Journal of Environmental Science and Sustainable Development

Volume 3
Issue 2 *December*

Article 10

12-31-2020

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Recommended Citation

Darus, Nurdiana; Tamimi, Maya; Tirawaty, Silvi; Muchtazar, Muchtazar; Trisyanti, Dini; Akib, Rangga; Condorini, Dyota; and Ranggi, Khair (2020). AN OVERVIEW OF PLASTIC WASTE RECYCLING IN THE URBAN AREAS OF JAVA ISLAND IN INDONESIA. *Journal of Environmental Science and Sustainable Development*, 3(2), 402-415.
Available at: https://doi.org/10.7454/jessd.v3i2.1073

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Journal of Environmental Science and Sustainable Development
Volume 3, Issue 2, Page 402-415
ISSN: 2655-6847
Homepage: https://scholarhub.ui.ac.id/jessd/

AN OVERVIEW OF PLASTIC WASTE RECYCLING IN THE URBAN AREAS OF JAVA ISLAND IN INDONESIA

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(Received: 19 October 2020; Accepted: 23 December 2020; Published: 31 December 2020)

Abstract

Plastic products have been an integral part of human lives. However, concerns over plastic pollution have been growing. Thus, alternative practices that allow more sustainable production and consumption pattern are urgently needed. Improving plastic recycling management is one of the solutions to prevent an increase in plastic pollution. This paper aims to uncover the potential of plastic recycling, to define factors that can leverage the expansion of the recycling process, and to evaluate possible measures that can realize such expansion, especially given the limited literature on these topics. Therefore, a four-month study, which involved two months of rigorous primary survey and interview and secondary data collection process to obtain valuable and accountable raw data, was conducted between October 2019–January 2020. The conducted study showed that the urban population in Java Island generated around 189,349 t of plastic waste per month, but only 11.83% of it was collected. The remaining 88.17% was either directly transported to landfills or littered in the environment. Five major plastic types were collected in the recycling stream, namely, rigid PP (25%), film HDPE (20%), rigid PET (20%), rigid HDPE (14%), and film PP (9%) with more than 80% of collected plastic waste originating from waste pickers. The paper highlights the major challenges in improving post-consumer recycling: (i) failure of post-consumer plastic recyclable to meet the quality industrial standard; (ii) limited recycling processes and infrastructure; (iii) low market demand for recycled products.

Keywords: Java Island; Plastic pollution; Plastic recycling potential; Post-consumer recycling; Recycling stream.

1. Introduction

Plastic products are integral parts of modern humans living on earth. Numerous people have reaped the benefits of using such products in their activities. However, in the last decades, a growing concern has focused on the waste from plastic products (Firdaus et al., 2020; Maruf,

2019; Sonia & Sunyowati, 2020). Plastic pollution, as highlighted by Jambeck et al. (2015), stems from unsustainable production and consumption behavior on plastic products (Gusti, 2016; Zulkhanadya & Listriani, 2020), and it has become a global issue that ignited a global movement (Lau et al., 2020). Goal 12 of the Sustainable Development Goal, Ensure Sustainable Consumption and Production Patterns prompt business actors (including industries) and consumers to alter their way of thinking and exercise such pattern (Blanc, 2015; Priyo et al., 2018). The entire lifecycle of plastic products needs to be shifted by including the risks of plastic pollution within each stage (Faraca et al., 2019; Gemechu et al., 2015). This process will entail the transformation of the conventional single-track "take-make-dispose" model into a fully circular "make-use-recycle" model.

A four-month study was conducted on the value chain of plastic recyclables in the region to increase our understanding of the plastic recycling landscape in Java Island. This study focused on understanding the potential of plastic recycling in the area, factors that can leverage the expansion of the recycling process (particularly post-consumer recycling), and possible measures that can promote such expansion. This research was conducted to complement existing studies focusing mainly on selected cities in Java Island, such as in Pangandaran (Permana et al., 2020), Banyuwangi (Siami et al., 2019), Yogyakarta (Putra et al., 2018), Surabaya (Pandebesie et al., 2019; Wijayanti & Suryani, 2015; Trihadiningrum et al., 2017), and Jakarta (Putri et al., 2018). However, these studies were conducted in a small area of Java Island and did not cover the entire island conditions, particularly those related to post-consumer plastic waste.

The study aimed to achieve two main objectives: to identify the feasibility of recyclable plastic collection and to understand the plastic recycling value chain and its business network in the urban area of Java Island. The first objective was addressed by assessing the current capacity of plastic waste collection and processing within the limited plastic recycling stream in the Java region (Priyo et al., 2018) and the feasibility of improving these technologies. Non-recyclable plastic chain and recyclable plastic waste, either unmanaged or transported to the final disposal sites (by the municipalities), were excluded from the study. The second objective was achieved by analyzing the current situation of recycling industries in the Java region. This study also illustrates the current plastic recycling value chain, the contributing factors that shape the recycling business, and how such factors affect the potential for expansion of such business.

2. Methods

A four-month study, which involved two months of rigorous primary survey and interview and secondary data collection process in obtaining valuable and accountable raw data, was conducted between October 2019–January 2020. The primary data were collected from a field survey, an online survey in the form of WhatsApp questionnaire, and FGD. The secondary data were collected by reviewing previous reports, academic journals, and diverse related websites. Surveys and interviews were conducted in the urban area of each region of Java Island (Western, Central, and Eastern Regions), targeting the collection and recycling actors involved in recyclable waste stream at upstream, midstream, and downstream segments. A total of 232 actors were surveyed and interviewed, comprising the following: upstream actors (waste pickers, Waste Bank Unit (WBU), *Tempat Pengolahan Sampah berbasis 3R* (TPS 3R) and *Tempat Pengolahan Sampah Terpadu* (TPST)); midstream actors (aggregators and Waste Bank Induk (WBI)); downstream actors (recycling factory and crushers) as shown in Figure 1.

For the study, the main primary data collection activity was a field survey, in which the information was collected from 16 waste pickers, 11 recyclers, 119 aggregators, 1 TPS 3R, 6 TPST, and 4 waste banks. This activity involved the visual analysis of the respondents' activity and a structured interview utilizing a predeveloped questionnaire. Given that each group of respondents (waste pickers, TPS3R and TPST, waste banks, aggregators, and recycler) had a different business process and prompted different information to obtain, varied questionnaires were prepared for each group.

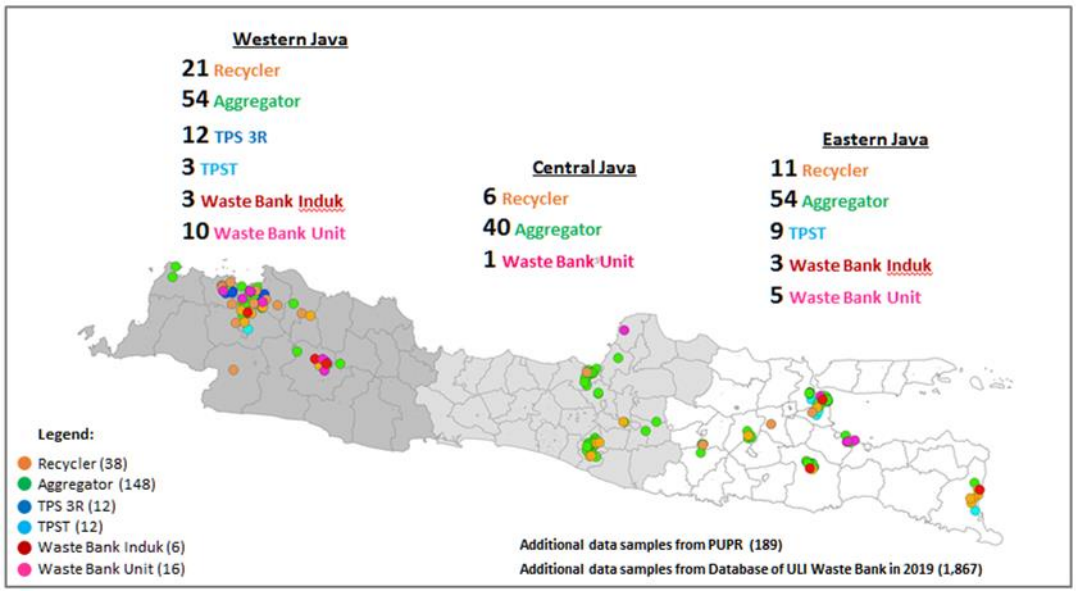

Figure 1. Sample distribution of the study

The online questionnaire used in the study was a WhatsApp questionnaire. Given that WhatsApp entails information sharing regarding the mobile phone number of respondents, the "snowball" method was utilized to identify the respondents. The study team utilized the network visited by the respondents during the field survey as the respondent for the online questionnaire. Using detailed and straightforward questions, the respondents can easily fill in the questionnaire and send back their response directly to the study team, allowing them to enrich their analysis by incorporating information from actors who were unqualified for direct visits. Like field surveys, a different set of questions was developed for various types of actors depending on their scope of work, and the data needed for analysis. Additionally, the snowball method allowed the study team to obtain the networking condition among the actors. Responses from 7 recyclers, 16 aggregators, and 2 waste banks can be obtained from this data collection method.

Literature review as the core of the secondary data collection process was the backbone for the study because it bestowed the researcher with underlying vital information to build the storyline, providing a research direction and the actors that should be involved in the study. In addition, this activity provided the researcher with information related to waste collection and recycling from 20 recyclers, 13 aggregators, 11 TPS 3R, 6 TPST, 40 waste pickers, and 1,883 waste banks. The secondary data would enrich the analytical process of the primary data. The secondary data were obtained from the websites of the Ministry of Environment and Forestry Republic of Indonesia (MoEF), Ministry of Public Works and the Housing Republic of Indonesia (MoPWH), Yayasan Unilever Indonesia (YUI), and Ikatan Pemulung Indonesia (IPI/Indonesia Scavenger Association).

Table 1. Source of secondary data

No.	Target Group	Data Obtained	Source of Data
1.	TPS 3R	Number of units	MoPWH (2019), MoEF (2019)
2.	TPST	Number of units	MoPWH (2019), MoEF (2019)
3.	Waste bank	Number of units, collection capacity, type of collected materials	MoPWH (2019), MoEF (2019), YUI (2019)
4.	Scavenger	Number of scavengers in DKI Jakarta	IPI (2018)

A modeling assumption method was used in the study to determine the value of the collection and recycling capacity of each actor involved in recyclable waste management networks. The value portrays a widely used generic profile. The study acknowledged that the primary and secondary surveys would show a wide range of values. This research can also identify accountable samples, which will be further surveyed and analyzed for each actor based on the primary survey and literature review process.

Given the limited data source available and time constraints, a limited number of sample data can be obtained in the urban area of each region (Western, Central, and Eastern Regions) within Java Island. However, with the robust sample selection process, the number of and selected samples can provide the study with the general profile and character of each actor. The data collected were primarily from the urban area of Java Island, where the recycling networks exist. Thus, the figures presented in this study represent the urban recycling value chain.

3. Results and Discussion

The urban population in Java Island generates around 189,349 t of plastic waste monthly. However, from this number, 11.83% of the plastic waste has been collected by upstream actors and WBI. The remaining 88.17% is either directly transported to landfills (and not processed in the recycling stream) or remains as uncollected and unmanaged plastic waste that is a loss to the environment (Figure 2).

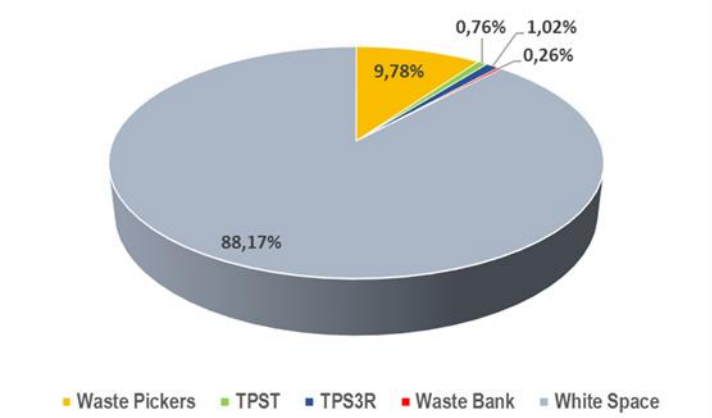

Figure 2. Proportion of collected plastic waste

Further delving into the contribution of each actor showed that waste pickers play a pivotal part in the waste collection process because they can collect plastic waste in a notably higher

number compared with other actors. IPI (2018) estimated that around 25,000 waste pickers operated in DKI Jakarta area. Based on this estimation, the number of waste pickers operating in Java Island was calculated. These waste pickers collected around 22,395 t plastic waste/month, which contributed to 9.78% of the total plastic waste collected in Java Island. This result showcases that despite being an informal and external actor to the formal waste management system, which is often labeled with a negative stigma, the role of waste pickers in the success and continuity of the plastic recycling stream should not be undermined (Kakinuma, 2019). Fostering their active involvement is crucial in building a plastic-responsible society.

Most of the plastics used in our daily lives, including rigid plastics (e.g., water bottles, plastic cups, bottles of household goods, helmet, etc.) and flexible plastic types (e.g., plastic films, plastic bags), are collected by informal sectors. Aggregators often specialize in collecting plastic; they can either only collect rigid or flexible plastics, although several collect both, depending on the market demand. The study exhibited that the most collected plastic types were rigid PP (25%), film HDPE (20%), rigid PET (20%), rigid HDPE (14%), and film PP (9%) (Figure 3).

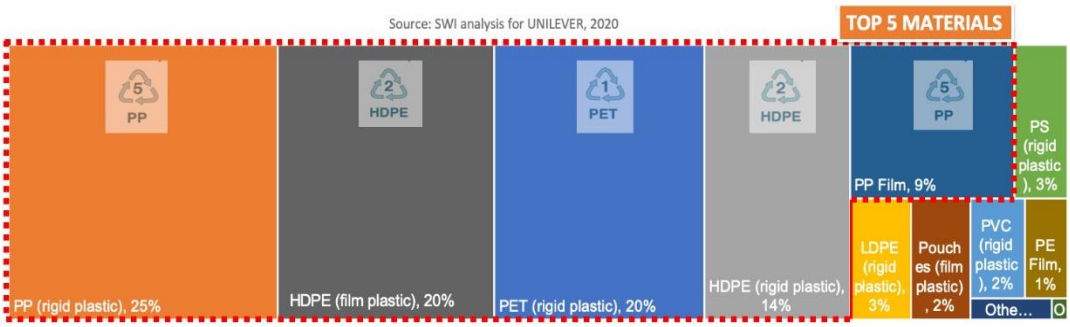

Figure 3. Top 5 plastic type collected by informal sector

Given the huge post-consumer recycling (PCR) potential (88.17% of uncollected plastics are further called white space) in Java Island, the map below describes the potential range between region and sub-region. This finding can indicate the area that should be given priority for advanced PCR. Central Java region, particularly Central Java I that comprises an urban area in Central Java Province, should be of the highest priority given that its white space proportion is the highest (93.75%). This area is followed by Western Java II, IV, and III with 91.13%, 89.95%, and 89.76%, respectively. On the other hand, Eastern Java I, which comprises the Greater Malang Area, should have the lowest priority due to its white space proportion, which has the lowest value in the region (78.85%). Figure 4 shows the map of PCR potential.

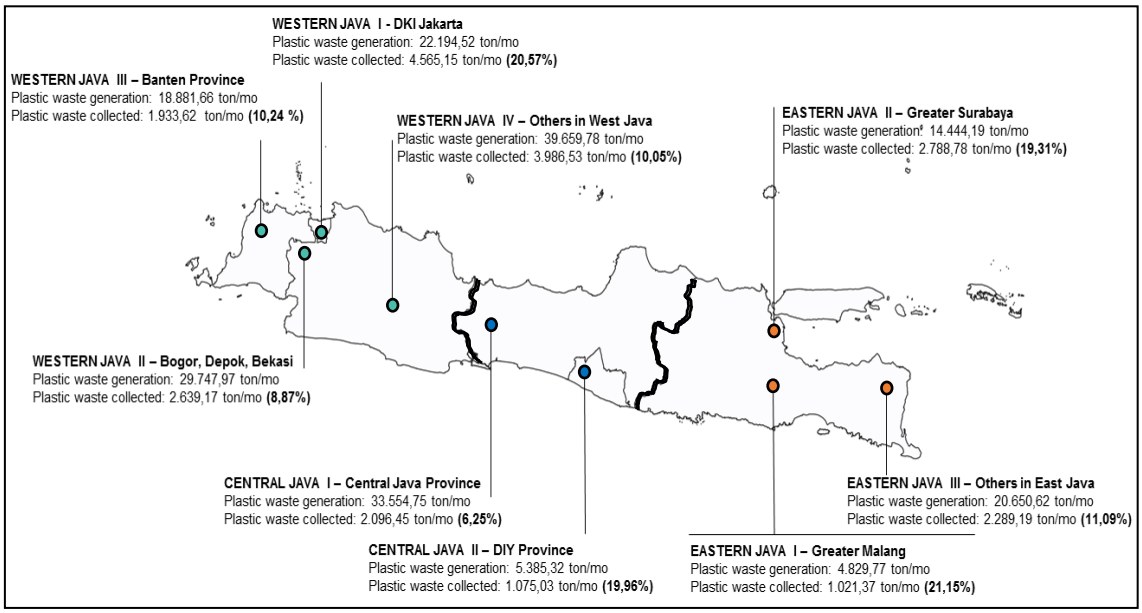

Figure 4. Collection capacity of plastic recyclables waste actors in each sub-region

Factoring in material shrinkage in midstream and downstream segments (5% in each segment), the recycling capacity of downstream actors in Java Island can then be calculated, and the value was at 20,325 t/month or 0.24 Mt/year. The actors in each segment commonly cross-sell their recyclables. For instance, TPS 3R often sells their collected waste to WBU, or in another case, WBI can sell their waste to aggregators (Dhewanto et al., 2018). This cross-selling practice has been accounted for in the study calculation and analysis (Figure 5).

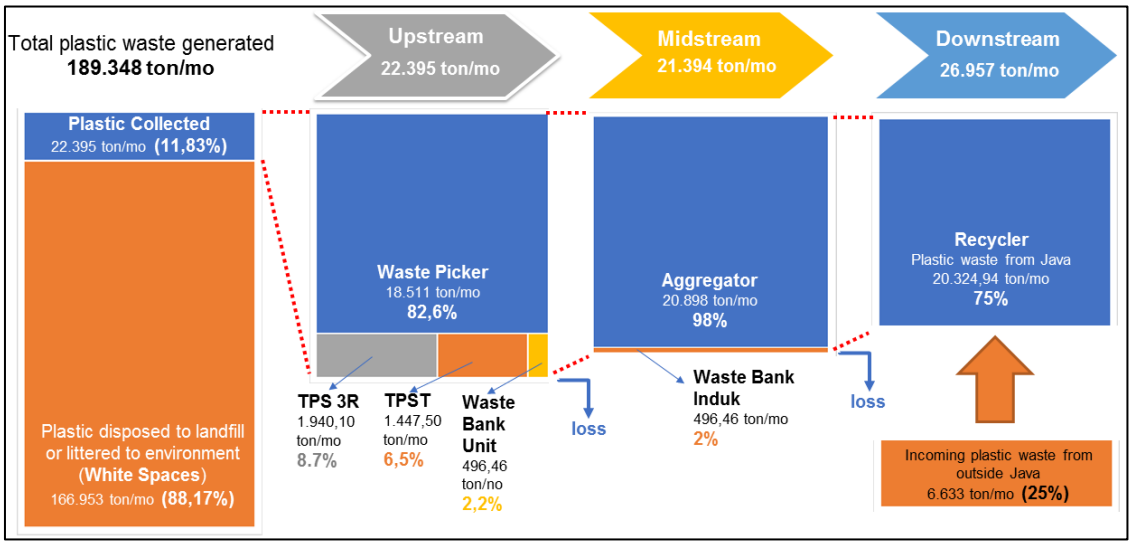

Figure 5. Total population within Recyclable Plastic Waste Networks

The total collected plastic waste in the Java region was calculated at 22,395 t/month. Waste pickers provide the largest contribution to this collection capacity, with a number that surpasses that of the other actors. However, the total collected plastic waste is a small fraction (11.83%) compared with >189,000 t of plastic waste generated in the area. In consideration of the broad condition of the plastics stream in Indonesia, over 70% of raw material supply used to produce plastics comes from virgin plastics (both domestic and imported), whereas recycled plastics (both pre and post-consumer recycling) contribute 30% (1.65 Mt/year) of the consumed plastics (Figure 6).

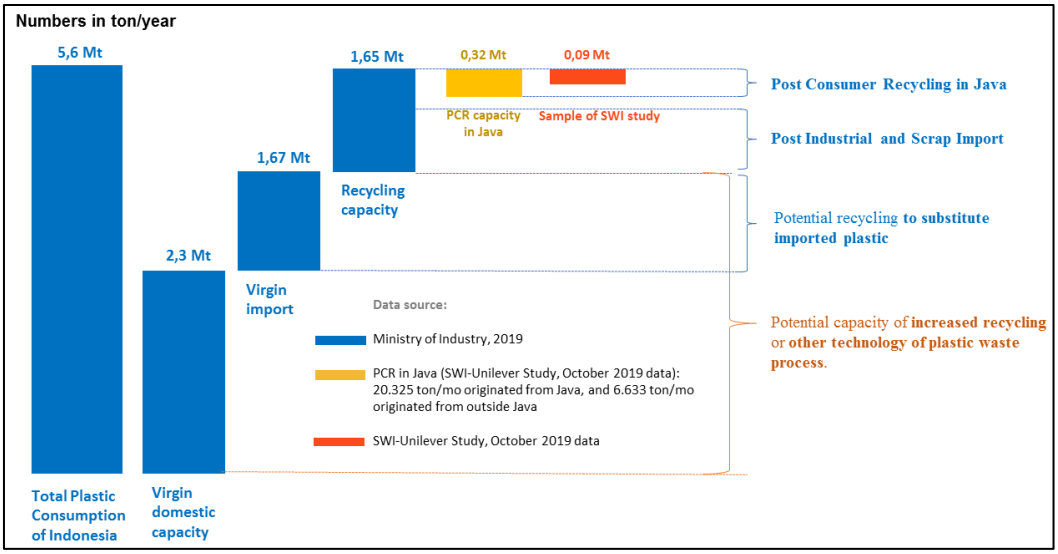

Figure 6. Positioning of post-consumer recycling within plastic material supply landscape

A comparison between this recycling capacity and the PCR capacity in Indonesia demonstrated a substantial gap that indicates how recyclable plastics are poorly managed. Thus, the recycling capacity of plastics should be optimized by driving the PCR capacity. Moreover, given the high plastic consumption, PCR has the potential as a substitute for virgin plastics in plastic production. The latter measure can be achieved either by optimizing the processing capacity or fostering collaboration among different actors involved in the recyclable plastic waste management system.

Expansion of PCR is the target here (Hahladakis & Iacovidou, 2019), and the first step to foster this expansion is to improve the collection and treatment of recyclable plastics. A significant proportion of white space in Java Island should not be treated as negative findings but as an opening to foster a PCR scheme for its management. PCR allows us to reduce waste-related environmental risks by diverting potential waste from ending up in landfills, open space, and water bodies and using them for our needs. This condition promotes a

circular economy by returning plastic disposal into the production line of other products that will be further consumed.

Reflecting upon the current white space, improving the collection of recyclable plastics would be the primary measure. This step can be achieved by (i) strengthening the role of waste banks and TPS3R in collecting recyclables (Raharjo et al., 2017); this program is intended for upstream actors with high accountability, such as waste bank and TPS 3R. The program will focus on community development and behavioral change promotion to increase the number of customers/service coverage (and the subsequent incoming waste) of the actors. Measures will also be implemented to improve their efficiency in the waste collection and sorting process, particularly in handling the increase in collected waste quantity to increase the collection capacity. Business-oriented recycling actors, such as private TPST, aggregators, and recyclers, are the targeted beneficiaries for these measures.

The program will entail the provision of incentives for incremental collection and improvement of infrastructure (only for the eligible entity) to promote acceleration. The logic is to foster an increase in recyclers' demand to drive the supply of plastic raw materials from midstream and upstream, forcing waste pickers and aggregators to increase their collection capacity. However, given that incentives will only be provided in a short-term manner, the program needs to be supported with the exploration of a new market for recycling products to ensure their sustainability: (ii) fostering a new market for recycling products to drive an increase in recyclers to demand raw materials; (iii) improving the livelihood of recycling actors, who are at the frontline of recycling, particularly in the informal sector. The program is proposed, reflecting upon the underprivileged condition of waste pickers, although they spearhead the collection of recyclable waste. Improvement of their socio-economic condition will be another focus. Among the proposed activities are addressing citizenship issues, regular medical check-ups, and raising awareness on health, hygiene, and safety behavior in their daily life and the working environment. Given that waste picking has been a family work that has been "strengthened" by the lack of access to education, this job is inherited from one generation to the next. The program aims to break this generational cycle by assisting waste pickers' family to access better education and equip them with vocational skills.

Furthermore, a successful PCR (domestic PCR) expansion needs more than enhancing the collection and recycling capacity. Implementing measures that can drive the optimization of collection and recycling capacity of upstream, midstream, and downstream actors may produce an ample supply of plastic recycles. However, whether a demand for this supply

exists remains a question. In consideration of this demanding context, the study identified three primary challenges to proceed with the expansion of the plastic recycling industry:

a. Quality of post-consumer plastic recyclables (Brouwer et al., 2019): After consumption, plastic wastes are often not segregated, thus increasing impurities and eventually failing to meet the industry standard and increasing the production cost of the PCR (Putri et al., 2018; Trihadiningrum et al., 2017). The existing recycling capacity shows potential (Ministry of Environment and Forestry Republic of Indonesia, 2020). However, post-industrial plastics and scrap imports are still the preferred options for existing recycling industries. Promoting the use of post-consumption plastic waste requires segregation practice at the waste source and applying the segregation-at-source collection model (Ulhasanah & Goto, 2018).
b. Limitation of recycling to certain types of plastics: Several plastics are not recycled widely (available technology is not commercially ready), for example, multilayer plastics, due to the limitation of technology (Sudibyo et al., 2017).
c. Low market demand: Post-consumer recycling capacity will be difficult to improve due to the lack of demand. Growing negative views and bans on plastic products can also discourage post-consumer recycling. The plastic industry's dependency on imported virgin plastic material can be potentially reduced if recycled plastic product use is widely promoted in various sectors (Relawati et al., 2020), such as automotive, infrastructure, property, etc.

4. Conclusion

A huge opportunity for the improvement of post-consumer recycling exists in Indonesia. The first step to such improvement is to increase plastic waste collection. The current rate of plastic waste collection in Java Island, where the informal collection system contributes to ±82.6% of total collection capacity, is ±11.83%. Thus, the informal sector plays a critical role in managing the waste collection process. Thus, the informal sector's skills, safety, and livelihood must be improved to further increase the waste collection rate in Java.

Additionally, increasing collection rates can be achieved by optimizing the formal and semiformal collection scheme, including TPS 3R, waste bank, and TPST. The study revealed that the five most collected materials by the recycling ecosystem (in the order of most collected) are PP rigid, PET, HDPE film, HDPE rigid, and PP film. Incentivizing the recycling content of these material-based products can potentially maintain or boost the recycling rate.

Plastic waste collection is not the only challenge in improving post-consumer recycling in Indonesia. At present, post-consumer recycling of plastic contributes ±30% of the existing recycling capacity. Post-industrial plastics and imported plastic scrap still account for the majority of recycling feedstock due to their considerably better quality than domestic post-consumer plastics. Therefore, improving the quality of domestic post-consumer plastics is critical to creating more recycling opportunities for the country. A huge amount of plastic waste generated in Java Island (±88.17%) ends up in landfills or polluting the environment. Improved plastic segregation at the source will not only substantially decrease the amount of plastic pollution but also potentially reduce our dependency on imported plastic. This goal can be achieved through the improvement of recycling demand, capacity, and its location distribution and technology application to process plastic waste. Further research can be conducted to explore the best technological application to enhance recycling capacity in Java Island.

Author Contribution

Nurdiana Darus and Maya Tamimi conceived of the presented idea. Silvi Tirawaty, Muchtazar, and Dini Trisyanti developed the theory and performed the computations. Rangga Akib and Khair Ranggi verified the analytical methods. Dyota Condorini supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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