

Demands and Material Flow of Recycled Polyethylene Terephthalate (PET) in Indonesia

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Abstract. It has been a resultant factor behind population growth leading up to increased consumption and demand for fast-moving consumer goods. Higher consumption fosters industrial growth but simultaneously increases plastic waste generation, one of which is polyethylene Terephthalate (PET). PET is widely applied as a packaging material due to its recyclable nature and affordability. Recycled PET functions as a substitute for raw materials produced directly from petroleum. This research aims to analyze the current PET recycling rates to substitute the demand for virgin PET materials in Indonesia. The material flow analysis in this study used the STAN 2.7 application with data sources from the literature and the Central Bureau of Statistics of the Republic of Indonesia. From this research, the consumption of PET in Indonesia is about 1 million tons annually. The bottled water industry is the major consuming of around 300,000 tonnes annually. Recycled PET can provide only 17% of the plastic PET plastic demand. Half of the PET is provided by imported virgin materials. Public-private-government collaboration considers promoting recycling and increasing proper waste management. The findings could act as evaluative tools indicating that the recycling rate can be enhanced to reduce the dependence on virgin material imports.

1 Introduction

Plastic is a challenging issue on a global scale. Waste issues only arise when the environment is unable to process and decompose it, even though waste production has been ongoing for an extended period [1]. Polyethylene Terephthalate (PET) plastic is a common material in Indonesia and is used in a variety of applications. The packaged mineral water industry is the greatest application of PET plastic, reaching 28% of all use [2]. The packaged water sector is among the most expanding industries in Indonesia. Indonesians prefer bottled package water products for a multitude of reasons, the primary reason consumers choose drinking

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packaged water is the lack of drinkable tap water. Indonesia's population increase annually, and estimated reach 284 million by 2029 [3], and depending on demographic trends, such as urbanization, migration, and aging, consumer habits and lifestyle could change [4]. Due to the condition of drinkable water that only 11.9% population has access to safe drinking water and fecal waste contaminates 70% of household drinking water sources in Indonesia [5], 85% of the population takes bottled drinking water [6].

Approximately 49% population in Indonesia consume bottled mineral water out of habit, while an additional 29% select high-quality bottled mineral water for health reasons. Various additional factors affecting packaged water usage include social and economic status, accessibility, the expense of water treatment, and convenient packaging [6]. This reason makes the availability of PET plastic necessary apart from the quantity, also meet the quality for packaging for direct contact with the product.

The increasing number in use of PET packaging is correlated with the rise in disposable packaging volume. The environmental impact of plastic packing will vary according on the specific type of plastic and its composition. PET bottles composed of 100% virgin PET (vPET) plastic will have different impact values compared to bottles composed from 100% recycled materials [7]. Consequently, mitigating the environmental impact of PET plastic waste can be achieved through recycling plastic. PET plastic waste is presently having a demand for recycling raw material, hence possessing both economic and material value [8]. The need for PET plastic waste as a raw material is essential to reduce the environmental impact of PET plastic needs. The availability of PET plastic waste suitable as raw material is essential for reducing the environmental impact of PET plastic consumption.

The objective of this research was to examine the demand for PET plastic and its material flow in Indonesia, especially within the significance of recycled raw materials in meeting the demand for PET plastic production. The study aimed to assess present recycling rates to substitute the virgin material demand in Indonesia.

2 Methodology

This study applied a qualitative descriptive methodology, combining a literature review and data analysis. The data collection was obtained from the Central Bureau of Statistics to assess the export and import of PET plastic and scrap PET trade in Indonesia. The PET national demand and production are based on the statistical data presented by the Ministry of Industry. Material Flow Analysis used the STAN 2.7 application for data calculation and for generating sankey diagrams.

3 PET Waste Management in Indonesia

PET plastic is a frequently used plastic material in everyday activities. The largest consumer of PET plastic is the Bottled Drinking Water Industry, which markets drinking water products commonly referred to as mineral water. Besides that, PET plastic is utilized by other businesses, including food packaging, cups, jugs, the thermoforming of PET sheets a container for medicinal bottles, pesticides, and household as is shown in Fig.1.

The absence of a waste sorting system, poor management of plastic waste, and improperly organized waste collection are among the waste problems in Indonesia. Several technological techniques for recycling PET waste have been adopted in Indonesia. However, the quality of PET bottle waste must be properly segregated and avoid contamination for the best quality of Recycling PET (rPET) [9]. Recycled PET plastic may be further manufactured into various forms or molded into certain products, provided that the recycled plastic is of

high-quality [10]. The engagement of the Indonesian population in waste segregation are still limited and become barrier to proper and effective waste management [11].

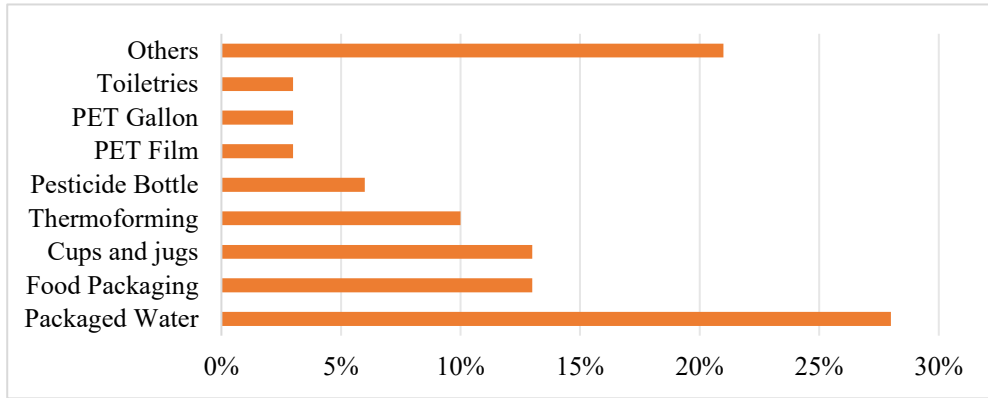


Fig. 1. Structure of PET Plastic Demand in Indonesia [2].

Currently, plastic waste management in Indonesia has poor management for the segregation type of waste. Consumers will dispose of PET plastic waste in municipalities or neighbourhood municipalities will carry the waste to collecting unit. The waste collecting process is carried out by the informal sector and the government through Community-driven Material Recovery Facility (CdMRF) [12]. Separated PET waste is transported to recycling facilities. PET plastic waste that has been gathered is sanitized, crushed and processed into recycled material. Additionally, the recycling process may be performed by recycling companies that partner with CdMRF and informal waste pickers [13].

Plastic waste management in Indonesia faces many challenges, such as high plastic waste contribution of up to 20% of the national waste volume. Lack of plastic waste segregation enforcement, limited waste segregating and collecting infrastructure, Extended Producer Responsibility (EPR) not fully established, and limited public awareness [14]. PET plastic management in Indonesia is shown in Fig. 2ig. 2.

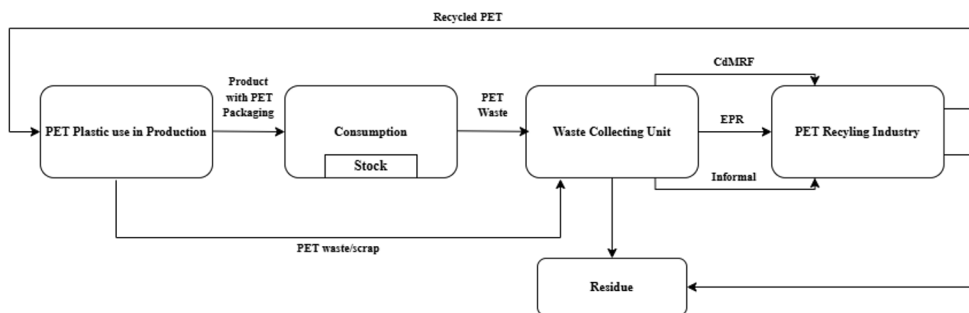


Fig. 2. PET plastic waste flow in Indonesia [11–14].

Based on research conducted in 2023, the implementation of a public-private partnership model is advised to enhance collaboration between the government and the business sector. Implementing economic incentives, such as deposit refund initiatives, could promote public engagement in recycling initiatives to return PET bottles for recycling. Finally, awareness and educational campaigns enhancing public knowledge of the significance of recycling and appropriate waste segregation is crucial [13]. In line with this research, the Indonesian government established The Ministry of Environment and Forestry (MoEF) Regulation

Number 75 Years 2019 about Waste Reduction Roadmap by Producers. The road-map is a mandate from Indonesian Law number 18 Years 2008. The Producer must manage their packaging and reduce waste generation by 30% with baseline on 2029 [14].

The manufacturer has implemented the Extended Producer Responsibility (EPR) to answer the challenge for MoEF regulation. The EPR Programme implemented by manufacture is a waste drop point, in collaboration with the CdMRF. Collaboration between the government, producers, recycling industry, industry associations and related waste collection agencies in the National Circular Economy Movement, plastic waste vending machines, construction and collaboration of Material Recycle Facility (MRF), and various other educational events and activities [15].

Other research on 2024, study about consumer behavioral in PET recycling in Indonesia highlight the importance of improved material recycling facility, to increased collection point and designated recycling facility. The scheme for programs that promote ethical responsibility and highlight community recycling achievements can inspire sustainable practices and foster positive social norms to improve customer engagement for PET recycling. Economic incentives, such as a deposit return system or other financial advantages, can motivate consumers to return their waste [16].

4 Demands and Material Flow of PET

4.1 PET Plastic Demand in Indonesia

Indonesia’s demand for plastic goods in 2021-2023 reached 26 million tonnes with an average demand 8.7 million tonnes per year. Domestic production can provide 23.8 million ton of plastic goods and only 22.23 (85%) million tonnes going to domestic market and 1.6 million tonnes for export. The national plastic goods demand cannot be fulfilled by domestic production, so the producer in Indonesia still have a demand for imported plastic goods is 3.76 million tonnes (14.5%) or 1.2 million tonnes per year [2]. The data for national demand for plastic goods as represented in the Table *Table 1*. The material flow of Indonesia plastic demand is shown in Fig. 3.

Table 1. Indonesia Plastic Demand in 2021-2023 (tonnes) [2].

Year	Domestic production	Export	Plastic for domestic	Import	Plastic demand
	a	b	c = a - b	d	e = c + d
2021	7,815,740	536,795	7,278,945	1,140.11	8,419,055
2022	7,983,590	528,691	7,454,899	1,311.26	8,766,160
2023	8,034,254	541,961	7,492,293	1,313.33	8,805,619
Total	23,833,584	1,607,447	22,226,137	3,764.7	25,990,834

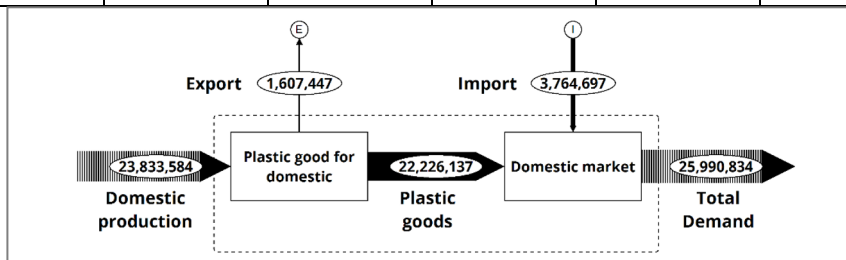


Fig. 3. Material flow of Indonesia Plastic Demand in 2021-2023.

Based on Fig. 3, indicates that total of plastic demand is 25.9 million tonnes with Indonesia Exporting 1.6 million tonnes plastic. The domestic plastic production is 23.8 million tonnes. The rest of the demand is fulfilled by importing plastic goods. The domestic production certainly requires raw materials from several sources. National plastic raw materials consist of domestic virgin plastic raw material reach of 9.41 million tonnes (34.8%), amount of 3.26 million tonnes (12.1%) domestic recycled plastic, 13.73 million tonnes (50.8%), virgin plastic imports, and 0.65 million tonnes (2.4%) plastic scrap imports. In addition to imports, Indonesia also exported 3.1 million tonnes of virgin plastic raw materials and exported export 0.12 million tonnes of plastic scrap raw material [2]. The data of raw material distribution for domestic plastic production are mentioned in Table 2.

Table 2. Plastic Raw Material Distribution (tonnes) [2].

Year		2021	2022	2023	Total
Virgin	f	2,999,000	3,106,200	3,306,200	9,411,400
Recycled domestic	g	924,593	1,063,281	1,275,938	3,263,812
Import virgin	h	4,468,347	4,690,071	4,574,612	13,733,030
Import scrap	i	180,422	208,404	261,361	650,187
Export virgin	j	712,25	1,050,473	1,342,356	3,105,079
Export scrap	k	44,372	33,893	41,501	119,766
Total raw material	$l = f + g + h + i$	8,572,362	9,067,956	9,418,111	27,058,429
Total	$m = l - j - k$	7,815,740	7,983,590	8,034,254	23,833,584

Data from the Directorate of Downstream Chemicals and Pharmaceuticals, Ministry of Industry (MoI), The national PET plastic demand is 12% of the total national plastic raw material demand, as mentioned in Fig. 4 [17]. Meanwhile, the fulfillment of the recycled PET raw materials is 17% of the total domestic recycled raw materials [2].

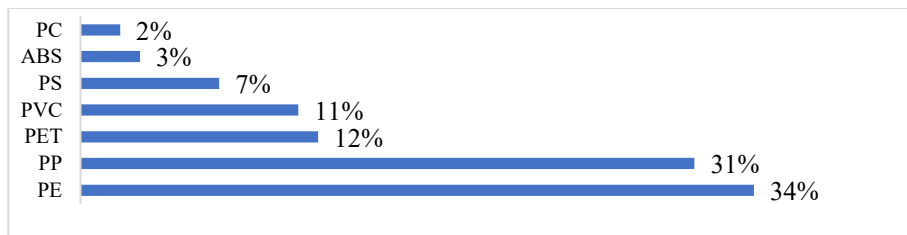


Fig. 4. Structure of Plastic Demand in Indonesia [17].

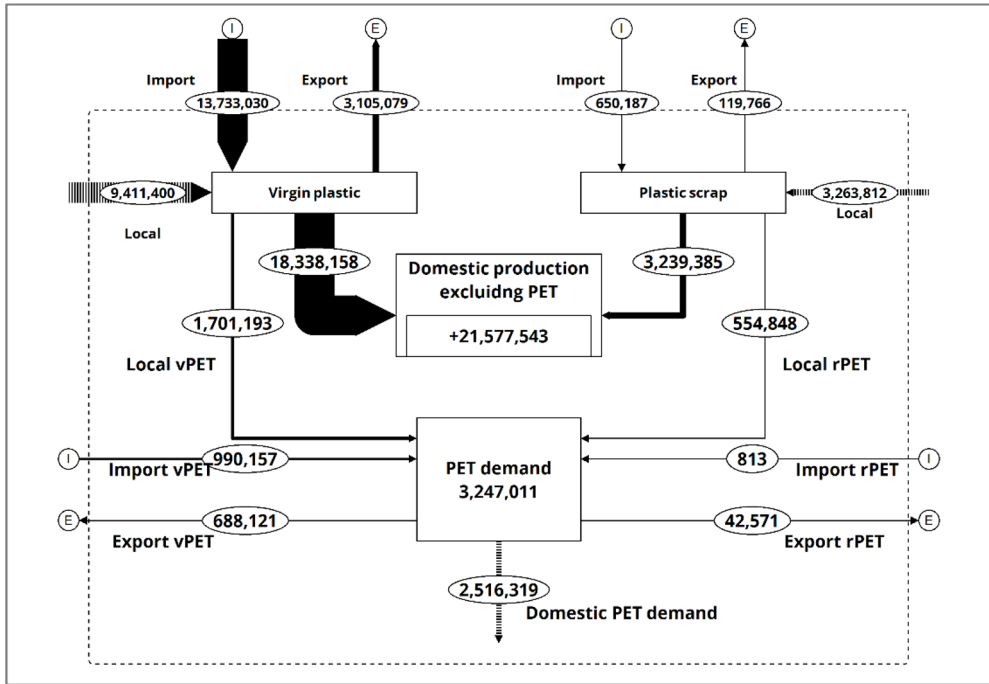


Fig. 5. Material flow of Indonesia PET material demand in 2021-2023.

In addition, based on data from the Central Bureau of Statistics of Indonesia from 2021-2023, PET scrap imports were 813 tonnes and PET scrap exports were 42,571 tonnes [18]. Meanwhile, virgin PET imports reached 990,157 tonnes and virgin PET exports reached 688,121 tonnes [18]. Domestic PET production can be determined by analyzing the national demand for plastic, the proportion of PET plastic required, the proportion of recycled PET plastic, and import-export data analyzed in the Material Flow as mentioned in Fig. 5 and detailed in Table 3.

Table 3. PET Plastic material distribution (tonnes) [2,17].

Year		2021	2022	2023	Total
Domestic pet demand	$n = 0.12 * 1$	1,028,683.4	1,088,154.7	1,130,173.3	3,247,011
PET scrap import	o	0	227	586	813
Domestic Recycled PET	$p = 0.17 * g$	157,181	180,758	216,909	554,848
Virgin PET import	q	316,919	337,577	335,662	990,157
Domestic virgin PET	$r = n - o - p - q$	554,584	569,593	577,016	1,701,193
PET scrap export	s	0	12,530	30,041	42,571
Virgin PET export	t	241,174	199,554	247,393	688,121

Based on the data mentioned in Fig. 3 and the data from Table 1, we can calculate the structure of PET plastic production in Indonesia from 2021 to 2023 as an estimation of the PET demand. Almost 1-million-ton PET plastic is used for production in the packaged water industries. The second largest is food packaging material. The detailed of PET plastic production estimate from 2021 to 2023 is mentioned in Table 4.

Table 4. Estimation for Distribution of Plastic PET Raw Material Demand [2,17].

Year	2021	2022	2023	Total
Package Water (28%)	288,031.36	304,683.32	316,448.53	909,163
Food Packaging (13%)	133,728.85	141,460.11	146,922.53	422,111
Cup (13%)	133,728.85	141,460.11	146,922.53	422,111
Thermoforming (10%)	102,868.34	108,815.47	113,017.33	324,701
Pesticide Packaging (6%)	61,721.01	65,289.28	67,810.40	194,821
PET Film (3%)	30,860.50	32,644.64	33,905.20	97,410
PET Gallon (3%)	30,860.50	32,644.64	33,905.20	97,410
Toiletries (3%)	30,860.50	32,644.64	33,905.20	97,410
Others (21%)	216,023.52	228,512.49	237,336.40	681,872
Total PET	1,028,683.44	1,088,154.72	1,130,173.32	3,247,011.48

4.2 Import and Export PET Plastic in Indonesia

4.2.1 Import PET virgin plastic

Based on the results of the import data analysis, it is known that Indonesia imported the most virgin PET from China, more than 200,000 tonnes between 2021 and 2023. The second largest source of imports was the United States of America (USA) [18]. Exports and imports from each country are uneven among the countries. Indonesia imports number significantly exceed the export number (Fig. 7), except for exports to Japan, which are much greater in value than imports of virgin PET plastic. Top ten importing country of virgin PET plastic in Fig. 6.

China is one of the world's largest manufacturers that produces of PET plastic raw material. PET production in China continues to grow along with the high demand for PET products. The production of PET Fiber increased from 4.6 million tonnes in 2000 to 31.5 million tonnes in 2018. Most of the PET (80%) of China's total PET consumption is used to produce PET fibre for textiles and garment [19]. his contrasts with Indonesia, where the main consumption is for beverage packaging.

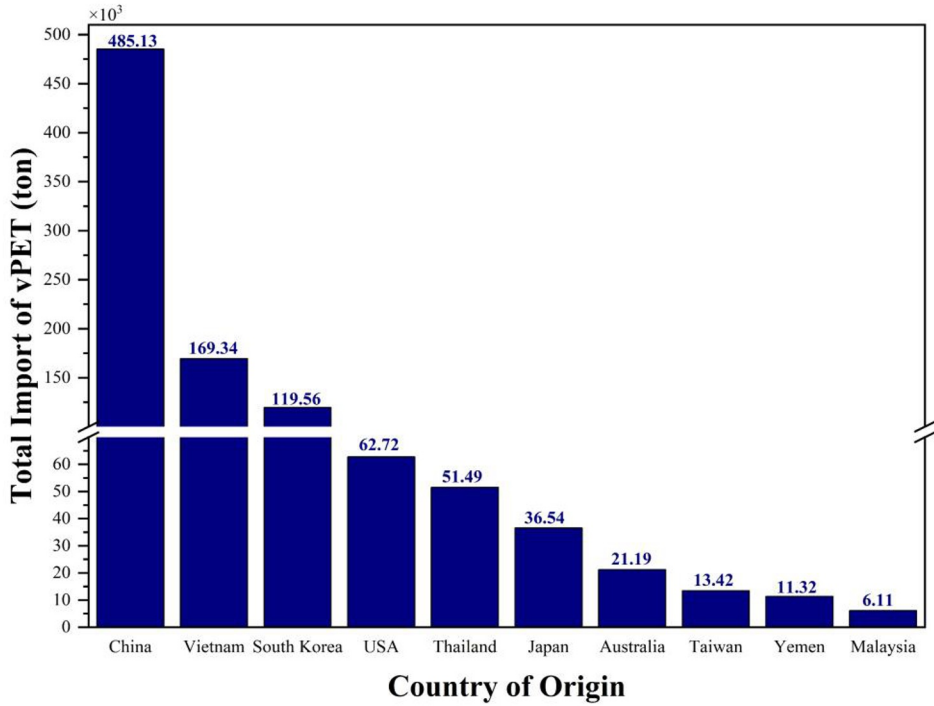


Fig. 6. Top ten countries of origin for import Virgin PET [18].

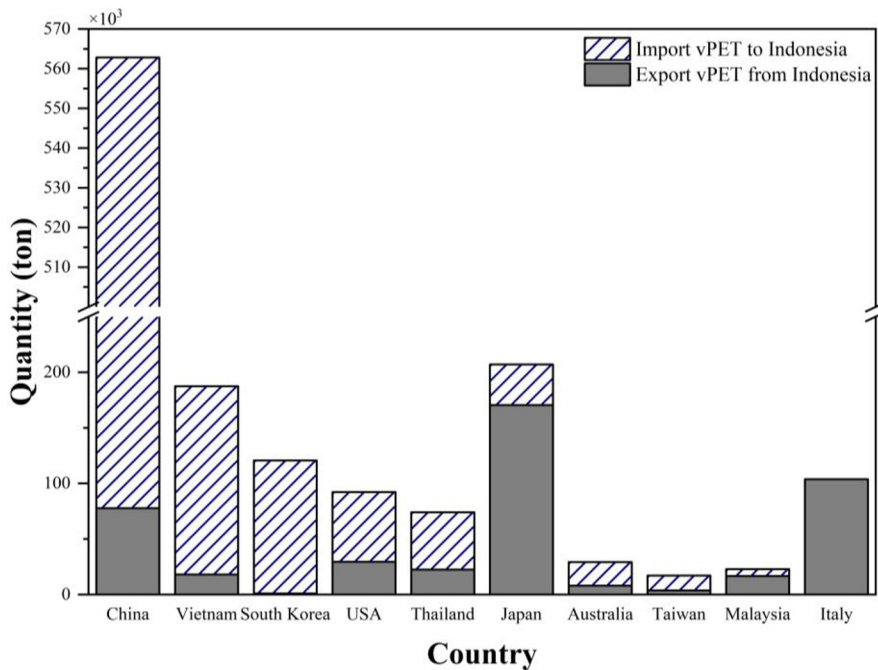


Fig. 7. Comparison of import and export values of virgin PET [18].

In Japan, the average Japanese person buys 183 PET bottles per year, or in a national total of over 23.2 billion consumption of PET bottles annually. The high consumption rate

indicates the need for efficient waste management techniques. In addition, Japan has become the highest PET bottle recycling rates country in the world, with a 93% collection rate and 85.8% recycling rate as in 2019. This condition reflects a high level of awareness and commitment to recycling and resource recovery in that country [20].

4.2.2 Export PET virgin plastic

Virgin PET plastic imported from Indonesia is in the form of granules or others. Virgin PET from Indonesia is produced from petrochemical industry. In 2021 to 2023 Indonesia only export 688 thousand ton of PET. It is a small amount if compared with import amount. Total country for export PET plastic is 58 [18]. The top ten of departing country for export virgin PET is mentioned in Fig. 8.

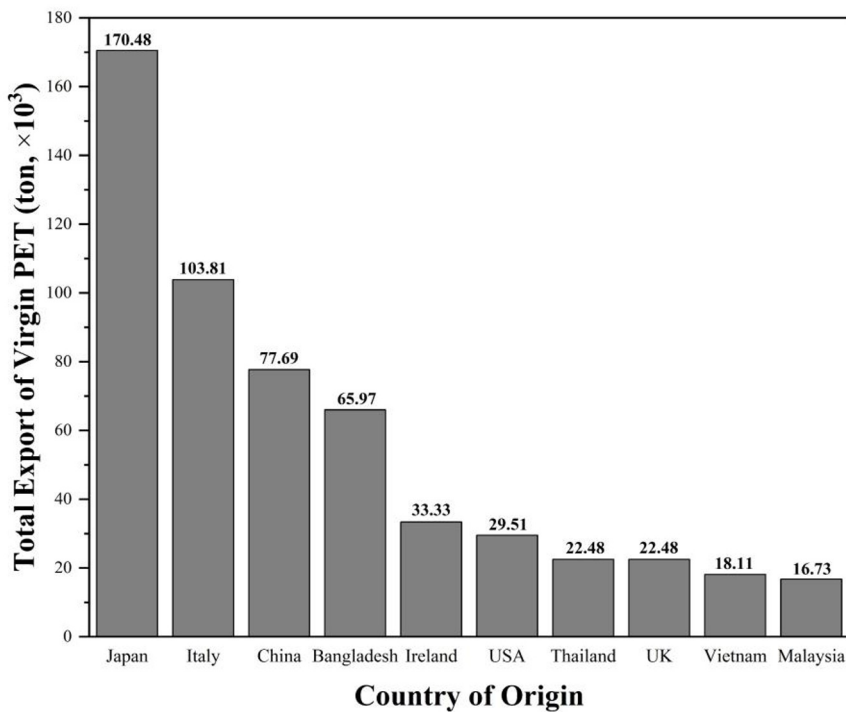


Fig. 8. Top ten countries of destination PET export.

4.2.3 Import PET Scrap

The amount of PET plastic scrap imported has a much smaller total due to the regulation of non-B3 waste/garbage imports. However, this flow still needs to be considered in describing the inflow and outflow of PET Plastic. In 2021-2023, there was only 813 tonnes of imports from 9 countries. The country of origin of PET scrap import to Indonesia is mentioned in Fig. 9. South Korea, Japan, Hong Kong, China, and the United Kingdom have also become importing countries with low contributions, which are 0.485, 0.270, 0.158, 0.086, and 0.001 tonnes, respectively.

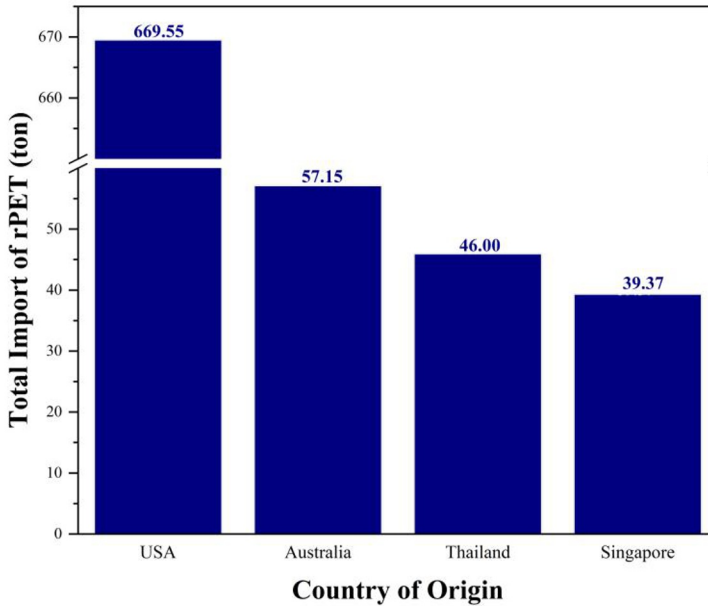


Fig. 9. The Origin Countries of PET scrap import to Indonesia.

The plastic waste import also substitutes used of virgin raw material, but on other hand, plastic waste in Indonesia still not well-managed. The Indonesian government faces an obstacle between the environment and socio-economy. Plastic is a source of Gross Domestic Product (GDP), but the consumption of single waste plastic increases the amount of domestic waste generation significantly. Plastic is affordable and accessible, but only about 10% of plastic waste ends up in recycling center. It's a consequence of the lack of education and awareness on proper waste management [21].

The Indonesian government implemented the Regulation of the Minister of Trade Number 31 of 2016 to regulate plastic waste imports, which outlines provisions for importing non-hazardous waste. A ban on plastic waste imports is also mandated under Indonesia Law Number 32 of 2009 on Environmental Protection and Management. In October 2024, the Minister of Environment announced plans to enforce a full ban on plastic waste imports starting in 2025, aiming to eliminate reliance on such imports [22].

Globally, 187 countries, including Indonesia, have agreed under the Basel Convention to restrict and control the cross-border movement of plastic waste. The Basel Convention governs the plastic waste trade, including contaminated and mixed materials, to ensure proper handling. Exceptions are made for plastics such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET), provided they are destined for certified recycling facilities and free from contamination. These regulation address improper waste disposal and reduce environmental leakage, thus fostering sustainable waste management practices [23].

4.2.4 Export PET Scrap

In comparison with PET scrap imports, the amount of PET scrap exports from Indonesia to other countries much higher. Amounted to 42,571 tonnes or 52 times the value of PET plastic scrap imports. The destinations for PET scrap exports consisted of 28 countries with the largest shipments to the United States and Malaysia. The Top ten countries of destination for PET scrap export show in Fig. 10.

The United States became an importer of plastic scrap due to demand of recycling industry for more cheap and affordable raw material to process into food grade pellets such as PET. The PET import in the USA rose 33% to 204.278 tonnes in 2023. US import plastic scrap includes items such as bottles, purges, leftover pairings, and flake. The US is dependent on cheap plastic recycling scrap because of the stagnant collection rate and high production cost [24].

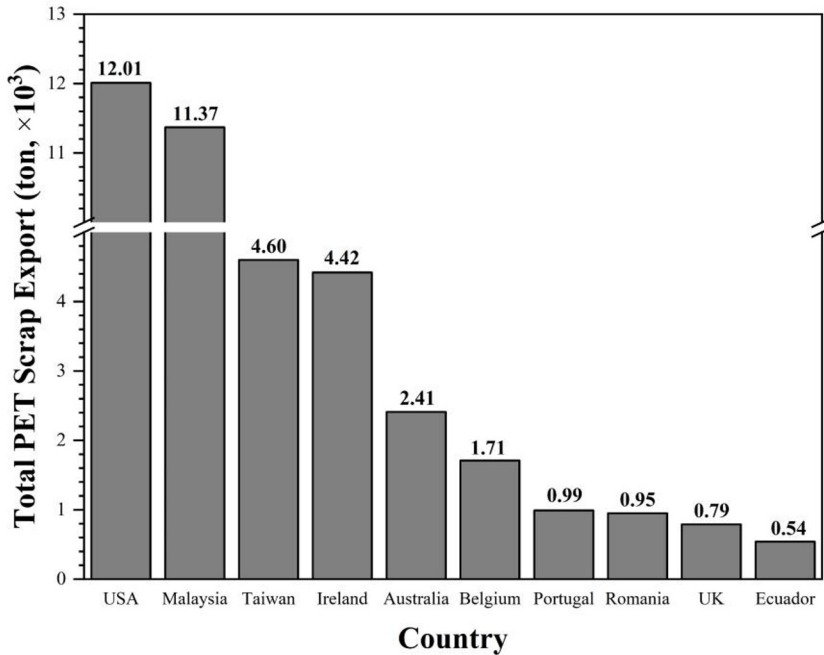


Fig. 10. Top ten countries of destination for PET scrap export.

5 Conclusion

Plastic waste is a major global concern due to its persistence in the environment. However, the demand for plastic packaging, particularly Polyethylene Terephthalate (PET), continues to grow annually owing to its durability and cost-effectiveness. In Indonesia, PET plastic consumption reached 3.25 million tonnes between 2021 and 2023, with the bottled water industry being the largest consumer, driven by the drinkable water shortage, hygiene and health concerns. The expanding population intensifies the demand for PET. Packaging as single-use plastic, PET packaging is a major contributor to waste generation.

Due to this condition, the Indonesian government intends to mitigate plastic waste with Presidential Regulation Number 97/2017, which establishes a target to decrease national waste by 30% by 2025. One of the initiatives for waste reduction is the enforcement of Regulation No. P.75/2019 by the Minister of Environment and Forestry, that has a policy to mandate producers to develop and execute a phased waste reduction road-map (2020-2029), aiming for a 30% waste reduction by 2029 relative to the company's baseline. Waste reduction pertains to products or packaging that are not readily degradable, highlighting that the product or packaging is compostable, biodegradable, recyclable, and incorporates recycled materials.

Indonesia faces considerable challenges in managing plastic waste due to inadequate waste segregation, improper waste management practices, and limited public awareness of recycling. Currently, 30% of the PET demand is met by imported virgin PET (990,157 tonnes). Between 2021 and 2023, recycling PET only supplied 554,848 tonnes of PET scrap for production, which accounts for just 17% of the total demand. Furthermore, the circularity of the PET materials remains low, which is disproportionate to the volume of waste generated. China is a major market for PET and the largest source of virgin PET imports to Indonesia. Japan is the primary destination for virgin PET due to its high demand for PET consumption. Conversely, the USA exports PET scrap as a raw material for its industries, as PET collection rates remain stagnant.

In conclusion, PET recycling not only focuses on volume but also on ensuring the quality of the recycled materials, making sure they are free from contamination. To improve waste management and recycling efforts, Indonesia's government plans to ban the import of plastic waste and focus on domestic recycling. Effective collaboration between the government, private sector, and the public is essential to enhancing waste management practices and increasing recycling rates, although challenges remain in terms of enforcement and public awareness.

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