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Marine and macroplastic litter monitoring and strategic recommendation for reducing pollution: case study from Semarang City

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Abstract: Indonesia is one of the largest contributors to global marine litter deposition, given its high population and the largest archipelagic country. The increasing problem of plastic littering has recently attracted the attention of researchers. This study aims to identify marine and macroplastic litter in Semarang City. A field survey was conducted by dividing the beach into 18 sampling grids, each with an area of 1 × 1 m2. A literature survey was also conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to identify literature that can be used to develop recommendations. The results showed that 6.26–11.16 grams/m2/day of marine litter and approximately 1.61–4.89 items/m2/day of plastic litter would be deposited on Semarang City beaches. The greatest contributors to macroplastic litter were polypropylene (PP) and low-density polyethylene (LDPE), which should be considered for further intervention. Strategic recommendations were developed based on an in-depth literature survey and best practices in the current field. These also include recommendations that can be used as a reference by policymakers and other stakeholders to reduce marine pollution. The results of this study are expected to provide a multiplier effect on reducing marine pollution for the city.

Introduction

Micro and macroplastics are widely found in marine ecosystems; the potential impacts of marine litter have thus attracted the attention of many researchers worldwide (Galgani et al. 2019, Löhr et al. 2017). Zooplankton and vertebrates ingest litter that accumulates in their bodies (Kaviarasan et al. 2020). This has had a profound biological impact, especially since plastic use has increased during the Covid-19 pandemic; however, no significant measures have been taken to reduce this litter (Sari et al. 2022). Other potential impacts of this litter include economic losses due to biodiversity loss, reduction in ecosystem provision, and an impact on human health, well-being, and the tourism sector (Beaumont et al. 2019). The majority of this litter originates from inadequately managed land-based activities , releasing debris into the river and accumulating in coastal areas (Binetti et al. 2020, Dobler et al. 2022). The fact that this marine litter sinks in beaches and coastal regions requires further investigation (Kaviarasan et al. 2020).

Given that Indonesia is the world's largest archipelagic country, it has the highest potential for marine litter deposition. Three years of field survey show that a vast macroplastic litter deposition, ranging from approximately 23.7 to 41.6 items/m^2, exists along the Cilacap coast (Syakti et al. 2017). In Tidung Islands, Jakarta, the density of marine plastic is around 1.53 items/m^2 (Hayati et al. 2020). In Bali, the most famous tourist spot in the world, around 0.08 to 1.69 items/m^2 with a weight ranging from 0.25 to 17.94 grams/m^2 of marine debris has accumulated in the coastal ranges (Suteja et al. 2021). Cordova et al. (2022) found that during the sampling periods of 2018–2019, the density of plastic debris stranded along Indonesian beaches ranged from 1.31 to 2.69 –items/m^2, with an average weight of 166.09 ± 75.55 grams/m^2. In comparison to other marine litters, plastic waste accounts for the highest proportion of the total litter (46 – 86.9%) and is found in many coastal areas of Indonesia (Renjaan et al. 2020). Despite these findings, the linkage between the daily accumulation of macro- and microplastic contamination in the coastal line of Indonesia yet remains unclear. Strategies and recommendations to reduce pollution are crucial as preventive measures against marine pollution.

This study aimed to estimate the amount of marine litter deposited on the beaches of Semarang City, taking into account the time and location of the survey. Tirang Beach is managed by the local community, while Marina Beach is operated a private company . Since Marina Beach also serves as an estuary for the Banjir Kanal Barat River, one of the significant rivers in Semarang City, it is more vulnerable to waste deposition from land sources. The primary focus of this study was to investigate the composition and distribution of marine and macroplastic litters on the two beaches. We believe that the data obtained from this study will contribute to recommending policies to reduce pollution. Moreover, strategic recommendations were developed using an in-depth literature review of the Scopus database.

Methods

General Information of Study Area

Semarang City is a coastal city with a 13.6 km long coastal line and five well-known beaches: Marina, Tirang, Cipta, Baruna, and Maron Beach. Marina Beach is the most famous for its tourist attractions. It is located on Yos Sudarso Street in the Development Recreation and Exhibition Center Complex (locally known as PRPP) in Tawangsari Districtof Semarang City, Indonesia. The reclamation of mangrove forests and ponds is underway on 20,000 m^2 of Marina Beach's area . With an average daily number of visitors approaching 2,000, the beach attracts 720,000 visitors annually. The facilities at Marina Beach include parking areas, toilets, prayer rooms, stalls, restaurants, and deer stables. Marina Beach features a flat surface with a slope of 2 – 4° directly facing the ocean.

Besides Marina Beach, Tirang Beach is also a famous tourist destination in Semarang City. Located in Tambakrejo Village, Tugu District, approximately 10 km from the city center through the Griya Padma Semarang Housing. Tirang Beach is managed by the local community-based organization called *Pokdarwis*. Known for its potential for barramundi and grouper fishing, the beach is a popular fishing spot and features a mangrove forest. Facilities at Tirang Beach include parking areas, stalls, toilets, and seat rentals. Geographically, Tirang Beach is relatively similar to Marina Beach, with the same degree of slope and a relatively flat surface. The main difference between the two beaches is that Marina Beach, located downstream of the Banjir Kanal Barat River, is more widely known. The Tirang Beach attracts approximately 100 – 200 visitors daily, significantly fewer than Marina Beach. Consequently, the litter characteristics at the two beaches differ. The sampling locations and beaches are shown in Fig. 1.

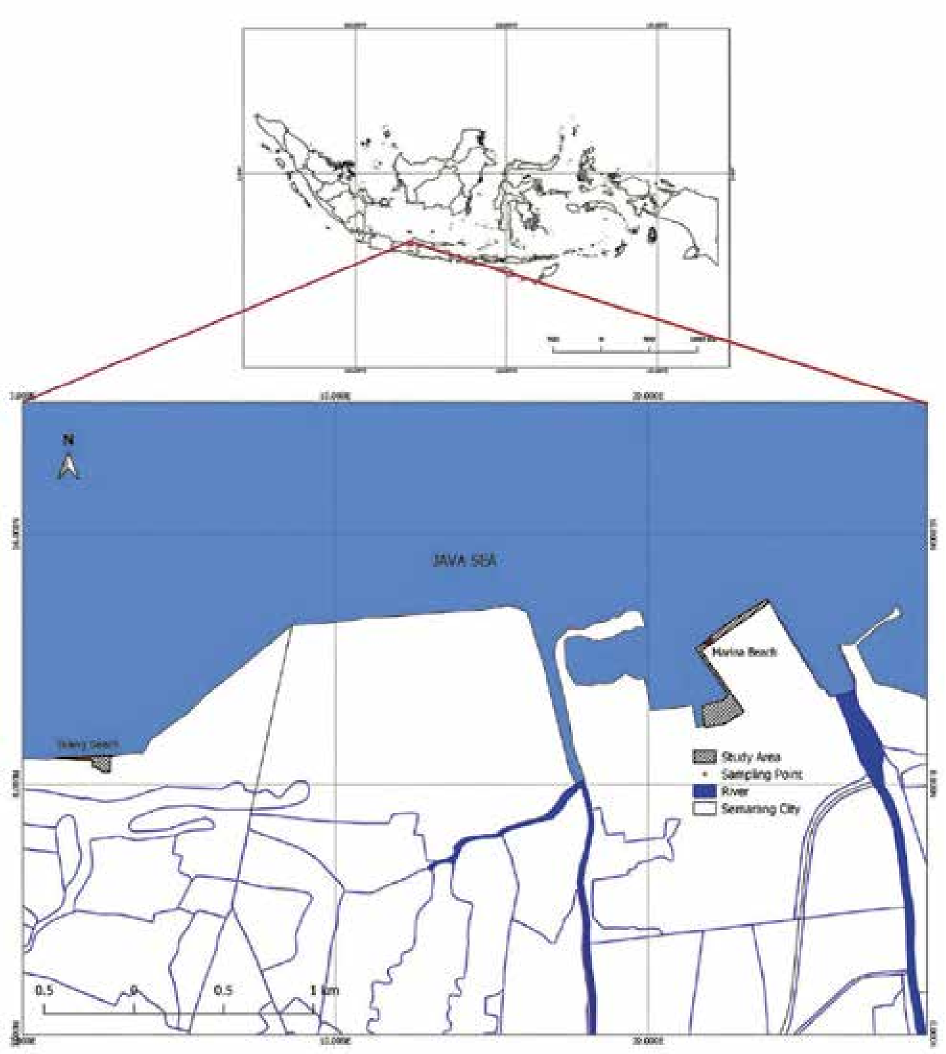

Figure 1. Study location.

Figure 2. Illegal waste dumping in (a) Marina and (b) Tirang Beach and sightseeing of beaches of (c) Marina and (d) Tirang.

Increasing tourist activities in these areas have led to waste management issues. Marine litter and illegal waste dumping have been observed in both regions (Fig. 2a – d). Pratiwi et al. (2021) found that marine pollution in Semarang City consists primarily of wood litter, plastic, glass, and fabric. Tirang Beach is predicted to be the second largest contributor (approximately 155.5 kg/day) of marine litter, with Baruna (227.4 kg/day) ranking first and Cipta Beach (92.4 kg/day) the third. Further investigations in this regard are thus warranted. The amount of litter found by Pratiwi et al. (2021) represents a 100 m long transect campaign survey, including land-based marine debris found around the transect line.

Field Sampling Procedure

A field survey was conducted in October 2022, twice on weekdays and holidays in other weeks. The sampling locations included Marina and Tirang beaches, each with 18 sampling points. The two sampling times provided a clear view of the patterns or differences between the varied numbers of visitors. A higher number of visitors were reported during the holiday period in all tourist areas. As seen in Fig. 3, during field sampling, the surveyors were equipped with zip locks, tape measures, and sticks to determine the sampling points and grid the sampling location. The sampling method involved measuring a line along the coast using a tape measure and then dividing it into 18 points with 5 m for each point and a grid size of 1 x 1 m^2. After determining the distance and sampling point, the grid area was marked with a stick. During the sampling, tweezers were used to collect all visible plastic objects in each quadrat from the sand surface.The top 5 cm of sand from each quadrat was sifted using a 1 mm-mesh size sieve, and any

Figure 3. Survey campaign in Marina (left) and Tirang Beach (right).

remaining debris was sampled. All litter samples were placed in zipper bags for laboratory measurements, while other types of debris, such as wood, metal, shell, and stone, were separated and discarded. If the sand samples were damp, they were air-dried in the laboratory before sieving to prevent contamination of the mesh screen cover. Observations of the shore features were also recorded at each location. In total, the quadrats covered anarea of 36 m^2 (2 sampling locations x 18 quadrats at each location) across the study area. The sampling procedure followed the methodology described by Ghaffari (2019). The total sampling areas for Marina and Tirang beaches were 12,500 m^2 and 3,500 m^2, respectively.

Sample Measurement

Marine litter was measured immediately after the field campaign using an analytical balance scale (Mettler Toledo). The litter was separated into 10 components: wood, cigarette butts, plastic straw, bottles and caps, sachets, paper and cardboard, clamshells, leaf and food waste, rubber, and other waste. The clamshells were classified as marine litter because they originated from the adjacent side-beach restaurant and resulted from waste generated by fishing activities (Corbau et al. 2023). Each type of wet litter was weighed to determine its potential for litter generation in the designated area. Subsequently, plastic litter was reclassified and reweighed according to the international recycling code, including polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS).

Data Analyses

Literature review and a preliminary field survey were conducted to determine the current conditions of waste management on Tirang and Marina beaches. A descriptive analysis was then conducted to interpret the collected data and their reflection on the variations. The densities of the marine and plastic items were calculated using Equation (1).

$$D = \frac{\sum I}{A} \quad (1)$$

where D is the item/weight density (items/m^2), $\sum I$ is the total number of items found in a grid area, and A is the area of the grid (m^2).

Finally, the Mann-Whitney Wilcoxon Rank Sum Test was employed to identify significant differences among the collected samples during both holidays and weekdays, focusing on the characteristics of the litter collected. This type of analysis was chosen because the data did not follow a normal distribution, precluding the use of descriptive analyses. The null hypothesis posited a significant difference between two independent samples. Statistical calculations were performed using SPSS 16.0. .

Literature Review Methodologies

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was used to determine the current research trends in marine/coastal litter in Indonesia and propose several recommendations for strategic actions to reduce marine litter pollution. The PRISMA methodology (Ramadan et al. 2022) divides the sampling methodology into four phases: identification, screening, inclusion, and qualitative analysis (Fig. 4). In the identification phase, a literature search was conducted using the Scopus database With the keywords "marine," "ocean," "debris," "litter," and “strategy” for preliminary identification. Forty-eight documents were identified in the initial identification process. Automation tools removed 11 based on exclusion criteria such as a publication age of 10 years (2023–2012), original research and review articles, journal papers (not proceedings), and English-only publications. During the screening phase, 37 documents were retrieved, and manual abstract, title, and full-text screening were performed to obtain eligible papers for in-depth analysis. Papers lacking information on pollution prevention or reduction strategies in their metadata were excluded from the analyses. At the end of the inclusion step, eight documents were read and qualitatively analyzed.

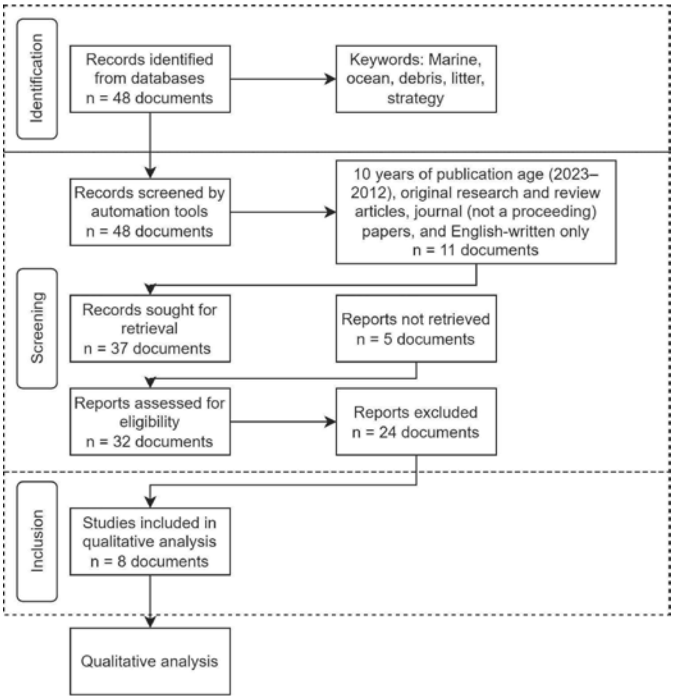

Figure 4. PRISMA methodology employed in this research.

Results and Discussion

Quantity of Marine Litters

During the field survey, it was found that the clamshells accounted for the maximum amount of litter found in Tirang, both on the weekends and weekdays, followed by wood and plastic litter. The amount of leaves and food waste was found to be lower than that in the research conducted by Pratiwi et al. (2021), but that of plastic litter was still higher in both cases (Fig. 5). The coastal environment of Tirang Beach is dominated by clamshells, whereas that of Marina Beach is prominently made up of paper and cardboard waste. Based on the sampling time, it was observed that the number of litters found during the field survey was higher on weekends in both sampling locations. The total marine litter on Tirang Beach collected during the field survey was 157.85 grams/day on the weekend and 112.69 grams/day on weekdays. On Marina Beach, the figures were 201.040 grams/day and

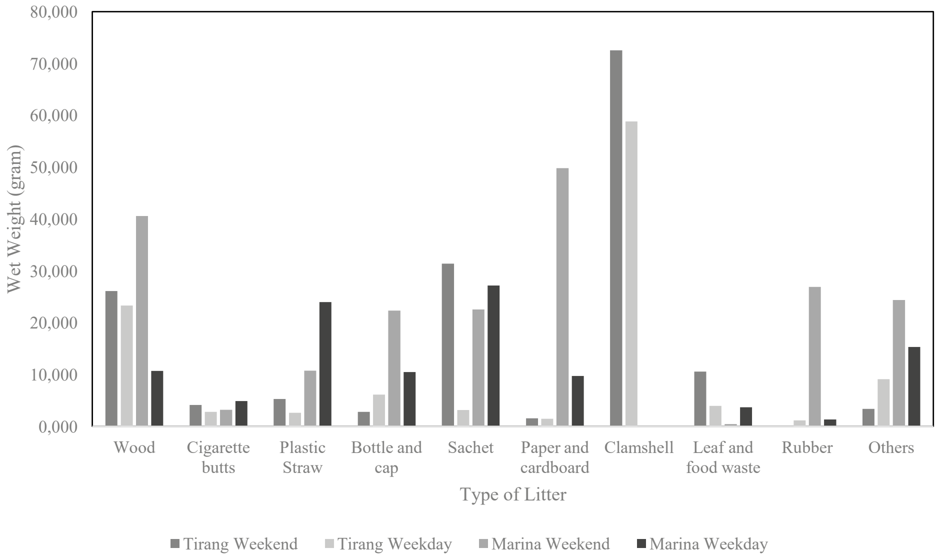

Figure 5. Survey campaign in Marina (left) and Tirang Beach (right).

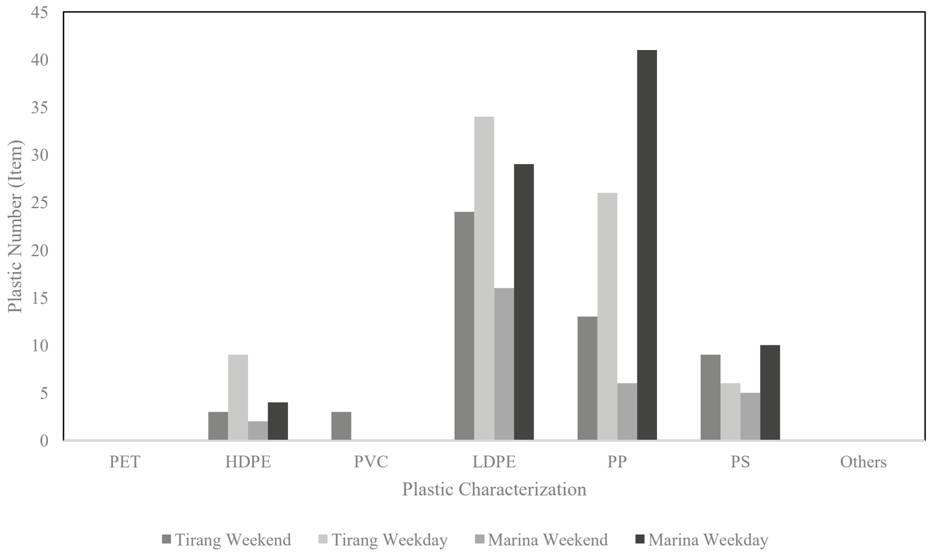

Figure 6. Macro plastic litter characteristics found in the Tirang and Marina Beach on the weekends and weekdays.

107.49 grams/day on weekends and weekdays, respectively. This indicates that the amount of marine litter in Tirang Beach on the weekend is 1.5 times higher than on the weekdays, while on Marina Beach, it is twice as much on weekends. The weight of litter found on each beach area was predicted to be around 6.26 – 11.16 grams/m^2, averaging to 8.04 ± 2.43 grams/m^2.day. The plastic litter stranded on the two beaches was calculated to be approximately 5.29 grams/day and 3.76 grams/day on weekends and weekdays, respectively. The total average amount of litter left on the Semarang City beaches was thus 4.52 ± 1.08 grams/m^2.day. For the entire surveyed area, total liter depositions in Marina and Tirang beaches scaled to approximately 128.64 kg/day and 72.32 kg/day, respectively, which is lower than estimations made by Pratiwi et al. (2021).

Total Items of Macro Plastic Litters

According to the quantity of macroplastic litter found in the field survey (Fig. 6), the number of items differed between holidays and weekdays on both beaches. Higher amounts of plastic litter were found on the weekdays on both the coasts. At Tirang Beach, at least 52 plastic litter items from all characteristics were found on weekends and 72 items on weekdays On weekends at Marina Beach, 88 plastic items were found , whereas only 29 items were found on weekends. The macroplastic litter deposited on Semarang City beaches has been predicted to be around 1.61 – 4.89 items/m^2/day,averaging the number of plastic items in both beaches to 3.40 ± 1.46 items/m^2/day. It was also assumed that at least 54,444 macroplastic items are deposited per day, along with other marine litter, on Marina and Tirang beaches. LDPE had a higher count (24 and 16 items for Tirang and Marina Beach) than PP (13 and 6 items) on weekends at both beaches. In contrast, PP was found to be higher on Marina Beach (41 items) than LDPE (29 items) on weekdays. The results show that the accumulation of LDPE was the highest, followed by PP, PS, and HDPE; these results need further discussion .

Table 1. Statistical test on marine litter generation

Indicators	Tirang vs. Marina		Tirang WE - WD		Marina WE - WD	
	Marine litter	Macro-plastic litter	Marine litter	Macro-plastic litter	Marine litter	Macro-plastic litter
Wilcoxon W	1,233.5	1,253.5	308	265.5	302	207.5
Z	-0.915	-0.681	-1.378	-2.161	-1.569	-4.007
Asymp. Sig. (2-tailed)	0.360	0.496	0.168	0.031	0.117	0.000

Statistical Analyses Results

No significant differences (significance level set at $p < 0.05$) were observed in the marine litter found on Tirang and Marina beaches during holidays and weekdays (Table 1). Each area and day reported the same amount of beach litter. Moreover, no significant differences were reported between the marine and macroplastic litter of the two beaches, suggesting that the litter characteristics of the two beaches are potentially the same. However, significant differences were found in the accumulation of macroplastics on the two beaches during the holiday season and on a weekday. The higher accumulation of plastic litter during weekdays on the beaches of Semarang City, needs to be investigated further in future studies.

Discussion

The amount of marine litter estimated by our study was lower than that reported by Cordova et al. (2022). However, their mean abundance of the stranded debris, ranging from 1.83 to 4.33 items/m^2, aligns relatively towel with our study. Both studies showed dominance of macroplastic litter, in which plastic sachets/multilayers of litter were found on both beaches. These plastic sachets are used to package items such as snacks, shampoo, lotion, and seasoning, known for being relatively affordable and cheaper than other forms of packaging. The three-year research of Cordova et al. (2022) and the findings of our study suggest that the composition of litter in marine environment has been constant over the years, reflecting the similar economic lifestyle of Semarang City citizens over the time. The hypothesis of this study assumed that litter accumulation originates from inland-based activities and waste transported by rivers from the surrounding area (Lauer and Nowlin 2022). Given that Tirang Beach attracts fewer daily visitors than Marina Beach, the amount of waste is less. Hayati et al. (2020) mentioned that the higher the number of tourists visiting beaches, the greater the possibility of litter scattered along the coastline. Effective tourism management is thus necessary to maintain a proper environmental status for both beaches.

Based on the beach characteristics, Marina Beach was found to have a higher marine litter weight but a lower plastic density. Because Tirang Beach is used not only for tourism but also for intensive fishing activity, the possibility of plastic density is higher at Tirang Beach, as evident from the several fishing lines and nets found on the beach during the transect study. In addition, the waste management on Tirang Beach is not as good as that on Marina Beach, further adding to the plastic waste. This assumption is supported by Hayati et al. (2020), who found that the use of plastic packaging by tourists may increase the possibility of plastic litter around the site. Therefore, inland waste management must be optimized. However, according to statistical analyses, the amount of litter in Marina and Tirang beaches was not significantly different, suggesting that the marine litter may have originated from the same source. With respect to the difference in macroplastic density between weekends and weekdays, it is suggested that higher anthropogenic activities from land may occur on weekdays. Therefore, tourism activity may not contribute significantly to plastic litter but rather to the overall marine litter (Renjaan et al. 2020).

As shown in Table 2, strategies can be used to prevent, mitigate, and reduce marine litter, especially in Semarang. Coastal clean-up is a highly recommended mitigation action for reducing the effects of marine litter pollution (Syakti et al. 2017). Regular coastal cleanup will increase public awareness and encourage people to protect their environment. Therefore, coastal clean-up can also be used as a preliminary preparation before monitoring and conducting field campaign surveys (Dasgupta et al. 2022, van Emmerik et al. 2020, Westlake et al. 2022). At present, there is a pressing need to formally integrate environmental education (EE) into Indonesia's national educational system. Achieving this integration demands significant effort. While EE material are freely accessible on the internet, incorporating EE into the learning process can enhance awareness and community engagement in addressing littering behavior (Sukma et al. 2020). Nevertheless, these strategies are time-consuming and costly, requiring the involvement of many stakeholders. Other approaches should be considered as options for behavioral change (Wu et al. 2017, Yenici and Turkoglu 2023). Other strategic recommendations for reducing litter pollution include increasing the number of waste collection points or bins, especially on beaches or in tourist areas (Westlake et al. 2022). This strategy prevents litter from escaping the tourist areas. However, this strategy also involves financial investments. In addition, without behavior change, people may still engage in bad practices even when the facilities are already available. Continuous spatial and temporal monitoring can provide a significant database for placing appropriate waste collection bins (Dasgupta et al. 2022). However, this strategy also comes with a higher cost for maintaining the sustainability of data collection. Good data validation and verification are required to ensure the robustness of the data as a baseline for policy development (Chitrakar et al. 2019).

Regulation is the most robust policy tool if effectively implemented. The prohibition of single-plastic use in some Indonesian cities has demonstrated several multiplier effects in reducing plastic usage. For example, Nurulhaq and Kismartini (2019) found a decrease in the number of single-plastic bags following the plastic ban. Their study showed that people with higher educational level tended to use reusable bags rather

Table 2. Strategic recommendation for reducing marine litter pollution in Semarang City and other coastal cities.

Strategies	Policy tools*	Strength	Weakness	References
Temporal and spatial coastal cleanup by crowd-based activities	Education	• Increase public awareness • Increase community engagement • Allow data collection and monitoring	• Time and cost consuming • Other approaches are needed to get good results from behavior change • Require strong coordination skills between stakeholders	(Dasgupta et al. 2022, van Emmerik et al. 2020, Westlake et al. 2022, Wu et al. 2017)
Enhance public awareness by applying environmental education at the household level	Education	• Increase public awareness • Increase community engagement	• Time and cost consuming • Require strong coordination skills between stakeholders	(Wu et al., 2017, Yenici and Turkoglu 2023)
Increase access to bin/ waste collection points	Programs	• Encourage people to leave litter behind • Reduce the debris escaping containment within the area	• Higher cost for providing the facilities • Need environmental education	(Dasgupta et al. 2022, Westlake et al. 2022)
Continuous temporal and spatial monitoring	Information	• Increasing the availability of data to identify the hotspot areas • Defining the appropriate waste collection points	• Cost for monitoring and intensity • Data validation	(Chitrakar et al. 2019, Dasgupta et al. 2022)
Prohibit the use of plastic bottles, bags, and other single-use items	Regulation and Standards	• Massively increase the reduction of litter escaping to the environment • Businesses can receive some recognition and incentives	• Need a firm commitment from the stakeholders • Need massive education to implement • The government should prepare other infrastructure to prevent improper waste management through the change of the system	(Lauer and Nowlin 2022, Yenici and Turkoglu 2023)
Compliance activities by the industries and law enforcement	Regulation	• Increase public awareness • Effective long-term behavior change	• Less effective and desirable • Fewer people or stakeholders are involved in the activities • Penalties are not supported by sufficient environmental education	(Westlake et al. 2022, Wu et al. 2017, Yenici and Turkoglu 2023)
Apply higher taxes and fees on plastic-based product	Taxes	• Reduce the need for plastic • Boost the usage of reusable goods	• A low-income household may be affected the most • Tax exemptions need to be defined and measurable	(Lauer and Nowlin 2022)
"Available Only Upon Request" policy	Procedures	• Reduce unimportant plastic waste • Saving businesses money	• Require employee training • Need consumer education	(Lauer and Nowlin 2022)

*Tools are determined based on the categories published on http://partcfood.msvu.ca/section4/ It was accessed on Dec 6, 2022.

than single-use plastic. Industries adhering to environmentally friendly practices also receive incentive schemes and recognition from the government and funding agencies, enabling them to thrive and increase their benefits. However, these efforts require a firm commitment from stakeholders and a comprehensive education or training system, which can be time- and cost-consuming, particularly for businesses (Lauer and Nowlin 2022, Yenici and Turkoglu 2023).

Applying higher taxes to plastic-based products is another effective strategy. This approach aims to reduce the demand for plastic and force producers to find other green alternatives for their products (Lauer and Nowlin 2022). As mentioned by Ummatin and Faria (2021), the implementation of on carbon taxes on the industrial system in Indonesia prompted a research for alternative solutions, such as utilizing plastic waste, which can be converted into refuse derived fuel (RDF), which is valuable for co-firing. Most of the cement industry began to consider this scheme and accept waste from households. Another noteworthy initiative is the "available only upon request" policy for plastic straws in many restaurants, serving as an excellent example of reducing plastic litter. This practice is an age-old food culture that may be useful in reducing marine litter. This practice has been widely adopted by many restaurants in Semarang City and various cities in Indonesia (Smith et al. 2019). This concept can be expanded and implementedat the city level for other types of product-derived plastics. However, successful execution of this strategy requires training for employees and consumers, particularly focusing on fostering responsible consumer behavior. In addition, a well-integrated inland waste management system is essential to prevent the scattering of waste throughout the environment (Ramadan et al. 2022). Furthermore, the study reveals a higher prevalence of clamshell, paper, and cardboard litter. An open discussion on effective recycling methods is imperative. In many countries, clamshells are being used as biochar (Wibowo et al., 2022), adsorbents (Nguyen et al., 2022, Monteiro et al., 2016), and even in concrete. Similarly, paper and cardboard wastes can be used to create new recycled paper (Popa et al., 2017). However, the recycling potential of those materials is still being developed by researchers.

Conclusions

This study determined the presence of approximately 8.04 ± 2.43 grams/m^2. day and 4.52 ± 1.08 grams/m^2. day of marine and macroplastic litter on the two Semarang City beaches, respectively. Consequently, an estimated 3.40 ± 1.46 items/m^2.day of plastic waste were found stranded, underscoring the significant plastic deposition on Semarang beaches. Among the various waste compositions, LDPE and PP accounted for the highest proportion . The quantity of marine litter deposited on the two beaches did not show a significant difference, whereas the amount of macroplastics was higher on weekdays. In the light of these findings, the study proposes some strategies to enhance the reduction of marine litter pollution, not only in Semarang City but also in other coastal cities. Many researchers have endorsed cleanup activities as mitigation measures. In addition, implementing the prohibition of single-use plastics emerges as a popular preventive action to reduce marine litter in marine environments. It is suggested that future studies should also consider how these recommendations work by assessing behavioral changes in littering and their impact on environmental preservation .

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References

Beaumont, N.J., Aanesen, M., Austen, M.C., Börger, T., Clark, J.R., Cole, M., Hooper, T., Lindeque, P.K., Pascoe, C. & Wyles, K.J. (2019). Global ecological, social and economic impacts of marine plastic. *Marine Pollution Bulletin*, 142, pp. 189–195. DOI:10.1016/j.marpolbul.2019.03.022

Binetti, U., Silburn, B., Russell, J., van Hoytema, N., Meakins, B., Kohler, P., Desender, M., Preston-Whyte, F., Fa'abasu, E., Maniel, M. & Maes, T. (2020). First marine litter survey on beaches in Solomon Islands and Vanuatu, South Pacific: Using OSPAR protocol to inform the development of national action plans to tackle land-based solid waste pollution. *Marine Pollution Bulletin*, 161, p. 111827. DOI:10.1016/j.marpolbul.2020.111827

Chitrakar, P., Baawain, M.S., Sana, A. & Al-Mamun, A. (2019). Current status of marine pollution and mitigation strategies in arid region: A detailed review. *Ocean Science Journal*, 54, pp. 317–348. DOI:10.1007/s12601-019-0027-5

Corbau, C., Nardin, W., Vaccaro, C., Vona, I., & Simeoni, U. (2023). Experimental design and field deployment of an artificial bio-reef produced by mollusk shell recycling. *Marine Environmental Research,* 183, 105833. DOI:10.1016/j.marenvres.2022.105833

Cordova, M.R., Iskandar, M.R., Muhtadi, A., Nurhasanah, Saville, R. & Riani, E. (2022). Spatio-temporal variation and seasonal dynamics of stranded beach anthropogenic debris on Indonesian beach from the results of nationwide monitoring. *Marine Pollution Bulletin,* 182, p. 114035. DOI:10.1016/j.marpolbul.2022.114035

Dasgupta, S., Sarraf, M. & Wheeler, D. (2022). Plastic waste cleanup priorities to reduce marine pollution: A spatiotemporal analysis for Accra and Lagos with satellite data. *Science of the Total Environment*, 839, p. 156319. DOI:10.1016/j.scitotenv.2022.156319

Dobler, D., Maes, C., Martinez, E., Rahmania, R., Gautama, B.G., Farhan, A.R. & Dounias, E. (2022). On the fate of floating marine debris carried to the sea through the main rivers of Indonesia. *Journal of Marine Science and Engineering*, 10, p. 1009. DOI:10.3390/jmse10081009

Galgani, L., Beiras, R., Galgani, F., Panti, C. & Borja, A. (2019). Editorial: Impacts of marine litter. *Frontiers in Marine Science,* 6, p. 208. DOI:10.3389/fmars.2019.00208

Ghaffari, S., Bakhtiari, A.R., Ghasempouri, S.M. & Nasrolahi, A. (2019). The influence of human activity and morphological characteristics of beaches on plastic debris distribution along the Caspian Sea as a closed water body. *Environmental Science and Pollution Research,* 26, pp. 25712–25724. DOI:10.1007/s11356-019-05790-y

Hayati, Y., Adrianto, L., Krisanti, M., Pranowo, W.S. & Kurniawan, F. (2020). Magnitudes and tourist perception of marine debris on small tourism island: Assessment of Tidung Island, Jakarta, Indonesia. *Marine Pollution Bulletin*, 158, p. 111393. DOI:10.1016/j.marpolbul.2020.111393

Kaviarasan, T., Naik, S., Sivadas, S.K., Dhineka, K., Sambandam, M., Sivyer, D., Mishra, P. & Ramana Murthy, M.V. (2020). Assessment of litter in the remote beaches of Lakshadweep Islands, Arabian Sea. *Marine Pollution Bulletin*, 161, p. 111760. DOI:10.1016/j.marpolbul.2020.111760

Lauer, N.E. & Nowlin, M.B. (2022). A framework for inland cities to prevent marine debris: A case study from Durham, North Carolina. *Frontiers in Marine Science*, 9, p. 983256. DOI:10.3389/fmars.2022.983256

Löhr, A., Savelli, H., Beunen, R., Kalz, M., Ragas, A. & Van Belleghem, F. (2017). Solutions for global marine litter pollution. *Current Opinion in Environmental Sustainability*, 28, pp. 90–99. DOI:10.1016/j.cosust.2017.08.009

Monteiro, R. J., Lopes, C. B., Rocha, L. S., Coelho, J. P., Duarte, A. C., & Pereira, E. (2016). Sustainable approach for recycling seafood wastes for the removal of priority hazardous substances

(Hg and Cd) from water. *Journal of Environmental Chemical Engineering*, 4(1), 1199-1208. DOI:10.1016/j.jece.2016.01.021

Nguyen, T. T., Huang, H., Nguyen, T. A. H. & Soda, S. (2022). Recycling clamshell as substrate in lab-scale constructed wetlands for heavy metal removal from simulated acid mine drainage. *Process Safety and Environmental Protection*, 165, 950-958. DOI:10.1016/j.psep.2022.04.026

Nurulhaq, H. & Kismartini, (2019). The effect of green marketing of plastic bag ban policy in modern retail stores on consumer green behavior in Bogor City. *E3S Web of Conference*, 125, p. 08003. DOI:10.1051/e3sconf/201912508003

Popa, C. L., Carutasu, G., Cotet, C. E., Carutasu, N. L., & Dobrescu, T. (2017). Smart city platform development for an automated waste collection system. *Sustainability*, 9(11), 2064. DOI:10.3390/su9112064

Pratiwi, A.H., Budiyono, B. & Dewanti, N.A.Y. (2021). Identification types of the marine debris and factors related them in Semarang City. *Jurnal Presipitasi: Media Pengembangan dan Komunikasi Teknik Lingkungan,* 18, pp. 64–72. DOI:10.14710/presipitasi.v18i1.64-72

Ramadan, B.S., Rachman, I., Ikhlas, N., Kurniawan, S.B., Miftahadi, M.F. & Matsumoto, T. (2022). A comprehensive review of domestic-open waste burning: recent trends, methodology comparison, and factors assessment. *Journal of Material Cycles and Waste Management*, 24, pp. 1633–1647. DOI:10.1007/s10163-022-01430-9

Renjaan, E.A., Silubun, D.T., Latar, D.I. & Makailipessy, M. (2020). Beach orientation and exposure accumulate types of marine debris on the coast of Dullah Island, kei archipelago, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 517, p. 012015. DOI:10.1088/1755-1315/517/1/012015

Sari, M.M., Inoue, T., Septiariva, I.Y., Suryawan, I.W.K., Kato, S., Harryes, R.K., Yokota, K., Notodarmojo, S., Suhardono, S. & Ramadan, B.S. (2022). Identification of face mask waste generation and processing in tourist areas with thermo-chemical process. *Archives of Environmental Protection*, 48, 2, pp. 79-85. DOI:10.24425/aep.2022.140768

Smith, E., Dziewatkoski, M., Henrie, T., Seidel, C. & Rosen, J. (2019). Microplastics: What drinking water utilities need to know. *Journal American Water Works Association*, 111, p. 26–37. DOI:10.1002/awwa.1393

Sukma, E., Ramadhan, S. & Indriyani, V. (2020). Integration of environmental education in elementary schools. *Journal of Physics: Conference Series*, 1481, p. 012136. DOI:10.1088/1742-6596/1481/1/012136

Suteja, Y., Atmadipoera, A.S., Riani, E., Nurjaya, I.W., Nugroho, D. & Purwiyanto, A.I.S. (2021). Stranded marine debris on the touristic beaches in the south of Bali Island, Indonesia: The spatiotemporal abundance and characteristic. *Marine Pollution Bulletin*, 173, p. 113026. DOI:10.1016/j.marpolbul.2021.113026

Syakti, A.D., Bouhroum, R., Hidayati, N.V., Koenawan, C.J., Boulkamh, A., Sulistyo, I., Lebarillier, S., Akhlus, S., Doumenq, P. & Wong-Wah-Chung, P. (2017). Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia. *Marine Pollution Bulletin*, 122, pp. 217–225. DOI:10.1016/j.marpolbul.2017.06.046

Ummatin, K.K. & Faria, N. (2021). Simulation of tipping fee policy to support municipal waste management into alternative fuel in the cement industry: a case study of Tuban landfill Indonesia. *IOP Conf. Series: Earth and Environmental Science*, 753, p. 012041. DOI:10.1088/1755-1315/753/1/012041

van Emmerik, T., Seibert, J., Strobl, B., Etter, S., den Oudendammer, T., Rutten, M., bin Ab Razak, M.S. & van Meerveld, I. (2020). Crowd-based observations of riverine macroplastic pollution. *Frontiers in Earth Science*, 8, p. 298. DOI:10.3389/feart.2020.00298

Westlake, E.L., Lawrence, E., Travaglione, N., Barnes, P. & Thomson, D.P. (2022). Low quantities of marine debris at the northern Ningaloo Marine Park, Western Australia, influenced by visitation and accessibility. *Marine Pollution Bulletin,* 174, p. 113294. DOI:10.1016/j.marpolbul.2021.113294

Wibowo, Y. G., Naswir, M., & Ramadan, B. S. (2022). Performance of a novel biochar-clamshell composite for real acid mine drainage treatment. *Bioresource Technology Reports*, 17, 100993. DOI:10.1016/j.biteb.2022.100993

Wu, W.-M., Yang, J. & Criddle, C.S. (2017). Microplastics pollution and reduction strategies. *Frontiers in Environmental Science and Engineering*, 11, p. 6. DOI:10.1007/s11783-017-0897-7

Yenici, E. & Turkoglu, M., 2023. Abundance and composition of marine litter on the coasts of the Dardanelles (Canakkale Strait, Turkey). *Environmental Monitoring and Assessment* 195, 4. DOI:10.1007/s10661-022-10511-z