity reduction in 2020–2022 was approximately 25 million tons. The quantity reduction was demonstrated during the COVID-19 pandemic when social activities such as travel and tourism decreased (Boonchanit, 2021).

The quantity of plastic packaging waste in Thailand has been increasing from 2010 to 2022 due to a massively growing population, rapid urbanization, and plastic production (Sharuddin et al., 2016). Plastic packaging waste increased in 2010–2015 (2.46–3 million tons) before declining in 2016–2020 (2.54–2.38 million tons) and increasing again in 2021–2022. The percentage range of plastic packaging was similar each year (7.91–11.79%) (Figure 1).

The post-industrial plastic material is a convenient and versatile product that is primarily used for packaging (Kunwar et al., 2016). Thailand has recorded a spike in plastic use, such as that of single-use plastic packaging, bags, and containers (Reuters, 2020). Since 2017, Thailand, Malaysia, and Vietnam have restricted plastic waste imports and imposed various bans to curb the overuse of single-use plastics and non-biodegradable plastic bags (Ng et al., 2023). However, the use of single-use plastics has increased again post-COVID-19 pandemic (Chen et al., 2021), considering the use of plastic bags was not completely enforced. For example, a few supermarkets still provide plastic bags, but with certain charges, and there is a high growth rate of delivery services (Boonchanit and Sujitra, 2021).

3.2 Forecast on plastic packaging waste using the economic index

The data analysis for forecasting plastic packaging waste was performed using Pearson's correlation at a significance level of 0.05 between the population and economic index and stepwise multiple regression for equation forecasting of the quantity of plastic packaging waste.

The results of the correlation determined that the quantity of plastic packaging waste correlated with the total population ($R = 0.266$). Moreover, there was a correlation with the economic index ($R>0.3$) for the economic leading index (No. 2); the wholesale index for pharmaceutics and medicine, fragrances, cosmetics and toilet products in specific stores (No. 7); the wholesale index for clothes, shoes and leather in specific stores (No. 9); the wholesale index for intermediate product sales (No. 12); the retail sales index for tobacco (No. 25); the retail sales index for durable goods (No. 27); the retail sales index for metal, paint and glass (No. 30); and the retail sales index for electric appliances, furniture, electric lighting equipment and household appliances in specific stores (No. 32). The retail sales index for books, newspapers and stationery (No. 33), wholesale index for building materials (No. 16), and retail sales index ordered via mail or internet (No. 47) have correlated values with an economic index more than 0.4 ($R>0.4$). A strong correlation existed between plastic packaging waste and the economic index when the value was close to 1 ($R = 1$), as represented in Table 1.

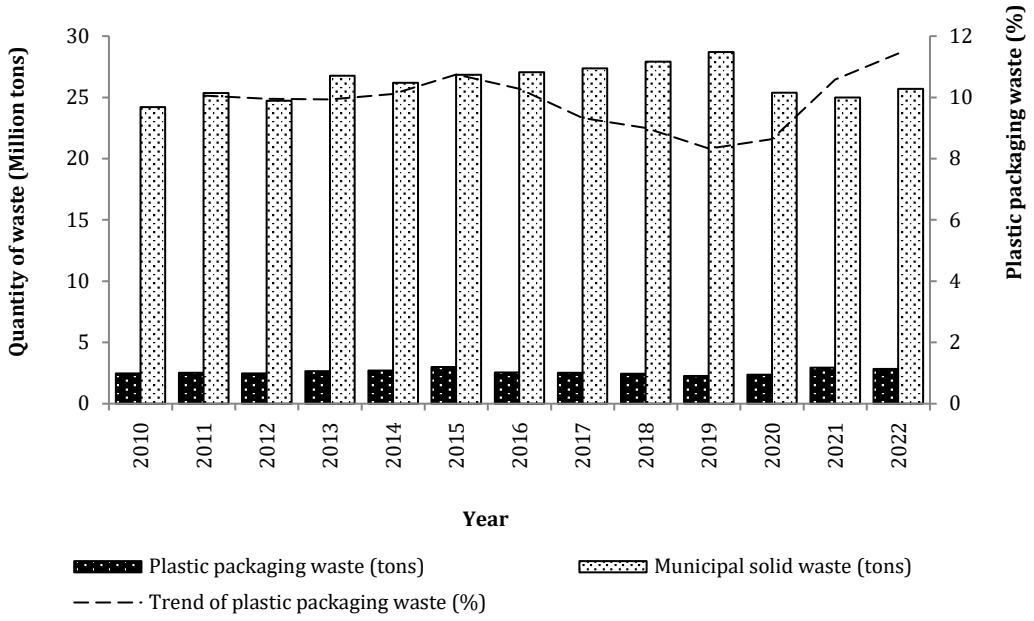

Figure 1. Trend of municipal solid waste and plastic packaging waste in Thailand

Table 1. Correlation of plastic packaging waste with economic index

No.	Economic index	Pearson correlation (R)	Sig. (2-tailed)
1	Total population	0.266**	0.009
2	Economic leading index	0.316**	0.002
3	Wholesale index	0.216*	0.034
4	Wholesale index for non-durable goods	0.244*	0.016
5	Wholesale index for food	0.254*	0.013
6	Wholesale index for beverage and tobacco products	0.190	0.064
7	Wholesale index for pharmaceutics and medicine, fragrances, cosmetics and toilet products in specific stores	0.301**	0.003
8	Wholesale index for durable goods	0.144	0.163
9	Wholesale index for clothes, shoes and leather in specific stores	0.328**	0.001
10	Wholesale index for electric appliances, furniture, electric lighting equipment and household appliances in specific stores	0.051	0.622
11	Wholesale index for household items	0.140	0.179
12	Wholesale index for intermediate product sales	0.302**	0.003
13	Wholesale index for machine and equipment	0.263**	0.010
14	Wholesale index for automobiles and automobile fuels	0.150	0.144
15	Wholesale index for metals and metal minerals	0.079	0.447
16	Wholesale index for building materials	0.443**	0.000
17	Wholesale index for waste and material waste	0.070	0.499
18	Wholesale index for other product	0.088	0.394
19	Wholesale index for regularly deliver products	-0.156	0.130
20	Wholesale index for general goods	0.148	0.151
21	Retail sales index	0.195	0.057
22	Retail sales index for non-durable goods	0.183	0.074
23	Retail sales index for food in specific stores	0.181	0.078
24	Retail sales index for beverage	-0.313**	0.002
25	Retail sales index for tobacco	0.357**	0.001
26	Retail sales index for pharmaceutics and medicine, fragrances, cosmetics and toilet products in specific stores	0.294**	0.004
27	Retail sales index for durable goods	0.336**	0.001
28	Retail sales index for audiovisual equipment	0.064	0.535

Table 1. Correlation of plastic packaging waste with economic index (continued)

No.	Economic index	Pearson correlation (R)	Sig. (2-tailed)
29	Retail sales index for textile	-0.068	0.508
30	Retail sales index for metal, paint and glass	0.308**	0.002
31	Retail sales index for wall and floor covering materials	0.188	0.067
32	Retail sales index for electric appliances, furniture, electric lighting equipment and household appliances in specific stores	0.344**	0.001
33	Retail sales index for books, newspapers and stationery	0.362**	0.000
34	Retail sales index for recreational products	0.148	0.151
35	Retail sales index for clothes, shoes and leather in specific stores	0.136	0.185
36	Retail sales index for used goods	-0.085	0.410
37	Sales index-department stores	0.170	0.097
38	Retail sales index for food, beverage and tobacco products on stalls and markets	0.180	0.080
39	Retail sales index for general goods	-0.042	0.684
40	Sales index for automobiles and automobile fuels	0.131	0.203
41	Sales index for automobiles	0.183	0.075
42	Maintenance and repair of vehicles	0.146	0.155
43	Sales index of automotive parts and accessories	-0.105	0.308
44	Retail sales index for other product	0.116	0.261
45	Retail sales index for new product	0.116	0.262
46	Retail sales index for other products on stalls and markets	-0.091	0.482
47	Retail sales index ordered via mail or internet	0.465**	0.000
48	Sales index of without a store	0.069	0.504

Note: *Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

The analysis of the stepwise multiple regression of the population, including the 47 economic index data and plastic packaging waste quantity was used to select appropriate variables. The results demonstrated that the wholesale index for food, retail sales index for beverages, and sales index without a store were influencing factors in the quantity of plastic packaging waste, which was less than the significance level of 0.05, as shown in Table 2.

The three variables that had the greatest influence on the change in plastic packaging waste quantity were the high index of wholesale for food, a significant increase in the population of 3.35% in 2020 from 2010(Department of Provincial Administration, 2003), and rapid urbanization (Sharuddin et al., 2016), with an 84% growth in delivery services or goods, resulting in a 62% increase in plastic packaging waste (Boonchanit and Sujitra, 2021). Post-COVID-19 pandemic, there was a 300% growth in delivery services or goods, related to the sales index of those without a store (Tanakasempipat, 2020). The market for food packaging was the largest, accounting for approximately 52% of all shipments (Elliott, 2016), and beverage packaging waste accounting for approximately 28% of PET bottles at 17% (Leonard, 2020).

Table 2. Regression coefficient analysis

Variable	Economic data/index	Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
	(Constant)	57132.325	17920.739		3.188	0.002
V_1	Wholesale index for food	486.620	68.510	0.772	7.103	0.000
V_2	Retail sales index for beverages	-364.572	96.638	-0.365	-3.773	0.000
V_3	Sales index of without a store	58.410	16.137	0.391	3.620	0.001

Note: Dependent variable: plastic packaging waste quantity (tons/ month)

The coefficient of determination (R^2) was 0.522, and the wholesale index for food, retail sales index for beverages, and sales index without a store explained the changes in plastic packaging waste quantity by 52.20%, while the other 47.80% was influenced by other variables. These results are congruent with those of Chang et al. (1993), who reported that populations shed little light on the prediction of the average waste rate. Other economic indices have been considered to be influential factors in waste in only a few cases (Hockett et al., 1995; Bach et al., 2004). The equation for forecasting the quantity of plastic packaging waste is represented in Table 3.

Table 3. Equation for forecasting plastic packaging waste quantity

Equation predicted	R	R^2	Adjusted R^2	Std. error of the estimate
plastic packaging waste quantity (tons/month) = $486.620V_1$ - $364.572V_2$ + $58.410V_3$ + 57132.325	0.741	0.549	0.522	8048.12902

3.3 Validity of the forecasting equation

The validity of the forecasting equation was described as a percentage using data from January 2018 to December 2022 (60 months). The forecasting equation was highly precise, with a five-year average of 78.57%. The distribution of forecast values, which were calculated using the equation and observation values from data on plastic packaging waste quantity from January 2018 to December 2022, demonstrated that most of the forecast values approached a linear trend (Figure 2).

The annual validity test of the forecasting equation observed a high average percentage for the last two years, equal to 87.06% in 2021 and 81.20% in 2022, whereas three years ago, it could have been calculated as a lower percentage, that is, 78.79% in 2018, 71.01% in 2019, and 74.79% in 2020 (Figure 3). The high-accuracy plastic waste prediction equation of this study may therefore be used to predict the amount of plastic waste in advance using influential variables to determine an appropriate approach to plastic waste management, in line with Thailand's national policy. This could be in line with the 20-year national strategy or the plastic waste management roadmap (2018–2030) for reducing and eliminating the use of plastic using environmentally friendly alternative materials.

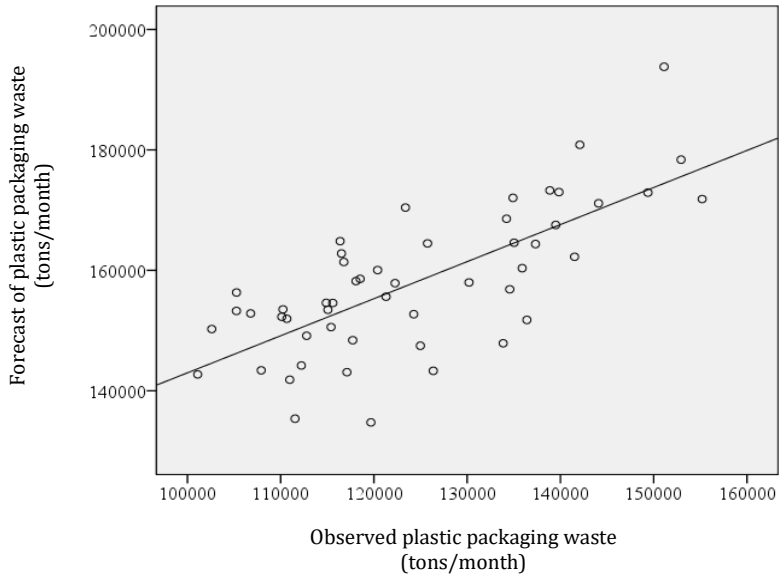

Figure 2. Distribution of the equation forecasting plastic packaging waste

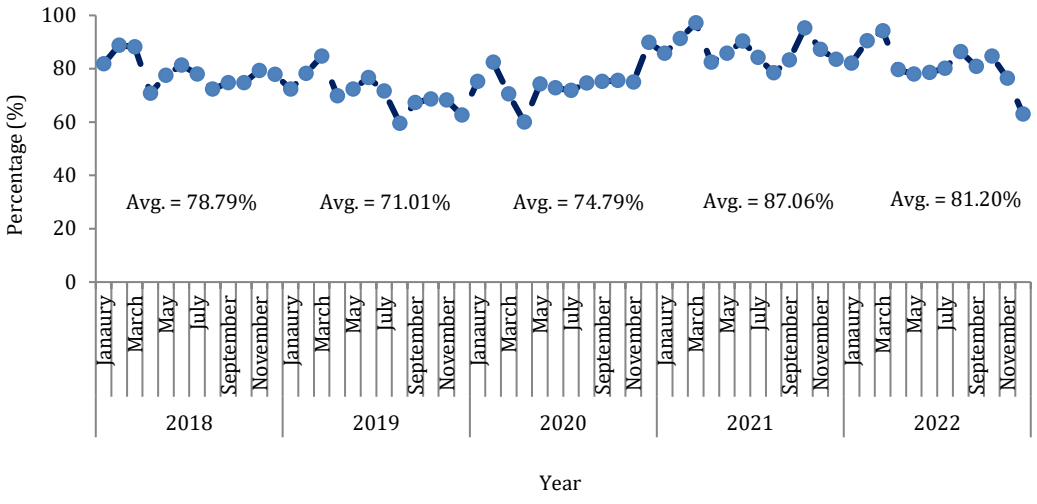

Figure 3. Percentage validity of forecasting plastic packaging waste

4. CONCLUSION

The second most common component of municipal solid waste is plastic waste, half of which comprises plastic packaging waste and single-use plastics. The increase in the quantity of municipal solid waste is therefore related to plastic packaging waste. From 2010 to 2022, municipal solid waste constantly increased, along with the quantity of plastic packaging waste, considering the substantial growth in population and rapid urbanization. This included the high growth rate of delivery services, ultimately affecting plastic production. Moreover, a decline exists in plastic packaging waste due to a ban to curb the overuse of single-use and non-biodegradable plastics.

Population has been a major factor in forecasting municipal solid waste and plastic packaging waste in the past; however, several studies have reported that population is only a small factor compared to economic factors. This study determined that economic factors explain the changes in the quantity of plastic packaging waste, including the wholesale index for food, retail sales index for beverages, and sales index without a store, considering food packaging as the largest market and the high growth in delivery services or goods, especially post-COVID-19 pandemic.

ACKNOWLEDGMENT

The authors would like to express their thanks to the Office of Industrial Economics, the Department of Provincial Administration, and the Bank of Thailand for providing the data for this research. This study did not receive any specific grants from funding agencies in the public or commercial sectors.

REFERENCES

Arumdani, I. S., Puspita, A. S., and Budihardjo, M. A. (2021). MSW handling of top 5 leading waste-producing countries in Southeast Asia. *IOP Conference Series: Earth and Environmental Science*, 896(1), 012003.

Bach, H., Mild, A., Natter, M., and Weber, A. (2004). Combining socio-demographic and logistic factors to explain the generation and collection of waste paper. *Resources, Conservation and Recycling*, 41(1), 65–73.

Bank of Thailand. (2023). *Economic and financial index and indicators*. [Online URL: https://www.bot.or.th/en/statistics/economic-and-financial-index-and-indicators.html] accessed on April 15, 2023. [in Thai]

Boonchanit, W. (2021). *Investigating sustainable consumption practices: a case of single-use plastics in online food delivery market, Thailand*. [Online URL: https://digital.car.chula.ac.th/cgi/viewcontent.cgi?article=5695&context=chulaetd] accessed on September 1, 2024.

Boonchanit, W., and Sujitra V. (2021). Plastic waste from online food delivery (part1): Problem situations and solutions. *Environmental Journal*, 25(1), 1–10.

Bueta, G. R. P., Torres, J. N. V., Kamaruddin, H., Cornelius, C. M., Pamatmat, M., Reyes, R. D., and Pine, V. (2021). *Waste Trade in Southeast Asia: Legal Justifications for Regional Action: 2021 Report*. EcoWaste Coalition. [Online URL: https://ipen.org/sites/default/files/documents/waste_trade_in_asean-final_revised.pdf] accessed on April 15, 2023.

Chang, N. B., Pan, Y. C., and Huang, S. D. (1993). Time series forecasting of solid waste generation. *The Journal of Resource Management and Technology*, 21(1), 1–10.

Chen, H. L., Nath, T. K., Chong, S., Foo, V., Gibbins, C., and Lechner, A. M. (2021). The plastic waste problem in Malaysia: Management, recycling and disposal of local and global plastic waste. *SN Applied Science*, 3, 437.

Department of Provincial Administration. (2003). *Population throughout the kingdom divided into Bangkok and other provinces according to the population registration evidence*. [Online URL: https://stat.bora.dopa.go.th/stat/y_stat45.html] accessed on April 15, 2023. [in Thai]

Elliott, B. (2016). *Latest EPA figures highlight effect of evolving ton.* Resource Recycling. [Online URL: https://resource-recycling.com/recycling/2015/06/23/latest-epa-figures-highlight-effect-of-evolving-ton/] accessed on April 20, 2023.

Hockett, D., Lobe, D. J., and Pilgrim, K. (1995). Determinants of per capita municipal solid waste generation in the Southeastern United States. *Journal of Environmental Management*, 45(3), 205–207.

Horton, A. A., Svendsen, C., Williams, R. J., Spurgeon, D. J., and Lahive, E. (2017). Large microplastic particles in sediments of tributaries of the river Thames, UK-abundance, sources and methods for effective quantification. *Marine Pollution Bulletin*, 114(1), 218–226.

Inglezakis, V. J., Zorpas, A. A., Venetis, C., Loizidou, M., Moustakas, K., Ardeleanu, N., and Dvorsak, S. (2012). Municipal solid waste generation and economic growth analysis for the years 2000–2013 in Romania, Bulgaria, Slovenia and Greece. *Fresenius Environmental Bulletin*, 21(8b), 2362–2367.

Kunwar, B., Cheng, H. N., Chandrashekaran, S. R., and Sharma, B. K. (2016). Plastics to fuel: A review. *Renewable and Sustainable Energy Reviews*, 54, 421–428.

Leonard, M. (2020). *Flexible plastic makes up 28% of global packaging: Report*. Supply Chain Dive. [Online URL: https://www.supplychaindive.com/news/flexible-plastic-makes-up-28-of-global-packaging-report/572025/] accessed on April 23, 2023.

Letshwenyo, M. W., and Kgetseyamore, D. (2020). Generation and composition of municipal solid waste: Case study, extension 7, Palapye, Botswana. *SN Applied Sciences*, 2, 1665.

Ng, C. H., Mistoh, M. A., Teo, S. H., Galassi, A., Ibrahim, A., Sipaut, C. S., Foo, J., Seay, J., Taufiq-Yap, Y. H., and Janaun, J. (2023). Plastic waste and microplastic issues in Southeast Asia. *Frontiers in Environmental Science*, 11, 1142071.

PlasticsEurope and EPRO. (2019). *Plastics the Facts 2019 – An Analysis of European Plastics Production, Demand and Waste Data*. The Association of Plastics Manufacturers in Europe and The European Association of Plastics Recycling and Recovery Organisations. [Online URL: https://plasticseurope.org/wp-content/uploads/2021/10/2019-Plastics-the-facts.pdf] accessed on August 22, 2024.

Pollution Control Department. (2023). *Action Plan on Plastic Waste Management Phase II (2023-2027)*. Ministry of Natural Resources and Environment, Thailand. [Online URL: https://www.pcd.go.th/wp-content/uploads/2023/06/pcdnew-2023-06-15_08-07-42_392659.pdf] accessed on September 1, 2024.

Praveena, S. M., and Aris, A. Z. (2021). The impacts of COVID-19 on the environmental sustainability: A perspective from the Southeast Asian region. *Environmental Science and Pollution Research*, 28(45), 63829–63836.

Reuters. (2020, May 12). Plastic piles up in Thailand as virus fight sidelines pollution battle. *The Japan Times*. [Online URL: https://www.japantimes.co.jp/news/2020/05/12/asia-pacific/plastic-thailand-coronavirus-pollution/] accessed on April 10, 2023.

Saengchut, P., Kongritti, N., and Viriya, H. (2021, December 20–21). The COVID-19 pandemic impact to plastic packaging waste quantity prediction from economic index data in Thailand [Paper presentation]. *The 6th Environment Asia Virtual International Conference on "Challenge of Global Environmental Changes in the 21st Century"*, Bangkok, Thailand.

Saengchut, P., Kongritti, N., and Viriya, H. (2022). Applying of economic index data for municipal solid waste quantity prediction in Thailand. *Asia-Pacific Journal of Science and Technology*, 27(05), APST-27-05-05.

Sharuddin, S. D. A, Abnisa, F., Daud, W. M. A. W., and Aroua, M. K. (2016). A review on pyrolysis of plastic wastes. *Energy Conversion and Management*, 115, 308–326.

Tanakasempipat, P. (2020). *Plastic piles up in Thailand as pandemic efforts sideline pollution fight*. Reuters. [Online URL: https://www.reuters.com/article/uk-health-coronavirus-thailand-plastic-idUKKBN22N12X] accessed on April 23, 2023.

The Office of Industrial Economics. (2023). *Domestic production and distribution: Plastic packaging types*. Packaging Intelligence Unit. [Online URL: https://packaging.oie.go.th/new/search_manufacturing_data.php] accessed on April 15, 2023. [in Thai]

UN Environment. (2017). *Summary Report: Waste Management in ASEAN Countries*. United Nations Environment Programme. [Online URL: http://www.rrcap.ait.ac.th/Publications/Waste_Management_in_ASEAN_Countries_Summary_Report.pdf] accessed on April 1, 2023.