Identification of plastic waste generation and composition to reduce environmental disaster risk (case study: public facility sources in Padang City)

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Abstract. Plastic waste is a material that is difficult to decompose and, if not managed properly, will cause environmental pollution. The degradation of plastic waste in aquatic environments can result in microplastics that threaten marine life, while the incineration of plastic waste produces toxic gases harmful to health. This study aims to identify the generation and composition of plastic waste as an initial step in reducing environmental disaster risks. The research was conducted at public facility sources in Padang City, including parks, beaches, recreational areas, and roads. Plastic waste generation at public facility sources in Padang City amounted to 13.76 tons/day, or 6.44% of the total public facility waste. The rate of plastic waste generation was 32.93 g/person/day or 1.13 l/person/day. The composition of plastic waste was dominated by PETE plastic at 43.21% and LDPE plastic at 25.56%, with 58.88% used for beverage packaging and 36.48% for food packaging. Only 11% of respondents from public facilities sort and sell plastic waste to collectors, while the remaining plastic waste was disposed of in landfill sites mixed with other waste. This can lead to environmental disaster risks around landfills, such as water and soil pollution.

1 Introduction

Plastic waste has recently become an important topic of conversation due to its ever-increasing quantity. Plastic is widely used because it is cheap, easy to obtain, and easy to use. Almost all food packaging and wrapping items use plastic, not to mention plastic for other needs such as household appliances and furniture, children's toys, sports equipment, electronic and medical equipment, and so on [1]. Based on data from the Ministry of Environment and Forestry (KLHK), waste generation in Indonesia will reach 19,542,090.78 tons by 2022. As much as 18% of the overall waste generation in Indonesia is plastic waste. This data places plastic waste in second place in the composition of waste by type [2]. If this plastic waste is not handled correctly, it will impact health and the environment because plastic is difficult to decompose. Plastic waste disposed of into the waters will cause pollution, thus disrupting the lives of marine animals [3].

Padang City, with an area of 694.96 km2, has the same problem as other cities regarding plastic waste. Based on SIPSN data in 2023, plastic waste composition in Padang City is 12.4% [2]. The source that produces the most plastic waste has yet to be known. However, research in the waters of Padang City found microplastic content of 1.667-8.333 particles/l, with the dominant types of microplastic polymers are polyethylene, polycarbonate, and polyethylene terephthalate. Microplastic particles contained in living organisms cause damage to the digestive system, inhibit growth, interfere with enzyme formation, reduce steroid hormone levels, impact reproduction, and cause exposure to toxic plastic additives [4]. The abundance of microplastics in Bungus Bay sediments, Padang City, was found to be 228.89 particles/kg of dry sediment [5].

Research conducted by Syahlan in 2019 stated that the percentage of plastic waste in domestic sources in Padang City was 19.62%, with a generation unit of 40.43 g/person/day in weight units or 0.84 l/person/day in volume units. The largest composition of plastic waste by type is PP at 42.97% and LDPE at 32.36%, while based on its use is as food packaging at 42.61% and others at 32.86%. Existing 3R activities that have been carried out amount to 25.48% of the total plastic waste, with the most active activities being selling plastic waste to stalls or collectors [6]. To obtain data on the generation and composition of plastic waste from other sources, this study was conducted at the source of public facilities in Padang City. The public facilities studied were parks, beaches, recreation areas, and roads [7, 8]. It is hoped that this research can add data on plastic waste generated from various sources in Padang City so that efforts can be made to manage it from the source, especially in reducing plastic waste. Based on Padang Mayor Regulation Number 44 of 2018 concerning Regional Policies and Strategies in the Management of Household Waste and

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Similar Waste, the waste reduction target in Padang City in 2025 is 30% of the total waste generated [9].

2 Methodology

The research stages consist of a literature review, data collection, and data processing and analysis. Data collection includes primary and secondary data. Primary data includes data on plastic waste generation, composition, and management at each source. Plastic waste generation and composition data were obtained from sampling and direct measurement in the field. Secondary data in the form of the number and location of public facilities in Padang City was obtained from the Padang City Statistics Agency (BPS).

Determining the number of samples based on SNI 19-3964-1994 concerning Procedures for Taking and Measuring Samples of Urban Waste Generation and Composition. The number of waste samples for non-domestic sources is calculated using Equation 1 [10].

$$S = C_d\sqrt{T_s} \quad (1)$$

with:

S = Number of samples
C_d = Coefficient for medium cities, C_d= 1
T_s = Total population

From the calculation results, the number of samples in this study was 18 units, with a survey reliability of 97.40%. Reliable survey reliability should be 90%-100% [8]. Table 1 shows the number of waste samples for public facilities in this study. The sampling locations were randomized by referring to the category of each public facility. Before sampling, a field survey was conducted to determine the sample location points and request the willingness of public facility managers to be sampled in this study.

Table 1. Number of waste samples from public facilities [11]

No	Facilities	Amount*	Sample
1.	Park	10	3
2.	Beach	5	2
3.	Recreational Area	60	7
4.	Road	1062	6
	Total		18

Furthermore, plastic waste samples were taken from each source for eight consecutive days at the same location. Before sampling, plastic bags were distributed to the sampling location points as containers for plastic waste. The waste collected in plastic bags is generated in one day (24 hours) [10].

Table 2. Plastic types [8]

No	Plastic Type	Example
1	PETE (*Polyethylene Terephthalate*)	Plastic in the form of bottles from mineral water, cooking oil bottles, juice bottles, and cosmetic bottles.
2	HDPE (*High Density Poly Ethylene*)	Plastic in the form of cosmetic bottles, liquid milk bottles, medicine bottles, and jerry cans of lubricants.
3	PVC (*Poly Vinyl Chloride*)	Plastic in the form of shampoo bottles, plastic tablecloths, building pipes, water hose pipes, and plastic toys.
4	LDPE (*Low Density Poly Ethylene*)	Plastics from frozen meat wrappers, plastic lids, plastic bags, and other thin plastics.
5	PP (*Polypropylen*)	Plastics from children's toys, plastic cups, and margarine wrappers.
6	PS (*Poly Styrene*)	Styrofoam food containers, CD cases, plastic cups, transparent plastic food containers, plastic spoons and forks.
7	Others/multilayer	Car parts, plastic packaging, baby feeding bottles, computers, lego toys, gallon water refills, household appliances, and electronic equipment.

Table 3. Plastic usage [12]

No	Plastic Usage	Example
1	Food packaging	Packaging of ice cream, noodles, biscuits, etc.
2	Beverage packaging	plastic bottles and sachet packaging for soft drinks, milk, juice, mineral water, energy supplements, and similar products.
3	Toilet packaging	Packaging of toothpaste, deodorant, hand soap and body wash, shampoo, facial cleanser and similar products.
4	Cosmetic packaging	Packaging of perfume, hand and body lotion, face cream, skin care, and other perfume and beauty products.
5	Home cleaning packaging	Packaging of floor cleaner, glass cleaner, *porcelain,* kitchen, cookware and others.
6	Laundry packaging	*detergent*, softener, bleach and others.
7	Lubricant packaging	Brake fluid, engine oil for vehicles and similar products.
8	Other packaging	Cooking oil, plastic bags, *hairspray* and similar items.

Plastic waste samples were brought to the measurement location every day to be measured for plastic waste generation and composition. The measurement of waste generation was carried out in weight units by weighing the waste and in volume units by measuring the volume of waste in the compactor. The volume of plastic waste measured is the volume in the compactor stomped three times on the ground [10]. Furthermore, the composition of plastic waste was measured by sorting plastic waste based on its type and use and weighing the weight of each type and use of plastic waste. Table 2 and Table 3 show plastic waste composition by type and use

In addition, interviews were conducted with managers, visitors, or users of public facilities at each source. The number of visitors or users of public facilities interviewed for each category was 30 respondents. The questions asked were related to the current management of plastic waste. This data is needed to determine the amount of plastic waste produced and the management carried out by the community using public facilities.

Data processing and analysis are carried out by analyzing waste generation, composition, and management of existing plastic waste that has been carried out in public facilities in Padang City. Waste generation is the amount generated from a location within a specific time. Waste generation can be expressed in weight units (kg/person/day) and volume units (liter/person/day) [7, 8]. From the calculation of waste generation for eight consecutive days, two waste generation for the same day were obtained, namely the first day (Q1) and the last day (Q8). The correction factor is the ratio between the average waste of the same day and the waste of the first day. The unit of waste (q) is obtained from the waste data divided by the number of residents of each facility (p) [8]. The equations used are:

$$Q_r = (Q_1+Q_8)/2 \quad (2)$$

$$f_c = Q_r/Q_1 \quad (3)$$

$$q = Q/p \quad (4)$$

where:

Q = waste generation (kg/day, l/day)
Q_1 = day 1 waste generation (kg/day, l/day)
Q_8 = day 8 waste generation (kg/day, l/day)
f_c = correction factor
q = generation unit (kg/person/day, l/person/day).

Waste composition analysis was conducted by dividing the weight of each plastic waste component by the total weight of plastic waste from each source. Plastic waste composition is expressed as a percentage of wet weight (%). The composition of plastic waste is calculated based on Equation 5 [8, 10].

$$C = (W_C/W_T) \times 100\% \quad (5)$$

where:

C = waste composition (%)
W_C = weight of waste component (kg)
W_T = total weight of waste (kg).

Data analysis of the plastic waste management system was carried out by processing the results of interviews with the population in public facilities. The results of data processing are presented in graphical form. Furthermore, recommendations for plastic waste management at the source of public facilities are made by prioritizing waste reduction activities through the 3R program, namely reduce by limiting the amount of waste, reuse by reusing waste, and recycle by recycling waste.

3 Results and discussion

3.1 Plastic waste generation in public facilities

The measurement results of plastic waste generation units at public facility sources in Padang City can be seen in Table 4. The average unit of plastic waste generated from public facility sources is 32.93 g/person/day in weight units or 1.13 l/person/day in volume units. Of all public facilities, the largest plastic waste generation units were found in park facilities, i.e., 71.47 g/person/day or 3.32 l/person/day. This is because the amount of plastic waste generated is large even though the number of visitors is less than that of other facilities. The composition measurement shows that the most plastic waste generated by the park is in the form of its use as beverage packaging, such as bottles and beverage cups. People use park facilities to relax and work in parks equipped with wifi, such as digital parks.

The unit of plastic waste generated at the end of the week is more than on other days because people visit public facilities more on holidays, such as parks, beaches, and recreation areas. This causes an increase in plastic waste generation at the end of the week. The total generation of plastic waste produced by public facilities in Padang City is obtained by multiplying the units of plastic waste generation by the number of public facilities and the population in each facility. From the calculation results, it was found that the total generation of plastic waste from public facility sources in Padang City was 13.76 tonnes/day, as shown in Table 5.

The plastic waste generated unit from domestic sources in terms of weight is larger than that of plastic waste generated from public facility sources. While in volume units, the waste generation unit from public facilities is larger. The average plastic waste generation unit from domestic sources in Padang City is 40.43 g/person/day in weight units or 0.84 l/person/day in volume units [6]. This difference is influenced by the type of plastic waste produced. In domestic sources, the dominant plastic waste is the PP type, which is often used as food packaging and children's toys, which have a greater weight. While in public facility sources, the dominant type of plastic is the PETE type, which is often used as a beverage bottle, so it has a larger volume.

The percentage of plastic waste at the source of public facilities can be calculated by dividing plastic waste generation unit in this study by the waste generation unit in public facilities in Padang City. The waste generation unit from public facilities in 2023 was obtained by applying to the waste generation unit from public facilities

by Ruslinda in 2009. The waste generation unit from public facility sources in 2009 was 0.19 kg/person/day or 1.80 l/person/day [13]. The projection results show the waste generation unit from public facility sources in 2023 is 0.22 kg/person/day. With a total of 1137 public facilities, public facility waste generation was 75.69 tonnes/day. The percentage of plastic waste in public facility sources in 2023 amounted to 6.44%. This percentage is smaller than the percentage of plastic waste from domestic sources of 19.62%. [6]

Table 4. Plastic waste generation units at public facility sources in Padang City

Public Facility	Waste Generation Units	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Average
Park	Weight (g/p/d)	65.37	53.81	56.27	64.52	59.61	90.01	110.71	71.47
	Volume (l/p/d)	0.18	3.53	3.32	3.88	4.07	4.23	4.05	3.32
Beach	Weight (g/p/d)	14.65	15.97	16.60	14.60	17.82	15.47	24.58	17.1
	Volume (l/p/d)	0.25	0.28	0.31	0.30	0.31	0.32	0.29	0.30
Recreation area	Weight (g/p/d)	32.79	35.53	36.05	22.22	46.02	49.39	48.45	40.22
	Volume (l/p/d)	0.06	0.90	0.88	0.91	0.99	1.08	0.95	0.83
Road	Weight (g/p/d)	2.84	2.85	2.68	2.64	2.62	2.81	4.06	2.93
	Volume (l/p/d)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Average	Weight (g/p/d)	28.91	27.04	27.90	28.77	31.52	39.42	46.95	32.93
	Volume (l/p/d)	0.15	1.20	1.15	1.29	1.37	1.43	1.34	1.13

Table 5. Plastic waste generation at public facility sources in Padang City

Public Facility	Number of Facilities*	Average Population	Waste Generation (g/person/day)	Total Waste Generation (Tonnes/day)
Park	10	30	71.47	0.02
Beach	5	300	17.10	0.03
Recreation area	60	200	40.2	0.48
Road	1062	4256	2.93	13.23
Total				13.76

3.2 Composition of plastic waste in public facilities

3.2.1 Composition by plastic type

The measurement results of the plastic waste composition by type at the source of public facilities consist of PET plastic type of 43.21%, followed by LDPE at 25.56%, PP at 16.27%, PS at 8.45%, HDPE at 4.16%, PVC at 1.69%, and other types of plastic 0.64%. The results of this measurement can be seen in Table 6. PET plastic waste is the most common type of plastic generated from all sources of public facilities. The composition of PET plastic waste in parks and recreation facilities is almost 50% of the total plastic waste generated. This is related to the activities carried out in parks and recreation areas, such as drinking and snack activities that produce plastic beverage bottles and food packaging. According to data from the Japanese Plastic Waste Management Institute (PWMI) for 2022, PET accounts for 29.70% of all plastic waste generated [14].

LDPE plastic waste is generated in the largest amount at beaches and recreational facilities in the form of shopping bags and lightweight plastic containers. PP, PS, HDPE, PVC, and other plastic waste are mostly found on the road, which comes from the use of various types of product packaging, including disposable food containers and household appliances made of PP, while other types of plastic (multilayer) come from waste that is thrown onto the road such as packaging for medicines, milk and so on.

Compared with the research on plastic waste from domestic sources, differences in the composition of the plastic waste produced were found. The largest composition of plastic waste from domestic sources in Padang City is the PP type at 42.97%, in the form of fast-food packaging waste, snack waste, and cooking spices. In addition, LDPE plastic was also produced at 32.36%, which was found in the form of plastic bags and food packaging [6].

3.2.2 Composition of plastic waste by use

The results of the measurement of the composition of plastic waste based on its use in public facilities in Padang City are shown in Table 7. The composition of this plastic waste consists of toiletries packaging 0.1 %, cosmetic packaging 0.74 %, house cleaning packaging 1.05 %, other packaging 1.83 %, laundry packaging and lubricant packaging did not contribute to plastic waste, while beverage packaging and food packaging contributed 58.88 % and 36.48 % of the total plastic waste, respectively. Most visitors who come to the public facility location shop for drinks and snacks sold at the location

Table 6. Composition of plastic waste by type

Plastic Type	Composition (%)				Average
	Park	Beach	Recreation Area	Road	
PET	54.97	38.31	47.43	32.14	43.21
HDPE	2.85	3.32	3.71	6.77	4.16
PVC	0.40	0.69	0.20	5.47	1.69
LDPE	19.32	34.62	26.02	22.30	25.56
PP	14.68	15.11	14.91	20.39	16.27
PS	7.77	7.94	7.63	10.48	8.45
Others	0.00	0.00	0.11	2.46	0.64

Table 7. Composition of plastic waste by use

Plastic Type	Composition (%)				Average
	Park	Beach	Recreation Area	Road	
Food Packaging	29.18	38.40	38.83	39.51	36.48
Beverage Packaging	68.41	55.58	57.53	54.02	58.88
Toiletries Packaging	0.00	0.69	0.19	1.14	1.01
Cosmetic Packaging	0.00	1.46	0.11	1.40	0.74
Home Cleaning Packaging	0.00	0.00	1.20	3.00	1.05
Laundry Packaging	0.00	0.00	0.00	0.00	0.00
Lubricant Packaging	0.00	0.00	0.00	0.00	0.00
Others	2.42	3.87	0.11	0.93	1.83

Plastic waste from toiletries, cosmetics, household cleaners, and other packaging each has a small contribution of 1-2%. Plastic waste from toiletry and cosmetic packaging is often found in beach facilities. This is related to swimming activities carried out by visitors in the beach area, especially by children. Plastic waste from cleaning applications is found in recreational facilities and on highways. This waste is supposed to come from other sources along the roadside. Plastic waste from other packaging is also found on the beach, including plastic bags and various types of products; this is caused by ocean currents carrying plastic waste from various sources to the beach. Meanwhile, plastic waste from laundry and lubricant packaging was not found in public facilities.

From the research on domestic sources in Padang City, it was obtained that the largest plastic waste composition based on its use was as food packaging at 42.61% and other packaging at 32.86%. Households in high-income groups produce the most plastic waste from food packaging and other waste compared to middle- and low-income groups. This is influenced by the lifestyle of high-income people who tend to consume packaged and fast food [6]. Meanwhile, research on non-domestic sources in Bandung City found that the composition of plastic waste used in food packaging, toiletries packaging, household cleaning packaging, and laundry packaging was 20% each [12]. The difference in activity affects the difference in each source in terms of plastic use in everyday life.

3.3 Plastic waste management at public facility

Data on existing plastic waste management in public facilities was obtained from interviews with respondents in public facilities, such as managers and visitors. Of the 18 public facility units sampled, only 11% have sorted, collected, and sold plastic waste to collectors. These public facilities are a digital park and Padang Beach. Digital Park managers provide segregated waste containers, one of which is for plastic waste. Next, the plastic waste is collected at the sorting location to be sorted, cleaned, and packed into sacks. This plastic waste is then sold to collectors. Meanwhile, waste management is carried out in the Padang Beach area by sorting, collecting, and selling waste to the Nabuang Sarok Recycling Center of PT Semen Padang. This activity is carried out by community groups around the beach area and environmentalist communities, which often hold environmental clean-up activities around the beach, especially on holidays.

As many as 81% of public facilities have not yet sorted and processed plastic waste. In this facility, plastic waste is collected at the temporary waste storage site and then taken to the waste final processing site for landfill. Plastic waste is difficult and can even take decades to decompose. Piling plastic waste in landfills, if not appropriately managed, will pose a risk of environmental disasters such as water and soil pollution. Polluted land and water will

cause problems with human health [15]. Figure 1 shows the existing management of plastic waste in Padang City public facilities.

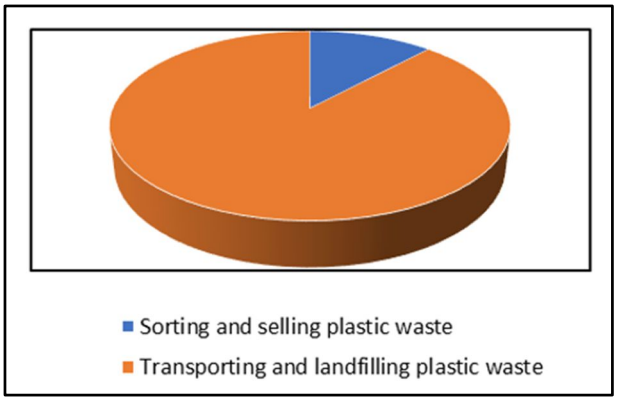

Fig. 1. Existing plastic waste management at public facilities

The interview results also showed that there have been efforts to reduce plastic waste. Visitors generally carry out this activity by bringing tumblers, but the percentage is only 28%. Carrying a tumbler can reduce plastic bottles and glass waste. Research from domestic sources shows that the use of tumblers can reduce plastic waste by 5.97% of the total plastic waste produced [16].

3.4 Recommendation

From the results of measuring the generation and composition, as well as the existing management of plastic waste, recommendations can be provided to reduce plastic waste generation from public facility sources, as follows:

1. For visitors to public facilities that are plastic waste generators, limiting plastic waste can be done by bringing a tumbler, a reusable shopping bag, and bringing their own food box to reduce plastic waste in the form of drinking bottles, plastic bags, and styrofoam.
2. For public facility managers who are waste managers in the public facility environment, it is recommended to provide separate containers and waste collection tools according to the type of waste generated. This sorting is intended to facilitate further waste management. In addition, managers are also asked to provide a location for processing plastic waste, at least for sorting, cleaning, and packaging. Furthermore, sorted plastic waste is sold to collectors (informal sector) or to Nabuang Sarok PT Semen Padang, which is one of the waste recycling centers in Padang City. This plastic waste can be reused as raw material in the waste recycling industry or can be used as biomass as an alternative fuel. For this reason, public facility managers must conduct socialization activities to limit, reuse, and recycle plastic waste. Socialization can be done by installing banners and posters in the public facility environment. Socialization can also be carried out in collaboration with environmentalist communities to hold enjoyable activities in terms of environmental awareness.
3. Vendors selling in public facilities are asked to provide refillable gallons of drinking water and use refillable cleaning containers. This activity can reduce plastic waste by reusing the plastic waste generated.
4. The government is advised to promote 3R activities by facilitating permits for related events in public facilities, providing infrastructure and facilities for plastic waste collection, and providing incentives and disincentives to public facilities that implement 3R activities. In addition, it is recommended to make a plastic waste reduction policy with fines for violators and to succeed in the paid plastic bag program in shops and cafes in recreational areas.
5. The informal sector is advised to become a partner in the reuse of plastic waste from public facilities. This informal sector comprises collectors, waste banks, and Nabuang Sarok PT. Semen Padang which can accept all types of plastic waste. This plastic waste will be burned in a kiln as an alternative fuel substitute. According to Novita and Damanhuri, plastic has a high calorific value ranging from 5000-13000 kcal/kg to help the combustion process [9].

4 Conclusion

The conclusions obtained from this research are:

1. The average generation of plastic waste from public facilities in Padang City was 32.93 g/p/d or 1.13 l/p/d. Parks had the highest generation unit at 71.47 g/p/d or 3.32 l/p/d, compared to recreation areas at 40.22 g/p/d or 0.83 l/p/d, beaches at 17.10 g/p/d or 0.30 l/p/d, and roads at 2.93 g/p/d or 0.09 l/p/d. The percentage of plastic waste in public facility sources is 6.44%. Plastic waste composition in public facilities is dominated by PET at 43.21%, followed by LDPE at 25.56%, PP at 16.27%, PS at 8.45%, and other types at 0.64%. Beverage packaging contributes the most plastic waste based on its use at 58.88%, followed by food packaging at 36.48%, while toiletries, cosmetics, house cleaning, and other packaging each have smaller contributions.
2. The existing management of plastic waste in public facilities involves the sorting and selling plastic waste to the informal sector, which is only carried out in 11% of existing public facilities. The remaining 81% collect plastic waste at TPS and then transport it to TPA for landfill, risking causing environmental disasters such as water and soil pollution.
3. Recommendations given in the management of plastic waste in public facilities for visitors are to limit the amount of plastic; and for managers, it is the provision of containers and segregated collection tools, the provision of locations and officers for sorting, cleaning, and packaging plastic waste. For traders in the public facility environment, it is done by providing gallons of drinking water and refillable cleaning packaging. For the government, it is recommended to promote the 3R activities of plastic waste by providing collection facilities, making plastic waste reduction policies, and providing

incentives and disincentives to public facilities that carry out 3R activities. For the informal sector, it is suggested that they can become partners in plastic waste utilization activities.

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