Improving residential plastic waste management strategies for increasing value added to environmental sustainability

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Abstract. The plastic waste which was not handled and managed properly has several negative environmental consequences. This study was conducted to assess the awareness, practice, and attitude towards the existing solid waste management programs of the community in Panggungharjo Bantul, Indonesia. It also aims to determine the correlation between the characteristics of the respondent and plastic waste management strategies. The study used a questionnaire survey method of post the community service program. The forty-five households were surveyed using a validated, self-administered instrument and would be analyzed. This study found that there was an increase in public knowledge and awareness of sorting waste, greenhouse gases, and the impact of solid waste on greenhouse gas emissions after the training. The households were aware of the existing solid waste management programs, sorted waste and processed plastic waste into shreds using the machines that have been granted so that they have added value if they are sold and recycled waste into more useful products. We have highlighted the challenges produced by insufficient plastic waste processing and the potential remedies that can be supplied to ensure a good atmosphere and lessen the causes of climate change.

1 Introduction

Industrial advancement results in a large amount of waste being dumped into the environment as a result of human activity, producing an enormous number of commodities. These wastes come in three different forms: solid, liquid, and gaseous [1–3]. Plastic is a common component of industrial waste, and its disposal in landfills causes serious environmental concerns [4–6]. Plastic products are used in many industries, including construction, healthcare, electronics, agriculture, the automotive industry, and packaging, and have become an integral part of people's daily lives [7]. Plastic is still in demand due to its many advantages, including resistance to erosive pressures, durability, utility, ease of manufacture, and low cost [8,9]. The fact that plastic waste decomposes slowly and can

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persist in the environment for hundreds of years qualifies it as non-biodegradable waste. These companies contribute to the rising global production of non-biodegradable plastic waste, which raises a number of environmental concerns [10].

Recycling holds great promise for lessening the need for new raw materials and decreasing landfill waste [11–13]. Waste recycling also benefits the environment by lowering pollution caused by the exploitation of raw materials, conserving energy, and even generating domestic employment [14]. The life cycle of a plastic product is shown in Figure 1, from usage through disposal or recycling. Numerous methods have been developed and are now being utilized to control non-biodegradable plastic waste. The technologies that treat traditional plastic waste and those that treat advanced plastic waste can be separated into two categories. The two conventional methods of getting rid of plastic waste are incineration and landfilling, both of which are constrained by a specific bottleneck. Energy-intensive and producing dangerous pollutants, incinerating plastic trash is not a sustainable practice [15]. Acidic gases, particulate matter, CO2, persistent organic compounds, and heavy metals are all very damaging byproducts that contribute to global warming and a variety of health issues, such as respiratory issues, an increased risk of cancer, and issues with lung function [16,17].

However, this city will face limited resources to effectively manage solid waste, including inadequate service supply, funding, environmental controls, administrative structure, expertise in complex systems, and sanitation [18]. Therefore, reducing solid waste at the source was shown to be the best way to handle solid waste [19]. In order to implement this strategy, community involvement in solid waste management was strongly suggested in impoverished countries [20].

The sustainability of the solid waste management system can be achieved by developing a community awareness campaign for recycling, sorting, and minimizing solid waste [21]. Individual economic conditions and community behavior may impact efforts to minimize solid waste at the source [22]. As a result, the community's participation in the implementation of the solid waste reduces, reuse, and recycle (3R's) program may be hindered by a lack of facilities and awareness. Some people might claim that they did not have enough time or space to participate in solid waste reduction efforts [23]. An intensive social strategy could keep the community engaged in carrying out suitable solid waste sorting and reduction actions [24]. Furthermore, markets for solid waste treatment products may assist the long-term viability of 3R's initiatives [23]. The objectives of environmental protection and management, which include planning, use, control, maintenance, supervision, and law enforcement, are preserving environmental functions and preventing pollution and/or environmental damage [25]. For human life to exist, the environment must exist because if the ecosystem is damaged, human life would also be affected. Every person has the right to equal rights in attaining a clean and healthy environment as part of their human rights, according to Article 65 (1) of Law No. 32/2009 [26]. To establish clean, healthy, beautiful, and sustainable villages, it is therefore necessary for the community to play a part in combating pollution and preserving the environment. The community and the government have a duty to protect and preserve the environment in order to create a good and healthy environment. The Law No. 32 of 2009 concerning the Protection and Management of the Environment defines the environment as the unity of space with all objects, powers, conditions, and living organisms. This indicates that efforts to sustain the environment through pollution control and environmental management involve humans as one of the influencing factors [27].

Environmental protection from pollution efforts goes beyond only throwing away and collecting waste; they can also involve processing waste to raise its economic worth and positively impact the environment. Environmental conditions that are clean, healthy, beautiful, and sustainable will be impacted through waste management and using the yard

to grow local food. It serves as a crucial foundation for creating a tourism village. A tourist attraction's popularity may decline as a result of poor environmental conditions [28]. The sixth Sustainable Development Goal, which is sustainable sanitation, involves environmental preservation. Diseases that can impair human health can originate in unsanitary environments. Welfare will decline if health is compromised. Achieving sustainable development is based on four guiding principles: satisfaction of human needs, preservation of ecological integrity, social justice in the form of justice for future generations, and the right to self-determination. Waste management is a type of environmental upkeep that can enhance well-being, satisfy fundamental requirements, and foster a wholesome environment for future generations [29,30].

However, preliminary observations show that there is still very little environmental management in Panggungharjo Bantul, Indonesia. On the side of the road, waste is sometimes still widely dispersed [31]. Because it not only harms the environment but also has the potential to spread epidemics, waste is an environmental issue that requires immediate action. Waste is the remaining solid products of regular human activities and/or natural processes, as defined by Law No. 18 of 2008. Household waste is a significant enough source of waste to significantly contribute to the overall amount of waste in the environment [32].

Based on the findings of the first stage of community service, it was known that some households were not sufficiently aware of and knowledgeable about waste management, and local governments had not organized community waste well [33]. According to Suparmini et al., environmental issues arise from a lack of public understanding of the value of environmental management and the carrying capacity of the ecosystem. This is because of a number of things, such as altered functions and environments, declining carrying capacities and environmental quality, a lack of coordination between different parties managing human, natural, and artificial resources, less efficient use of land and space, and environmental pollution [34,35]. However, because the community is unaware of the technology and its advantages associated with the process of solid waste, especially plastic, to be of higher value, they are unconcerned with the issues that arise and the consequences that will be had. As a result, training was needed to help the residents of the Panggungharjo Bantul improve the abilities that already belong to the community. The goal is to raise awareness among the general population about how to process residential plastic waste to increase the value added. The value-adding processes include sorting, washing, aggregating into commercial quantities, drying, compacting, and cleaning [36]. According to Plastic Zero, sorting adds value to plastic waste [37]. The recovered wastes' quality and monetary value are improved through value addition.

In emerging economies, the waste collectors recover the majority of the waste [38, 39]. This suggests that evaluating the many methods in which value is added to the recovered waste is vital. It is essential to comprehend how value is added to enhance sustainable value creation processes in the converting and manufacturing industries. Circular economies can be attained by focusing on sustainable value creation.

2 Methodology

2.1. Study site

This study was undertaken in Panggungharjo Bantul, Indonesia. Based on observations, it was found that the potential for plastic waste needs to be managed with human resources from Panggungharjo to be used as a value-added product by turning it into shreds using a

shredding machine by empowering local communities through their involvement in the process of planning, managing, and conveying opinions.

2.2. Survey design and administration

We polled the houses there to find out how people in the study region handle their plastic garbage. Slovin's equation was used to calculate the sample size for householders [40, 41]. 10% was the estimation error that was employed in this study. To conduct the survey, 45 households were produced by Slovin's equation. The number of home samples from various economic strata was determined using the stratified random sampling method, and they were then pooled into one sample [42].

There are four components in the final survey questionnaire (appendix). Section A maps out the socio-demographic characteristics (i.e., age, marriage status, education level, income). Section B reveals the household's knowledge related to waste management (i.e., knowledge in waste sorting, greenhouse gases, impact of solid waste on greenhouse emission); Section C reveals the household facilities related to waste management (i.e., availability of solid waste bank, training program on 3R); Section D reveals the household's activities to manage the waste (i.e., existence of environment cadres, activities of waste management, willingness to sort waste, rank of non-organic waste types); Section E reveals the technology of waste management (i.e., knowledge of the technology, willingness to apply the technology, benefit of the technology).

Table 1. List of predictor variables and scale of each variable.

Predictor	**Scale**	**Predictor**	**Scale**
Socio-demographic characteristics of the households		Household facilities related to waste management	
Age (X1)		Availability of solid waste bank (X8)	
<20	1	Not available	1
20-50	2	Available	2
>50	3	Availability of training program on 3R (X9)	
Marriage status (X2)		Not available	1
Married	1	Available	2
Unmarried	2	Household's activities to manage the waste	
Education level (X3)		Existence of environment cadres (X10)	
Elementary School	1	Does not exist	1
Junior High School	2	Exists	2
Senior High School	3	Activities of waste management (X11)	
Bachelor/Undergraduate	4	Manage	1
Income (X4)		Doesn't manage	2
Low	1	Willingness to sort waste (X12)	
Middle	2	Willing	1
High	3	Not willing	2
Household's knowledge related to waste management		Rank of non-organic waste types (X13)	
Knowledge in waste sorting (X5)		Plastic	1
No knowledge	1	Glasses	2

Sufficient knowledge	2	Metal	3
High level of knowledge	3	Other	4
Knowledge in Greenhouse Gases (X6)		Technology of waste management	
No knowledge	1	Knowledge of the technology (X14)	
Sufficient knowledge	2	No knowledge	1
High level of knowledge	3	Sufficient knowledge	2
Knowledge of the impact of solid waste on greenhouse emissions (X7)		High level of knowledge	3
No knowledge	1	Willingness to apply the technology (X15)	
Sufficient knowledge	2	Willing	1
High level of knowledge	3	Not willing	2

2.3. Data Analysis

The chi-squared ($\chi 2$) correlation test was run using SPSS software to ascertain relationships between the predictor factors and the response variables. The respondent variables covered the community activities to increase the value added of solid waste, and each was given two nominal scales as follows: Using technology to increase value added of plastic waste (Y2): respondent activity in using technology to shred plastic waste. If the respondent didn't use technology, then Y2 = 0; if they did, then Y2 = 1.
Table 1 contains a list of the predictor variables.
Using the following hypothesis, correlations between response variables and predictor variables were found:

1. If there is no correlation between the response variables (Y) and the predictor variables (X), then hypothesis (H0) is accepted.
2. If there is a correlation, then hypothesis (H1) is accepted.

The significance values (α) and Pearson χ^2 values were used to determine the correlations between the predictor and response variables.
The following procedure was used for the correlation test between the predictor and response variables:
1. If the computed Pearson χ^2 value was higher than the χ^2 value in the table or the calculated value was less than 0.1, the predictor and response variables are correlated (reject H0 and accept H1).
2. If the computed Pearson χ^2 value was lower than the χ^2 value in the table or the calculated value was higher than 0.1, the predictor and response variables are not connected (accept H0 and reject H1).

3 Results and discussion

3.1 Residential solid waste composition

The residential solid waste was dominated by plastic (61 %), followed by paper (26%), other (7%), metal (4%) and glass (2%) (Figure 1). The generators' favored products for sorting and selling to garbage collectors included plastics, paper, and metal waste components. Sorting, in the opinion of Plastic Zero [29], gives polymers more value. Sorting is done by purity, color, and type for waste materials like polymers. Both the

quality and the price value of the recovered trash are improved by adding value. Informal waste collectors retrieve the majority of the waste in emerging economies [37, 38]. This suggests that evaluating the many methods for adding value to the recovered waste is vital. In order to improve sustainable value-creation processes in the manufacturing and conversion industries, it is essential to comprehend how value is added. Achieving circular economies requires a strong focus on sustainable value development.

The waste components that were separated and sold to waste collectors most frequently included paper, plastic, and metal. Sorting gives polymers value, according to Plastic Zero [29]. Sorting is done by purity, color, and type for polymers and other waste products. The quality and worth of the recovered wastes are enhanced by adding value. The majority of waste in underdeveloped economies is retrieved by unofficial waste collectors [37, 38]. This suggests that it is important to evaluate how recovered waste is given extra value. To enhance sustainable value-creation processes in the manufacturing and converting industries, it is essential to comprehend how value is added. Circular economies can be attained by focusing on sustainable value creation.

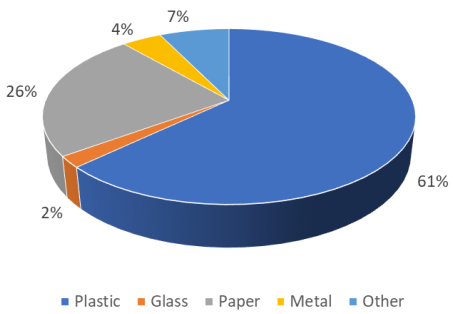

Fig. 1. The residential solid waste categories

3.2 Community activities in solid waste separation

Sorting recyclable components, such as plastics, paper, and metals, from decomposable and residual ones is one of the community activities involved in solid waste separation. Eighty percent of the 45 participants in the direct interview survey were asked to complete segregated and collected recyclable solid trash for further processing. 20% of people choose not to engage in this activity. Ninety-three percent of people who separate their waste said they were willing to collect it with their community and sell it to waste collectors, while the remaining 7% said they would not participate in this activity (Figure 2).

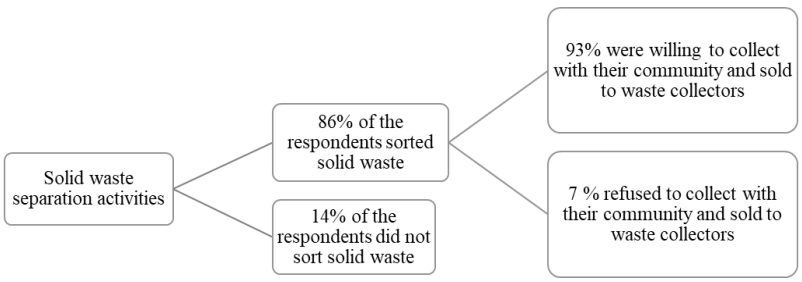

Fig. 2. Community activities in solid waste separation.

From the three possible explanations given to survey participants who separated their solid waste, 56% stated community leader guidance as the reason (Table 2). The remaining 25% claimed they separated their solid waste because of self-awareness. Other respondents (19%) said that the causes were a result of training. This is supported by the government of Bantul Regency, Indonesia, which is trying to develop a village-based waste management system [43].

Table 2. Reasons of respondents in performing solid waste separation.

Reasons	Percentage (%)
Self-awareness	56
Community leader instruction	25
Effect of training	19
Total	100

The respondents' excuses for not sorting the solid waste were as follows: No technical knowledge for further treatment (87 %) and no facilities for storing the sorted solid waste materials (23 %).

Table 3. Reasons for respondents who did not do solid waste separation.

Reasons	Percentage (%)
No technical knowledge for further treatment	87
No facilities for storage of the sorted solid waste materials	23
Total	100

3.3 Solid waste management

The majority (68%) of those surveyed who separated solid waste reported that non-compostable waste items such as plastics, paper, and metals were sold directly to waste pickers (Table 4). Homeowners in Bantul, Indonesia, frequently adopt this mindset since it is the most practical way to get more revenue from solid waste. The solid waste is then sold to the agent, who performs minimal processing on the recyclable solid waste, including washing, shredding, pelletizing, and packaging the plastic waste.

Table 4. Treatment of separated solid waste by community.

Treatment of separated solid waste	Percentage (%)
Directly sold to waste pickers	68
Treated by other means	32
Total	100

Such phenomena were widespread in Asia's emerging nations, where basic recycling methods were used [36]. The industrial industries buy recycled materials that have been treated [32, 37]. The remaining 32% of respondents handled the recyclable waste items in different ways, such as giving them to community leaders or solid waste pickers or storing them in the solid waste bank.

3.4 Value Addition and Recycling

The knowledge of plastic shredding machines increased after the community service program was conducted. This machine was the technology for increasing the value added to plastic waste. The value addition to the recovered wastes improved the quality as well as the price value. Chopped plastics are much more expensive than plastic in its original form. This is because shredding sorted plastic will make it easier for the industry to recycle plastic waste into new products at a lower cost.

Table 5. Knowledge of plastic shredding machines as technology for increasing the value added to plastic waste.

Knowledge of plastic shredding machine	Percentage (%)
No knowledge	0
Sufficient knowledge	93
High level of knowledge	7
Total	100

With the increase in respondents' knowledge about the benefits of shredding machines, all respondents are willing to use these machines to process plastic waste so that it has a much higher selling value, so as to increase their income.

Table 6. Willingness to use plastic shredding machines as technology for increasing the value added to plastic waste.

Knowledge of plastic shredding machine	Percentage (%)
Willing	0
Not willing	100
Total	100

There are waste collectors who gather valuable discarded wastes like plastic and return them to the economy in many developing economies. Reintroducing these discarded materials into the economy helps to create a circular economy. However, the contribution to a circular economy depends on the operations carried out on these recovered materials. The recycling procedures create value by adding value to the recovered plastic waste. Value-addition procedures are used in recycling operations to create value. This suggests that recycling operations are improved once the value is found in the recovered plastic waste. Recycling is important for creating a circular economy. Waste materials are transformed into fresh resources and added back into the networks of production. The kinds of value addition to the recovered plastic waste are a focal point in a circular economy since it views wastes as materials. Recycling has moved from being a nicety to becoming a need as the value of turning waste into useful products has become essential to life.

3.5 Correlation between the respond variables and the predictor variables

As shown in Table 7, the community involvement in using technology to increase the value-added of plastic waste correlated with the socio-demographic characteristics (i.e., age, marriage status, education level, income), the knowledge related to waste management (i.e., knowledge in waste sorting, knowledge in Greenhouse Gases, and knowledge in the impact of solid waste on greenhouse emission), the facilities related to waste management (i.e., a training program on 3R's activities, rank of non-organic waste types), the activities to manage the waste (i.e., activities of waste management, and willingness to sort waste),

the technology of waste management (i.e., knowledge of the technology, and willingness to apply the technology).

The training program correlated with the shredding activity since it informed the neighborhood about the value and technique of sorting residential solid waste. This outcome was in line with a previous study's finding that regular training programs could improve solid waste separation by the generators [7].

The test results also revealed that knowledge of the technology and willingness to apply the technology correlated with the shredding activity to increase the value added to residential plastic waste.

However, there was no correlation between the shredding of household plastic waste and the presence of solid waste banks or environmental cadres. This may indicate that the community, whether it has waste banks and environmental cadres or not, has embraced the use of technology for shredding as a component of their participation in residential solid waste management.

Table 7. Result of χ^2 correlation test between community using technology to increase value added of plastic waste and the predictor variables.

Predictor variables	df	χ^2 value	Result
Age (X1)	1	34.773	Reject H0
Marriage status (X2)	1	12.857	Reject H0
Education level (X3)	1	15.625	Reject H0
Income (X4)	1	12.971	Reject H0
Knowledge in waste sorting (X5)	1	16.425	Reject H0
Knowledge in Greenhouse Gases (X6)	1	13.966	Reject H0
Knowledge of the impact of solid waste on greenhouse emissions (X7)	1	11.177	Reject H0
Availability of solid waste bank (X8)	1	1.098	Accept H0
Availability of training program on 3R (X9)	1	11.035	Reject H0
Existence of environment cadres (X10)	1	.026	Accept H0
Activities of waste management (X11)	1	11.152	Reject H0
Willingness to sort waste (X12)	1	12.769	Reject H0
Rank of non-organic waste types (X13)	1	11.867	Reject H0
Knowledge in the technology (X14)	1	12.523	Reject H0
Willingness to apply the technology (X15)	1	38.919	Reject H0

4 Conclusion

Despite the lack of some facilities (such as trash banks and environmental cadres), the community in Panggungharjo Bantul has participated in executing the 3R's activities for residential solid waste. This demonstrated the high levels of community awareness and 3R's activities engagement. The promotion initiatives should focus on establishing better and clearer roles for society and government organizations. Consider using predictor factors to enhance the effectiveness of the promotion campaign if they exhibit significant correlations with neighborhood initiatives aimed at increasing the value added to solid waste. The many forms of value addition are important elements of value creation in industrial processes. As important decisions are made to create a sustainable circular economy, this knowledge of the various forms of value addition is therefore essential for plastic manufacturers, converters, and policymakers.

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