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ARTICLE

Community-based municipal solid waste management system on Pulau Mantanani: Strategies, challenges and possible solutions

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ABSTRACT

The amount of municipal solid waste (MSW) generated in Malaysia has risen steadily in the past few decades. MSW management, particularly in small island communities, is a major challenge faced by local authorities. In Malaysia, MSW management involves the participation of multiple government bodies from the federal to the state and local levels, either directly or indirectly. A study conducted by Reef Check Malaysia (RCM) in 2017 found that there was no system for MSW management on Pulau Mantanani, Sabah. In response, RCM collaborated with government bodies and local stakeholders to test several strategies aimed at improving MSW management on the island. Between 2019 and 2024, Pulau Mantanani generated an average of 169 kg of MSW per day. The largest waste component was food waste, followed by non-recyclable plastic waste, with glass and metal making up the smallest proportion. To implement the MSW management strategies, a total of 23 local islanders have been hired on a part-time basis. The current system, while adequate and viable in the short term, has successfully prevented more than 212 tonnes of MSW from polluting the island's environment and ecosystems, long-term sustainability remains uncertain. Even so, the project demonstrates that community-based MSW management can be an effective approach in remote areas such as Pulau Mantanani, where local authorities are unable to manage MSW directly.

INTRODUCTION

Swift industrial development and urban growth in Malaysia in the past few decades have significantly increased municipal solid waste (MSW) generation (Mohd and Mashitah 2013). In most developing countries, collection and disposal of MSW fall under the jurisdiction of local authorities. MSW management systems in these countries often face multiple challenges, including limited waste collection coverage, inconsistent services, open burning, crude open dumping, which encourages the breeding of flies and disease vectors, and unregulated scavenging activities (Ogawa 2000). Many developing countries and cities in Southeast Asia are incapable of implementing effective MSW management due to weaknesses in policy implementation, regulation and enforcement, institutional capacity, financial resources, technical expertise, technology, awareness, and public involvement (Agamuthu et al. 2009; Ngoc and Schnitzer 2009). Consequently, MSW management in Malaysia, particularly on small islands, remains a major challenge for local authorities (Siti et al. 2019).

In Malaysia, the management of MSW involves multiple government bodies from the federal to the state and local levels, either directly or indirectly. Governance in Malaysia is based on parliamentary democratic framework with a three-tiered governmental structure comprising the Federal Government, State Government, and Local Authorities. The role of the Federal Government in MSW management is primarily advisory and coordinative in nature. Administrative responsibilities fall under the Ministry of Housing and Local Government, with the Local Government Department and the Town and Country Planning Unit playing key roles. State Governments are responsible for providing guidance and support to Local Authorities, particularly in strengthening their institutional and financial capacities to manage MSW effectively. Local Authorities hold the primary responsibility for the implementation of MSW management, including the decision to either manage MSW collection internally or outsource collection to private service providers (Zaini 2011).

A study conducted by Reef Check Malaysia (RCM) in 2017 found that there was a lack of a MSW management system on Pulau Mantanani ("Pulau" means island in Malay), Sabah; solid waste was predominantly disposed of through open burning or dumped on beaches and into the sea. Tour operators commonly practiced open burning or dumping on their premises or directly into the sea, depending on the waste volume, type, and available land. Local villagers, by contrast, primarily practiced open dumping along the beachfront. In response, the Federal Government (Ministry of

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KEYWORDS

municipal solid waste, management, small island, community-based, coral reefs

Urban Wellbeing, Housing and Local Government, and the National Solid Waste Management Department) launched an MSW management initiative on the island in March 2017. This initiative, part of a broader 'Low Carbon Island' project, involved an investment of RM1.3 million in equipment aimed at more effectively managing solid waste generated by the local community. However, solid waste from the tourism sector was excluded from the initiative, with tour operators remaining responsible for their solid waste management practices. The system implemented included the collection of solid waste from villagers, transportation to a collection centre on the island for processing, and subsequent transfer to the mainland. While the system demonstrated partial success, significant challenges emerged during its expansion to the entire island (Reef Check Malaysia, unpublished report). Feedback from local stakeholders to the government initiative, as highlighted by RCM's study, indicated a willingness to improve MSW management practices. In response, RCM collaborated with government agencies and local stakeholders to test a series of strategies aimed at improving MSW management on Pulau Mantanani.

This paper presents an overview of the strategies implemented for MSW management on Pulau Mantanani, along with an assessment of their outcomes. It also includes a brief discussion of the key challenges encountered and potential solutions for improvement. The initiative can provide a basis for the development of more effective and sustainable MSW management systems, not only for Pulau Mantanani but also for other islands with similar environmental and socioeconomic contexts.

STUDY AREA

Pulau Mantanani refers collectively to a group of three islands, namely Pulau Mantanani Besar, Pulau Mantanani Kecil, and Pulau Linggisan (Figure 1). Pulau Mantanani is situated in the South China Sea, approximately 22 km off the coast of Kota Belud on the northwestern shore of Sabah, Malaysia. Access to the islands is typically via a 45-60 minute speedboat journey from Rampayan Jetty in Kota Belud. Among the three islands, only Pulau Mantanani Besar is inhabited, with most houses situated very close to the shoreline, a few metres above the high-tide line. The island hosts two villages: Kampung Padang, the larger settlement, and Kampung Siring Bukit, both of which are home to members of the Ubian indigenous community of the Bajau ethnic group (Mastura et al. 2016). The total population is slightly over 1,000 (Mastura et al. 2016). Traditionally, fishing has been the primary source of livelihood and dietary protein for the local population. Pulau Mantanani has recently become a popular tourism destination, particularly among day-trippers.

In 2012, Reef Check Malaysia, a non-governmental organisation (NGO) focuses on sustainable management of marine ecosystems in Malaysia, initiated conservation activities on Pulau Mantanani. This initiative was introduced after the island was identified as a hotspot for destructive fishing practices, particularly fish bombing. In addition to monitoring coral reef health on the island, RCM implemented complementary activities such as reef rehabilitation, environmental education programmes in local schools and beach clean-up efforts. These activities were carried out through monthly field visits. In 2016, to enhance the effectiveness and sustainability of its initiatives, RCM established a permanent field office on the island and launched the "Cintai Mantanani" (Love Mantanani) programme. The programme aimed to conserve the coral reef ecosystems surrounding Pulau Mantanani while enhancing livelihoods of the local community. The key focus of the initiative was to support the establishment of a community-managed marine protected area, empowering local stakeholders to take an active role in marine resource management. The goal was to promote sustainable management of natural resources on the island for the long-term benefit of both the environment and the community.

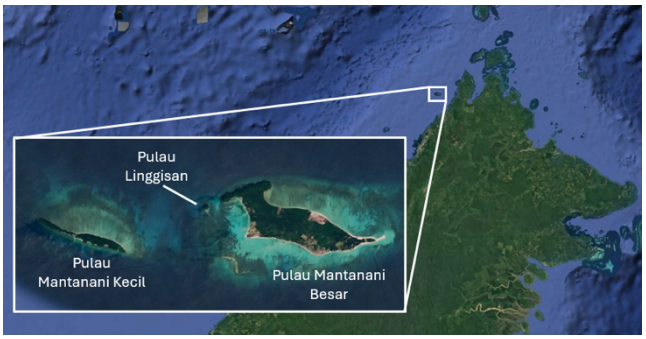

Figure 1: Map of Pulau Mantanani

STRATEGIES

This section outlines the strategies implemented to develop and operationalise an effective MSW management system on Pulau Mantanani. The approaches encompass (i) trial run and scoring system, ii) waste collection and segregation, (iii) recycling and disposal and (iv) community engagement and are summarized schematically in Figure 2.

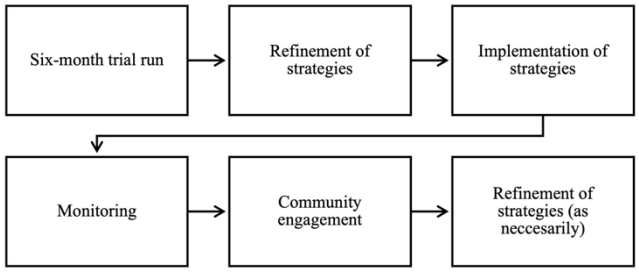

Figure 2: Process of strategies employed for the development and implementation of the MSW management system on Pulau Mantanani.

Trial Run

In November 2018, a six-month trial was initiated involving 30 households, randomly selected from among the island community to assess participation and quantify daily MSW generation, enabling refinement of MSW management strategies and broader system replication. The system was fully implemented in November 2019.

Scoring System

Compliance was assessed using a daily monitoring form designed to collect data on household participation in the MSW management system, types of waste generated, usage of provided waste bins, and adherence to waste segregation practices. Each category in the monitoring form was assigned a predetermined point value to reflect its relative importance. The raw scores were multiplied by their corresponding weights to compute a weighted average compliance score. One monitoring form was completed per household on a daily basis during solid waste collection activities. At the end of each year, households that achieved a compliance rate of over 80% were awarded certificates as a means of encouraging continued participation and reinforcing awareness that daily solid waste disposal practices were being monitored.

Municipal Solid Waste Collection

All participating households were briefed on the MSW management system and were provided with at least two types of

bins to facilitate segregation and storage of solid waste. Each morning, two locally hired part-time staff conducted door-to-door collection of solid waste. Another local part-timer was hired to oversee the daily coordination and implementation of the system. Participating households were instructed to place the designated bins in front of their houses by 08:00 each day to ensure timely collection. Solid waste was collected manually using a wheelbarrow. During the collection process, a standardized daily monitoring form was completed for each household by the collection personnel. To reduce bias and favouritism, particularly in instances where participating households had familial relationships with collection personnel, forms were independently verified by the project coordinator each day. Upon reaching full capacity, the wheelbarrow contents were transported to the designated collection centre for further processing. This procedure was systematically repeated until all participating households had been served.

For the management of recyclable waste, over 90 recycling bins, constructed from PVC mesh with a heavy cement base for stability, were strategically placed throughout the villages and shared among households. When a bin was full, the recyclable waste was collected and transported to the designated collection centre for further processing.

Municipal Solid Waste Segregation and Storage

A collection centre was established in each village – one at Kampung Padang and another at Kampung Siring Bukit. Each collection centre was approximately 20 ft x 30 ft and was fenced to prevent access by roaming cows. At the collection centres, solid waste was segregated and recorded by type and quantity. The weight of each solid waste category was determined using a calibrated hanging scale. Non-recyclable waste was packaged and stored onsite, while recyclable waste was transported to the Mantanani Plastic Recycling Centre. The recycling centre was equipped with a plastic shredder and a baler machine and powered by a solar energy system. Recyclable plastics made from PET, HDPE, LDPE and PP were shredded for use in upcycling product-making; remaining plastics were compacted using the baler machine to reduce volume, facilitating easier packing, storage, and transportation. The collected data were systematically analyzed on a yearly basis to assess trends and compliance.

Municipal Solid Waste Disposal

Food waste generated on the island was fed to the free-roaming cows. Every month, non-recyclable waste was transported off the island using a locally owned boat known as Lansa, with transportation costs ranged from RM800 to RM1,000 per trip. The Lansa transported the waste to an awaiting Roll-on/Roll-off (RORO) bin, rented from the Kota Belud District Council at RM300 to RM400 per unit, at Rampayan in Kota Belud. The waste was subsequently transferred to and disposed of at the Kayu Madang Landfill. Recyclable waste was transported off the island only four to five times per year, depending on the volume of recyclables collected and the availability of the recycling company based in Kota Kinabalu, which managed the transfer of recyclable waste to their processing facility. The revenue from selling recyclable materials covers only approximately 10% of the transportation and disposal fees.

Community Engagement and Awareness-Raising Programme

From 2019 to 2024, a minimum of two community engagement sessions were held annually with the local villagers to share information on the quantity and characteristics of MSW collected, updates or changes to the MSW management system, and to reinforce the importance of proper MSW management practices. These sessions also served as a platform for locals to voice concerns, provide feedback, and seek clarification on related issues. In addition to these engagements, a variety of awareness-raising activities such as clean-up events and educational campaigns were conducted annually, targeting students and children on the island.

Supplementary Livelihood from Municipal Solid Waste Management System

Local islanders involved in the daily operation of the MSW management system received monthly compensation. This approach aimed at encouraging the community to view the programme not only as environmentally and socially beneficial but also as a source of stable income. To add value to recyclable waste, an initiative was introduced in 2021 to produce refrigerator magnets using collected plastics made from PET, HDPE, LDPE and PP. Additionally, RCM supported the local community in expanding and marketing an existing upcycling project that involved producing wallets from single-use plastics such as coffee sachets.

RESULTS

Between 2019 and 2022, the participation rate of villagers in the MSW management programme on Pulau Mantanani was 100%, with all 178 households on the island actively involved. In 2023 and 2024, the participation rate declined to approximately 83%, with 30 households from Kampung Siring Bukit withdrew from the programme. The participation rate of tour operators was less than 15% and was limited to the years 2022 and 2023. Detailed figures are presented in Table 1.

The average amount of MSW generated on Pulau Mantanani was approximately 62,000 kg per year (169 kg per day) (Figure 3). The largest component was food or organic waste, which accounted for over 80% of the total MSW generated, followed by non-recyclable plastic waste, with glass and metal making up the smallest proportion (Figure 4).

Between 2019 and 2024, a total of 23 local islanders were employed part-time to implement the MSW management system on Pulau Mantanani. The upcycling project contributed to local economic development through the production and sale of items made from recyclable and single-use plastics. Table 2 presents the sale of refrigerator magnets and wallets during this period as part of the upcycling initiative.

Table 1: Number of households and tour operators participated in the MSW management programme between 2019 to 2024.

	Number of Households	Number of Tour Operators
2019	178	0
2020	178	0
2021	178	0
2022	178	1
2023	148	1
2024	148	0

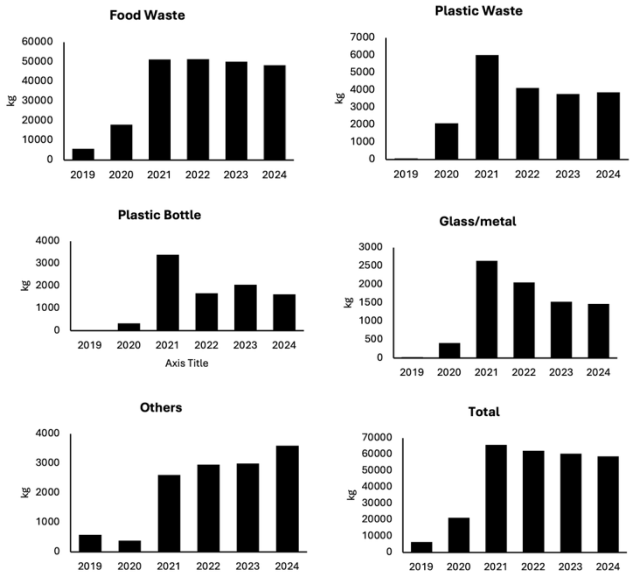

Figure 3: Amount of municipal solid waste generated on Pulau Mantanani between 2019 to 2024.

Table 2: Sale of refrigerator magnets and wallets from upcycling project between 2019 to 2024.

	Sale (RM)	
	Refrigerator magnets	**Wallets**
2019	-	180
2020	-	252
2021	200	180
2022	1,000	3,300
2023	400	540
2024	100	900

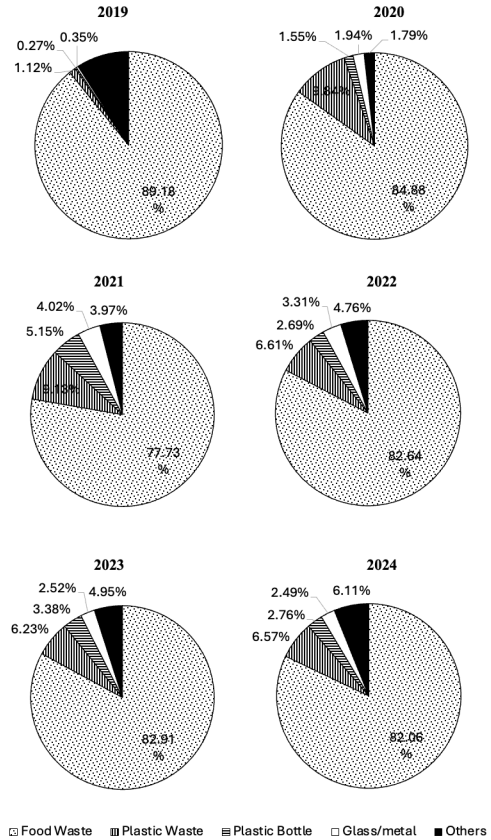

Figure 4: Proportion of MSW generated on Pulau Mantanani between 2019 to 2024.

DISCUSSION

Municipal Solid Waste Generation

The total amount of MSW recorded on Pulau Mantanani in 2019 and 2020 was significantly lower compared to the amounts recorded between 2021 and 2024. The low volume recorded in 2019 can be attributed to the initial phase of the MSW management system. During that period, villagers were still adapting to the practice of segregating and disposing of solid waste in designated bins, in contrast to their previous habit of crude open dumping. Additionally, limited trust in NGOs and the absence of local islanders, who owned homes on the mainland and were often away from the island, further reduced active participation and contributed to the lower volume of MSW recorded during this period.

In 2020, the reduced amount of MSW was primarily due to the COVID-19 pandemic and the resulting government-imposed movement restrictions, which disrupted implementation of the MSW management system. Furthermore, the sharp decline in tourism during the pandemic had a direct economic impact on the islanders. With reduced income and lower purchasing power, household consumption decreased, leading to a corresponding reduction in solid waste generation. Despite these challenges, the pandemic period enabled the project team to strengthen compliance monitoring of the MSW management system through the implementation of scoring system.

The reduced amount of MSW in 2023 and 2024 was primarily due to a decline in participation, which dropped by approximately 17% following the withdrawal of 30 households from Kampung Siring Bukit. The collection centres in both Kampung Padang and Kampung Siring Bukit had been constructed with permission on land owned by local islanders. However, in 2023, the landowner in Kampung Siring Bukit withdrew permission and prohibited households located on his land from participating in the programme. To avoid conflict and prevent difficulties for the 30 affected households, the implementation of the MSW management system in Kampung Siring Bukit was discontinued.

Land-related issues in MSW management are not unique to island settings. As highlighted by Ngoc and Schnitzer (2009), the establishment of new landfill sites is increasingly challenging even in urban areas, due to public resistance to new landfill operations near their residential areas. Thus, the landowner's decision to withdraw permission for the collection centre is consistent with broader land-use conflicts commonly associated with MSW infrastructure.

Municipal Solid Waste Generation Characteristics

MSW generated on Pulau Mantanani was predominantly composed of food or organic waste. This finding is consistent with waste composition studies conducted across Malaysia over the past two decades, regardless of geographic context from large cities such as Kuala Lumpur (Kathirvale et al. 2003), to national level assessments (Agamuthu et al. 2009), and even small island settings like Pulau Perhentian (Siti et al. 2019) and Pulau Kapas (Siti and Jumadil 2019).

During the initial phase of the MSW management system on Pulau Mantanani, open-air composting was introduced as a method for treating food waste. However, the strategy proved unsuitable, as the average daily generation of food waste, estimated at 130 to 140 kg, required substantial land area. Furthermore, the composting process produced strong odours, leading to frequent complaints from nearby residents. Alternative strategies were subsequently

trialled, including underground burial and enzyme-assisted composting. These approaches also failed due to various constraints, such as the presence of scavenging animals, limited land availability, insufficient manpower, lack of composting enzymes, and limited technical knowledge.

Given these challenges, the most viable current solution has been to feed the collected food waste to the island's free-roaming cows. Many of these cows are left unattended and are malnourished, often resorting to foraging through improperly discarded MSW, including non-organic materials such as paper, plastic, and including diapers. Attracted by the smell of the collected food waste, the free-roaming cows began encroaching on the collection centre and damaging fences and recycling bins. To mitigate this issue, collected food waste is now fed to the cows each morning at a designated open dumping area adjacent to the collection centre. This approach not only addresses the challenge of food waste disposal but also helps improve the health of the cows by providing a more appropriate and organic food source.

Lack of Participation from Tour Operators

Between 2019 and 2024, tour operator participation in the MSW management system implemented by RCM was limited. Only a single operator participated, and only during 2022 and 2023. High turnover among tour operator ownership and management significantly hindered sustained involvement. Due to RCM's status as an NGO and its dependence on external project funding, participating tour operators were required to finance the cost of their participation. This approach was a major barrier to engagement, as many operators were reluctant to cover the costs involved and preferred to manage their solid waste independently.

The reluctance of tour operators to finance MSW management is not an isolated case. A similar situation has been documented in Pulau Perhentian, where tour operators are required to pay maintenance fees for MSW removal services provided by a solid waste contractor appointed by the Besut District Council. Under this arrangement, waste is collected from centralised points on the island and transported to the mainland for disposal. Despite the mandatory fee structure, many refuse to pay these charges and continue to engage in open dumping practices (Siti et al. 2019).

The majority of island-based resort operators and day-trip tour operators on Pulau Mantanani engaged in crude open burning and open dumping practices. These practices are not confined to islands without formal waste collection services, such as Pulau Mantanani. They also occur in islands where formal services exist but become unavailable during certain periods, such as during the monsoon season in Pulau Perhentian (Siti et al. 2019) and Pulau Kapas (Siti and Jumadil 2019), when safety concerns disrupt waste transport. Moreover, such improper disposal practices are not limited to remote or underserved areas. Even in urban settings with continuous formal waste collection services, some companies resort to open burning and open dumping to reduce the expenses related to proper waste processing and transportation (Pushpan 2021). Beginning in 2023, a transition toward more responsible practices was observed among island-based resort operators as they began transporting solid waste daily to the mainland for disposal or utilising private on-site waste treatment technologies.

Local Community Engagement and Involvement in the Municipal Solid Waste Management System

Drawing on lessons from the Federal Government's challenges in implementing the "Low Carbon Island" initiative on Pulau Mantanani in 2017, RCM prioritized early and continuous community engagement in the development and implementation of the new MSW management system. Community awareness and education activities were conducted prior to and throughout the implementation period. These efforts proved effective, as evidenced by consistently high levels of participation among locals. Although a decline in participation was observed in 2023 and 2024 due to land-related issues, overall participation remained high. Feedback collected during engagement sessions indicated general satisfaction with the system, and locals expressed a desire for the programme to continue. Residents also expressed willingness to support the initiative moving forward further reflects a positive reception of the MSW management approach.

The "Cintai Mantanani" programme, initiated by RCM on Pulau Mantanani, aimed to empower the local community to take leadership in managing natural resources, including through active involvement in the MSW management system. While participation in household-level solid waste segregation and disposal was relatively high (particularly when collection services operated consistently), participation in higher-level solid waste management activities such as collection, segregation, storage, recycling, and transportation remained low unless financial compensation was provided. Even when paid positions were offered, the turnover rate remained high.

Nevertheless, the simplicity and effectiveness of the current community-based MSW management system, coupled with the absence of alternative MSW management infrastructure, has made it the most practical solution available at present. Between 2019 and 2024, the system successfully prevented over 212 tonnes of MSW from polluting the island's environment and surrounding ecosystems. Community-based MSW management has been recognised as a promising approach where local authorities are unable to manage MSW directly, particularly in remote areas (Parizeau et al. 2006). Such systems rely on the active participation of locals in tasks including solid waste collection, transportation and diversion, an approach currently implemented on Pulau Mantanani. Community-based approaches to management are increasingly recognised as essential for achieving international conservation goals. Both the Kunming-Montreal Global Biodiversity Framework and the Sustainable Development Goals advocate for greater participation of local communities in biodiversity conservation. Malaysia, as a signatory to these international agreements, has demonstrated its commitment to fulfilling these obligations. This is reflected in the country's National Policy on Biological Diversity and Twelfth Malaysia Plan (Chelliah 2022; Shahir 2024).

The community-based MSW management system implemented on Pulau Mantanani is consistent with key national policy frameworks, including the National Solid Waste Management Policy, the National Cleanliness Policy, and the Malaysia Roadmap Towards Zero Single-Use Plastics. These policies collectively aim to establish a holistic and environmentally sustainable solid waste management system, promote a nationwide culture of cleanliness to safeguard public health and environmental quality, and reduce reliance on single-use plastics through increased recycling, reuse, and adoption of sustainable alternatives. Together, they support national objectives for environmental sustainability and the transition toward a circular economy.

The sale of refrigerator magnets and wallets produced under the upcycling initiative is highly dependent on tourist arrivals to the island. The marked increase in sales observed in 2022 can be attributed to a one-time bulk purchase made by a corporate entity, rather than a rise in visitor-driven demand.

POSSIBLE SOLUTIONS

Continuous Community Engagement and Awareness-Raising Programme

According to Zurbrugg (2002), willingness to participate in MSW management depends largely on public awareness and attitudes. Therefore, continuous community engagement and awareness-raising activities should be carefully planned and tailored to the local context of Pulau Mantanani to enhance their effectiveness. One study suggests that particular attention be given to children and youth, especially teenage girls, as they tend to demonstrate greater concern for environmental issues compared to boys (Haron et al. 2005). Sustained participation from the younger generation is considered a key component in ensuring the long-term sustainability of the MSW management system on the island.

Awareness-raising approaches and methods should also be tailored specifically to resort operators and day-trip operators. As a short-term strategy, efforts should emphasize knowledge sharing, awareness, and competencies in environmentally friendly solid waste management practices. For long-term effectiveness, the approach should be designed to encourage sustained participation and commitment.

Municipal Solid Waste Prevention and Reduction

MSW prevention should be prioritised as the most effective strategy for reducing overall MSW generation (Staniskis and Stasiskiene 2005). In addition to minimising the volume of solid waste, prevention measures can reduce the associated costs of MSW management, including expenses related to collection, recycling, transportation, and final disposal (Wang et al. 2010). One key area for intervention is food waste. Introducing small-scale, household-scale composting practices for both local households and tour operators could substantially decrease the amount of food waste generated on the island.

Another major contributor to MSW on Pulau Mantanani is single-use plastic bottles, primarily due to reliance on bottled water. Saltwater intrusion has rendered groundwater sources unsuitable for consumption, leading most residents to rely on bottled water for drinking and cooking. Tour operators also provide bottled water to guests, further exacerbating plastic waste generation. To address this issue, short-term mitigation strategies should include the installation of rainwater harvesting and purification systems at both household and resort levels. Additionally, the establishment of water refill stations within each resort and at strategic public locations around the island can significantly reduce the use of single-use plastic bottles. For long-term sustainability, the development of a centralised clean water supply and treatment infrastructure is recommended.

Community-based and Sustainable Municipal Solid Waste Management System

While the current community-based MSW management system on Pulau Mantanani is considered adequate and viable in the short term, long-term sustainability remains uncertain. Financial viability remains a critical challenge, as the current system depends heavily on corporate funding and community participation. Additionally, sustaining local capacity and long-term commitment to the system have proven difficult. Moreover, the system has not effectively integrated solid waste generated by tour operators, particularly day-trip operators, and lacks the capacity to manage larger volumes of solid waste.

To manage a larger volume, including all MSW generated on the island, increased and consistent operational capacity is required. This includes a larger and consistently trained workforce, appropriate machinery and equipment, and access to a permanent, adequately sized area for solid waste processing and storage. Meeting these requirements will necessitate a substantial increase in financial investment. It is proposed that funding sources be diversified, including contributions from government agencies. At a minimum, the island should be provided with machinery, equipment, and access to government-owned assets, either through direct provision or free use arrangements. Additionally, proper technical training must be provided to local personnel hired to operate MSW management systems and equipment, ensuring safe and effective system operation over the long term. Finally, there is a need to enhance local ownership and build institutional sustainability within community-based MSW management models.

CONCLUSION

The experience of Pulau Mantanani provides valuable insights into the development of effective and sustainable MSW management systems in small and remote islands with similar contexts. The case underscores the need to prioritise waste prevention, particularly concerning food waste and single-use plastics, as a cost-effective and environmentally sound strategy. The findings further demonstrate that locally adapted management models can substantially improve environmental outcomes, even where formal governmental services are limited.

The results also highlight the importance of collaborative governance arrangements that integrate community participation into local MSW service delivery systems, suggesting that national policy frameworks should formally recognise and support such systems. Strengthening partnerships with local stakeholders is essential to ensure equitable distribution of responsibility and to enhance overall system performance.

The Pulau Mantanani case further demonstrates that strong community ownership, targeted awareness programmes, and phased capacity building can form the foundation of an effective and adaptable MSW management system. However, long-term viability requires diversified funding sources, technical training, institutional support, and access to dedicated space and equipment. These are the conditions that many community-driven environmental programmes struggle to secure without external assistance.

Overall, the lessons from Pulau Mantanani highlight the value of integrated, context-sensitive strategies that combine community participation, supportive governance structures, and targeted infrastructure investments.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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