frontiers | Frontiers in Marine Science

TYPE Systematic Review
PUBLISHED 15 December 2023
DOI 10.3389/fmars.2023.1250736

OPEN ACCESS

EDITED BY
Mario Barletta,
Federal University of Pernambuco, Brazil

REVIEWED BY
Lucia Fanini,
University of Salento, Italy
Maria Ines Tavares,
Federal University of Rio de Janeiro, Brazil

*CORRESPONDENCE
Noir P. Purba
noir.purba@unpad.ac.id

RECEIVED 30 June 2023
ACCEPTED 27 November 2023
PUBLISHED 15 December 2023

CITATION
Purba NP, Pasaribu B, Faizal I, Martasuganda MK, Ilmi MH, Febriani C and Alfarez RR (2023) Coastal clean-up in Southeast Asia: lessons learned, challenges, and future strategies. *Front. Mar. Sci.* 10:1250736. doi: 10.3389/fmars.2023.1250736

Coastal clean-up in Southeast Asia: lessons learned, challenges, and future strategies

Noir P. Purba[1]*, Buntora Pasaribu[1], Ibnu Faizal[1], Marine K. Martasuganda[2], Muhammad Hafidz Ilmi[2], Choerunnisa Febriani[2] and Raffy R. Alfarez[2]

[1]Marine Science Department, Faculty of Fishery and Marine Science, Universitas Padjadjaran, Bandung, Indonesia, [2]Komitmen Research Group, Universitas Padjadjaran, Bandung, Indonesia

The significant accumulation of marine debris on beaches poses a challenge and raises serious concerns to the global environmental sustainability. It has been previously reported that Southeast Asian (SEA) is one of the global hotspots of marine debris contributor to almost 30% of marine debris pollution to the world oceans. This review discusses the challenge and provide the information of mitigation efforts associated with beach clean-up initiatives to combat the marine debris in Southeast Asia. We employ the comprehensive of qualitative data analysis from relevant literature reviews and conducting a structured study specific to the region, therefore, this research highlights the prevalence and characteristics of marine debris that addressed Coastal Cleanup Activities (CCA) in Southeast Asian. Plastic debris remains type of marine debris commonly found across the beaches. Furthermore, Coastal Clean Up (CCU) activities involving local communities have progressively gained prominence in addressing marine debris issues by utilizing educational outreach to raise awareness effectively. Participants in these initiatives include students, tourists, and high school students. The crucial gap of Coastal CCA required the consistent application of scientific methods during beach clean-ups in Southeast Asian. The importance of community involvement, the adoption of scientific methodology, regular clean-up initiatives, and the potential of marine citizen science formulation could potentially contribute in facilitating an effective approach of marine debris management and education in Southeast Asia. Given the substantial component of initiatives, the result of this study proposes the focus on marine citizen science emerges in the future as a potential avenue for educating and engaging the public awareness towards understanding and tackling marine debris accumulation in Southeast Asian beaches.

KEYWORDS

marine litter, beach cleaning, plastic pollution, coastal pollution, community action

1 Introduction

Marine debris or marine litter refers to substances that are disposed of, abandoned, or remain in marine and coastal ecosystems due to both human and natural actions (Irwin, 2012; Galgani, 2015). Many beaches worldwide have become ending points for stranded debris (Ryan et al., 2009; Jambeck et al., 2015; Maharani et al., 2018). It has been reported that debris in coastal areas is transported from land-based and sea sources, facilitated by wind, ocean currents, rivers, and other oceanographic factors (Maximenko et al., 2018; Akbar et al., 2022; Harris et al., 2021).

The issue of coastal debris, driven by several factors such as improper waste management, lack of public awareness and education, insufficient massive action, and inadequate policy and regulation enforcement, has gained significant attention in recent years (Vince and Hardesty, 2018; Herdiansyah et al., 2021).Over the past decade, this issue has become a focal point for governments, scientists, and various stakeholders (Seltenrich, 2015; Vriend et al., 2021) due to its significant impact on socioeconomic, ecosystem, and environmental factors (Gall and Thompson, 2015; Van Dyck et al., 2016; Faizal et al., 2022). To tackle this environmental challenge, there is an urgent need for comprehensive measures to manage and mitigate debris problems (Ng et al., 2023). Nevertheless, collecting marine debris remains challenging, which leads to it being left stranded on beaches for long periods and having a negative impact on coastal ecosystems (Kong et al., 2023). Previous studies have stated that countries in Southeast Asia (SEA) are the top contributors to the mass production of solid municipal waste pollution, generating an estimated 1.14 kg/capita/day worldwide (Ng et al., 2023; Jambeck et al., 2015; Arumdani, 2021). Furthermore, countries in SEA contribute almost 30% of marine debris pollution to the world's oceans (Jambeck et al., 2015; Omeyer et al., 2022). The Association of Southeast Asian Nations (ASEAN) encompasses a vast coastline spanning over 100,000 kilometers, and several member states engage in significant economic and industrial activities that generate marine debris. As a result, addressing marine debris through community action in ASEAN holds great relevance and importance (Putri and Hudaya, 2022; Kandziora et al., 2019).

Engaging in beach clean-ups is one of the actions taken to address the issue of marine debris (Battisti et al., 2020; Catarino et al., 2023). Beach clean-up efforts are not only pertinent to the national action plans in Southeast Asian countries but are also interconnected with regional action frameworks (UNEP, 2016). Coastal communities within ASEAN heavily rely on the ocean for their livelihoods, making them particularly vulnerable to the impacts of marine debris. Implementing community-based initiatives to combat marine debris brings numerous benefits (Sur et al., 2018; Apriliani et al., 2021). These initiatives not only help address the problem at its source but also contribute to government mitigation and enhance regulation. By fostering a sense of ownership and empowerment among community members, these initiatives promote sustainable and effective solutions for tackling marine debris in the region (Uneputty et al., 1998; Apriliani et al., 2021). Various findings have mentioned community initiatives that address the issue of marine debris in SEA (Uneputty et al., 1998; Maharani et al., 2018; Sur et al., 2018; Apriliani et al., 2021; Faizal et al., 2022). However, it is important to note that there is a significant lack of capacity in plastic waste management across SEA as well as the transport of marine debris to neighboring countries (Purba et al., 2021), encompassing both the public and private sectors. Therefore, mitigating marine debris has become a crucial issue that requires immediate attention (Fauziah et al., 2021; Graham, 2023).

In this review, our aim is to examine the current state of coastal clean-up (CCU) efforts to address marine debris in Southeast Asia, present updated data on its characteristics, and seek answers to ongoing efforts to combat this issue. Our approach to answering these questions involves examining recent literature on beach clean-up activities in SEA and utilizing a meta-analysis of peer-reviewed journal articles published from 2012 to 2022. The primary objective of this study is to provide accurate information on the initiatives undertaken to combat marine debris in Southeast Asia. Our goal is to contribute to the formulation of effective strategies that can effectively reduce marine debris in the region and assess the impact of implemented activities. Therefore, this review will facilitate more impactful actions toward addressing the marine debris problem in Southeast Asia from a social-ecological perspective.

2 Materials and methods

2.1 Literature review

This study focuses on beach clean-up activities in 10 countries in SEA, including Indonesia, the Philippines, Malaysia, Brunei Darussalam, Vietnam, Thailand, Cambodia, Singapore, Myanmar, and Timor Leste. No analysis was conducted for Laos because this country has no beaches. The specific focus of the research lies in examining the removal and management of macro debris, defined as items with a diameter exceeding 2.5 cm (Lechthaler et al., 2020; UNEP, 2016).

In this study, we used Publish or Perish software (Harzing, 2007) to collect literature data pertaining to coastal clean-up activities from various academic databases, including Google Scholar, Crossref, Scopus, Semantic, and Open Alex. The literature used as data for this study consisted of journal articles published between 2010 and 2023. To conduct our journal search, we utilized keywords such as "marine debris," "marine litter," "beach clean-up," "coastal clean-up," and "coastal clean-up community." Additionally, several searches also used the national languages of the respective countries in SEA, which were subsequently translated into English.

The initial data obtained after conducting a literature search using the specified keywords yielded a total of 16,483 journal articles and reports. Subsequently, data screening was performed using Microsoft Excel, which revealed 2,502 duplicate articles (15.18%), resulting in 13,981 remaining articles. Among these articles, some had missing information in terms of authorship, title, or inaccessible literature links. The literature entries with missing information (blanks) accounted for 539 articles (3.27%), resulting in a final dataset of 13,442 articles. The final selection involved examining the titles and abstracts of the nonduplicate and

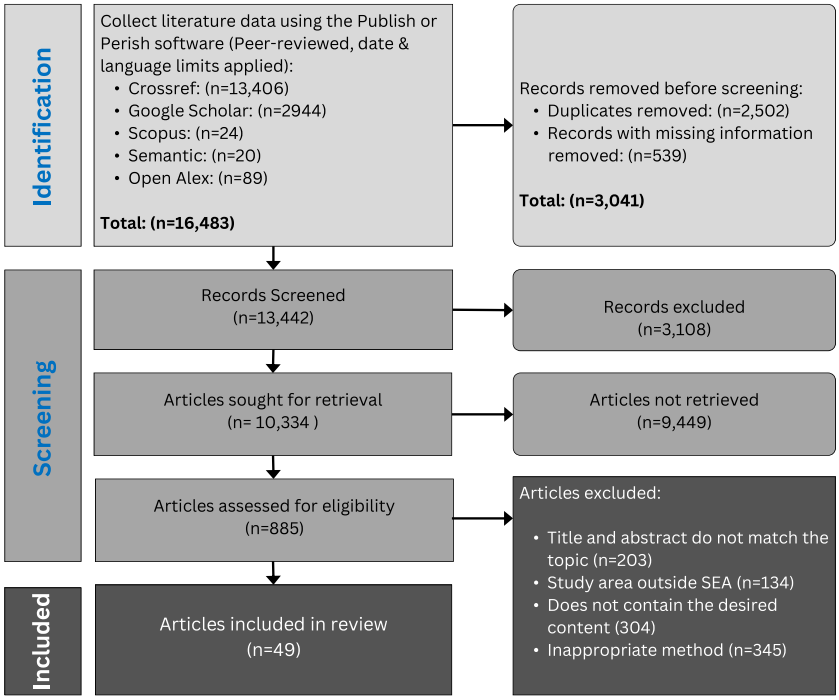

FIGURE 1
Prisma flowchart of the structured literature review process.

nonblank entries. A total of 13, 393 articles (81.25%) were not relevant to our research topic, leading to the utilization of only 49 articles (0.30%) in the final analysis (Figure 1).

The keywords we employed were not confined to academic publications; instead, we broadened our search to include online news sources. Conversely, information obtained from news outlets often fell short of meeting our specific requirements. For example, it may have lacked essential details such as the nature of debris, precise geographic locations, information about the participants involved, and other relevant particulars. For Indonesia specifically, the primary source of coastal clean-up data was obtained from the Komitmen Research Group (KGR) and Universitas Padjadjaran, which have conducted coastal clean-up activities in various locations (Faizal et al., 2022). Subsequently, the following aspects were examined and utilized as analytical material: the quantity of waste data (waste weight and types), details of beach cleaning activities, the locations of coastal communities, necessary costs, and challenges encountered during coastal clean-up operations.

2.2 SEA coastal characteristics and litter management

Southeast Asia (SEA) is one of the regions in Asia with a high population and population density, ranking as the third largest in Asia. Due to its significant population, SEA faces challenges in waste management. In fact, several countries in this region are among the largest contributors to plastic marine debris globally. For instance, Indonesia (10%), the Philippines (6%), Thailand (3%), and Malaysia (3%) are major contributors to plastic marine debris (Jambeck et al., 2015). It is estimated that these countries collectively contribute one-third (30%) of global plastic waste. Moreover, the coastline length in Southeast Asia varies, with Indonesia having the longest coastline of 95,181 km, followed by the Philippines (36,289 km), Myanmar (14,708 km), Vietnam (11,409 km), Malaysia (9,323 km), Thailand (2,614 km), Cambodia (435 km), Brunei (269 km), and Singapore (268 km).

Based on previous findings, coastal debris in SEA originates from various sources, including tourists, traders, local communities, and rivers (Purba et al., 2021; Vriend et al., 2021). Furthermore, previous data reveal the substantial contribution of coastal cities in the region to marine plastic waste. For instance, coastal cities in Indonesia contribute between 0.68 and 0.86 million tons per year of plastic waste to the marine environment (Jambeck et al., 2015). In Malaysia, approximately 0.14 to 0.37 million tons of plastic waste is indirectly disposed of in the oceans, leading to severe pollution, particularly impacting aquatic life (Zahari et al., 2022). Thailand discharges an average of 9.3 kton/year of plastic waste into the marine environment annually (World Bank, 2022). In Vietnam, it is estimated that 3.1 million metric tons of plastic waste are generated on land each year, with a portion of it finding its way into the marine ecosystem (Thang, 2019; World Bank, 2021). The Maritime and Port Authority of Singapore (MPA) collects approximately 1,000 tonnes of debris from the sea annually. In the Philippines, a staggering 2.7 million tons of plastic waste is generated yearly, with an estimated 20 percent ending up in the ocean (Pérez-Guevara, 2022). Myanmar contributes 71,068 tonnes of marine plastic litter, while Cambodia contributes 94,000 tonnes of marine plastic debris annually (OECD, 2019a; OECD, 2019b). In Timor Leste, approximately 68.4 tonnes of plastic waste are generated daily,

with an estimated 56.6 tonnes mishandled and potentially entering the marine environment through uncontrolled landfills or direct littering (PRIF, 2018).

However, a comprehensive analysis of numerous scientific studies in SEA has underscored the predominant role of rivers as the primary source of marine debris. It was reported that there was a significant increase in the accumulation of marine debris from riverine sources, with a 46% increase in the abundance of personal protective equipment (PPE) observed at river outlets transported to Jakarta Bay. Furthermore, a 99% increase in microplastics was reported in the South China Seas during the COVID-19 pandemic (Cordova et al., 2021; Ku-Yusof et al., 2023). These rivers act as major conduits, transporting a significant amount of waste and litter from various land-based sources, including urban areas, industrial zones, and improperly managed waste disposal sites (World Bank, 2020).

2.3 Coastal debris observation method

There are various methods employed in beach clean-up activities throughout SEA. The simplest approach involves collecting debris and measuring its weight without identifying the specific types. Typically, these methods are implemented without scientific preparation, as participants are merely invited to the beach and tasked with collecting debris. The primary focus of such activities is to clean up the beaches, but their effectiveness and long-term impact remain questionable due to the absence of a well-informed and systematic approach. There is a wide variety of methods for collecting marine debris outlined in guidelines from around the world; however, several activities use methods based on guidelines provided by organizations such as OSPAR (Wenneker et al., 2010), CSIRO, UNEP (Cheshire et al., 2009), and NOAA (Opfer et al., 2012) (Table 1).

Usually, the use of these kinds of standard methods often involves the participation of academics and students. These guidelines included sampling techniques, instruments, and data analysis procedures. Another modified guide is found at https://marinedebris.id, which originates from Indonesia and has been customized to address local waste types. In general, the participants were involved in collecting debris with lines in transect methods or quadrat transects. The debris was then sorted and counted. For further analysis, the types of waste are categorized into nine distinct categories: plastics, fabric, glass, ceramic, metal, paper, rubber, biodegradable materials, and others.

3 Results and discussion

3.1 Coastal debris characteristics

In this study, marine debris is classified into nine categories based on the coastal clean-up (CCU) activities conducted between 2012 and 2022 along the coastlines of Southeast Asia. It was found that plastic waste, constituting 40%, predominates in the coastal regions of countries in SEA (Figure 1). The selection of these nine waste categories based on the identification of waste materials has been consistently documented across various scientific studies in SEA (Ng et al., 2023). These categories have been chosen as a common denominator to ensure a standardized and comprehensive approach to waste characterization and analysis. Using these categories as guidance, we facilitated a more robust and systematic observation of waste-related phenomena and the potential for broader insights into waste management and environmental impacts. Most marine debris is found on beaches with high recreational activities, such as Pangandaran Beach, Kuta, Seribu Island, and Nembrala in Indonesia (Apriliani et al., 2021; Faizal et al., 2022). Additionally, coastal regions predominantly inhabited by fishing communities contribute significantly to marine debris resulting from anthropogenic activities, particularly in fishing operations. Examples include Batu Rakit Beach and Pasir Panjang Beach in Malaysia (Fauziah et al., 2021).

TABLE 1 Guidelines for monitoring and sampling coastal and marine debris.

No.	Title of the guidelines	Institution	Source	Count
1.	NOAA Marine Debris Monitoring and Assessment Project	National Oceanic and Atmospheric Administration	Burgess et al., 2021	18
	African Marine Litter Monitoring Manual	African Marine Waste Network	Barnardo and Ribbink, 2020	NA
2.	Guidelines For Marine Debris Sampling	Diver Clean Sea Action, Unpad, BRIN	Faizal et al., 2021	5
3.	*Marine Litter Monitoring Methods Handbook*,	United Nations Environment Programme	COBSEA and CSIRO, 2022	11
4.	Handbook of Survey Methodology: Plastics Leakage	CSIRO	Schuyler et al., 2017	1
5.	Guidelines For the Monitoring And Assessment Of Plastic Litter In The Ocean	GESAMP	GESAMP, 2019	NA
6.	Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area	OSPAR	Wenneker et al., 2010	NA
7.	Others	NA	NA	11

NA, Not Applicable.

Plastics are commonly found because they represent everyday household packaging waste. Research conducted by Faizal et al. (2021) has also identified plastic waste on several beaches in Indonesia. Plastics, widely used in packaging materials, tend to accumulate and persist in the environment due to their durability and slow decomposition rate (Maharani et al., 2018). The improper disposal and inadequate waste management of these everyday plastic items contribute to their presence in coastal areas, including beaches (Lechthaler et al., 2020).

The distribution of coastal clean-up communities, also known as ocean guards, that have conducted beach cleaning activities can be found in various countries in SEA. Some of these communities specifically focus on marine pollution and marine debris. However, the majority are engaged in the field of conservation. These communities consist of different types, including nongovernmental organizations (NGOs) and local communities established by residents in response to their concerns about the polluted coastal areas caused by marine debris. In Indonesia, several NGOs, such as the Komitmen Research Group (KGR) and Universitas Padjadjaran, have actively conducted coastal clean-up activities in various coastal locations throughout the country (Faizal et al. (2021).

Residents have also established local communities, such as coastal communities in Bali and Lombok Islands, which are actively involved in beach cleaning efforts. In Malaysia, several NGOs, such as the Malaysian Nature Society and Reef Check Malaysia, have conducted coastal clean-up activities on beaches across the country. Furthermore, local communities such as Kelab Alami and Komuniti Pesisir also play a role in maintaining beach cleanliness and reducing marine debris. In Thailand, several NGOs have been actively involved in beach cleaning activities and education related to marine debris issues. Local communities are also engaged in beach cleaning efforts in popular tourist destinations such as Phuket and Pattaya. In the Philippines, several NGOs, such as Save Philippine Seas and Plastic Free Seas, have actively contributed to beach cleaning initiatives and campaigns for plastic waste reduction. Local communities also contribute to maintaining beach cleanliness on islands and in coastal areas of the Philippines. Local communities also participate in maintaining beach cleanliness in various coastal locations in Vietnam (Figure 2; Supplementary Material).

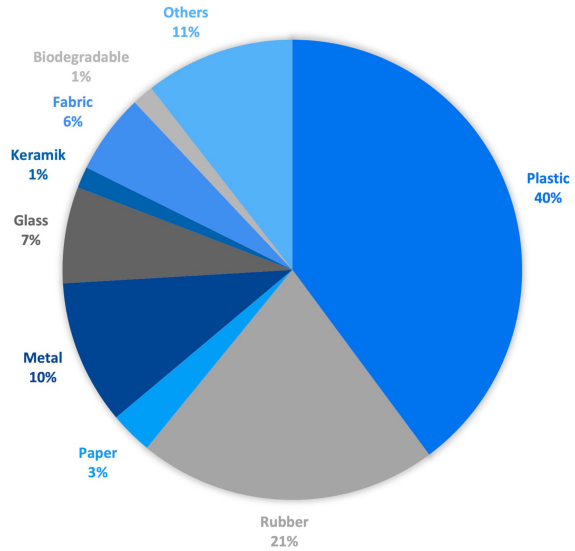

FIGURE 2
Type of *debris* based on nine categories.

The largest number of communities engaged in waste-related activities is found in Indonesia, with approximately 144 communities, followed by Thailand, with 29 communities. Malaysia has 28 communities, Myanmar has 12, and Singapore has 10. According to the table, Indonesia has the highest number of CCU communities in Southeast Asia, which can be attributed to its extensive coastline. Most of these communities in Indonesia are based in Bali. CCU communities in Bali are often initiated by foreign tourists who visit the island and are concerned about the highly polluted condition of its beaches. These communities emerge because several countries in the region are major contributors to marine debris in the world's oceans (Jambeck et al., 2015). In general, beach cleaning activities are not carried out regularly due to cost constraints. Previous research has shown that beach clean-up events are often conducted in conjunction with Earth Day or the national anniversary. Beach clean-up events are typically organized by a diverse range of stakeholders, including local communities, NGOs, and government agencies.

In terms of age range, participants in CCU activities in SEA can be divided into several occupational groups, including researchers, college students, NGOs, local communities, and other stakeholders (Figure 3; Supplementary Material Table 1). Researchers are the most frequent participants in CCUs, as they require data for their research purposes. However, CCU activities should be organized and instilled in communities from an early age to foster a culture of environmental awareness and care for the surrounding environment.

Different groups of people participate in beach clean-ups. For example, activities carried out on Indonesian beaches involved students of at least K11 and K12 age. The selection of students of this age is due to the ability of this age group to comprehend and complete the Marine Debris form. Beach clean-up events actively involve a broad spectrum of participants, including government, private companies, local and international NGOs, and students. Ideally, the activities are conducted within a single day, starting with socialization and presentations about marine debris, followed by a simulation of indoor waste collection. The final session involves collecting debris on the beach. In government-involved activities, participants typically go directly to the beach and begin collecting trash.

3.2 The cost of cleaning beaches

One way to reduce costs is by using volunteers for the cleaning process (Ryan & Swanepoel, 1996). According to research conducted by Cruz et al. (2020), a typical coastal clean-up (CCU) involves four personnel supervised by a team leader. They usually use plastic bags to collect waste, with an average weight ranging from 10 to 20 kg. Other equipment used includes rubber boots and gloves for personal protection. Some municipalities also use grabbers, ropes, and hooks attached to plastic bags to facilitate

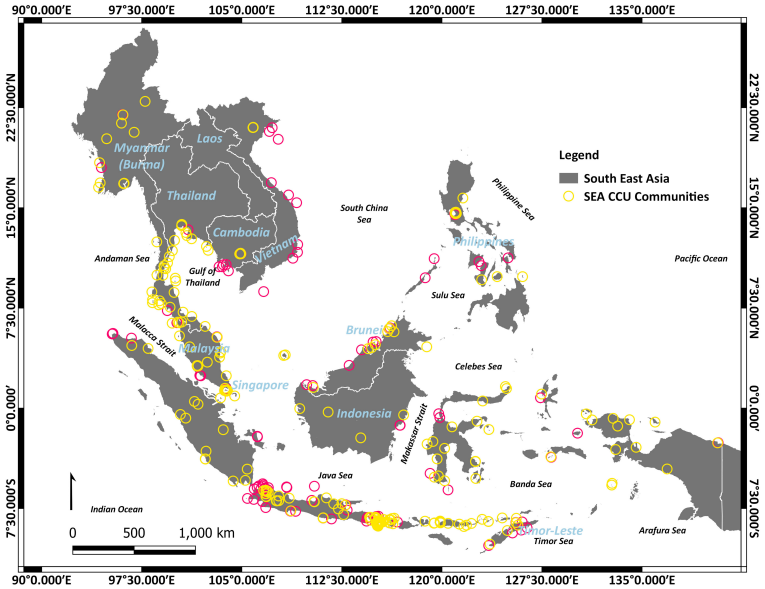

FIGURE 3
Hotspots of CCUs and marine debris communities in SEA.

waste collection. Workers walk along coastlines, gather large amounts of debris, and are assisted by a driver with a light pickup truck to transport the collected waste to the disposal site (Cruz et al., 2020). Research conducted by Hiwari et al. (2019); Maharani et al. (2018), and Faizal et al. (2021) stated that a minimum of 10 students are involved in beach cleaning activities using GPS, sheet forms, ropes, and safety uniforms. Several factors need to be considered to determine the cost needed for organizing a beach clean-up event, including participant mobilization, provision of safety uniforms, location, cleaning kits, and meals. In ceremonial events, coastal clean-up activities may incur higher costs due to the presence of government officials. However, the cost of regular cleaning operations using the line-in transect method is relatively low, at approximately 100 USD for 10 participants. The calculated cost pertains to expenses incurred in the field, excluding transportation, accommodation, and other costs.

3.3 Lessons learned from CCU

Coastal clean-up activity is still considered an unimportant activity by coastal communities. Often, the local people find coastal clean-up activities unappealing. However, for long-term strategy, it should turn into a community-led action. This method emphasizes getting local communities actively involved and empowered to tackle their own challenges (Vince and Hardesty, 2016). Efforts undertaken by local organizations or groups to clean up beaches serve as important and positive ways to address beach pollution and environmental issues. These local initiatives demonstrate how various stakeholders join forces to tackle beach cleaning on a broader, often international scale (Urbina et al., 2020). Therefore, greater efforts are needed to raise awareness among local people about this activity. However, in coastal areas, certain locations, such as mangrove forests, are unsuitable for clean-up due to their remote and steep terrain. Previous research has stated that mangroves serve as a natural trap for marine debris (Martin et al., 2019). The accumulation of debris density can harm mangrove forests, which can have negative consequences for marine biota and human community surroundings (Okuku et al., 2023).

To establish precise baselines and facilitate meaningful comparative surveys, it is essential to gather data of the highest quality. Thus, the inclusion of quality control measures in research experiments and survey protocols is essential, ensuring the accuracy of data collection and reducing potential uncertainties (Figure 4). The findings indicate that following brief training, citizen science data matched the quality of data collected by researchers, although variations were observed among student participants (van der Velde et al., 2017). On the other hand, feedback from participants related to beach clean-up activities is crucial to knowing their perspectives and becomes an important input for the following actions.

Coastal clean-up activities require significant preparation and a focus on sustainability (Battisti et al., 2020). Education through socialization and regulations from local governments are two crucial aspects in achieving this. Some beach cleaning activities are not carried out regularly, leading to a lack of awareness among the community. Without clear regulations or policies, communities and waste contributors will continue to supply trash to the ocean. Likewise, without education and socialization, the awareness of the community toward environmental care will not grow. Both are needed to foster and awaken the community's legal and societal consciousness.

Most of the waste placed in recycling bins is buried instead of recycled. Nearly all authorities channel the waste collected from the coast to landfills. The disposal of solid waste that is not recycled, burned, or stored in final disposal sites remains a recurring problem (Owusu-Ansah et al., 2022). The efficiency of waste management can simplify the process of separating waste, a practice often lacking in many developing countries. It requires a robust waste management

FIGURE 4
CCU activities in several regions in Indonesia from Komitmen Research Group (KGR) **(A, B)** collecting debris in Kronjo beaches, Serang and Muara Gembong, Bekasi, **(C)** sorting and counting the debris, **(D)** clean-up with student K12 in Pangandaraan beach, West Java-Indonesia.

system to garner attention from multiple stakeholders. By implementing waste management that involves categorizing waste, it becomes possible to decrease the buildup of plastic waste that ultimately ends up in the ocean (Zahari et al., 2022). It has been reported that waste management is often ineffective in developing countries, leading to most of the litter being disposed of in landfills (Chonchubhair et al., 2019; Schmaltz et al., 2020).

Lightweight and long-lasting debris is swept into rivers and wastewater systems, eventually reaching the sea, where it combines with waste discharged by ships (Ryan & Swanepoel, 1996). Usually, coastal clean-up activities also require considerable expenses for logistics before, during, and after the event. Williams et al. (2016) state that beach cleaning is crucial to eliminate trash from the shore. Conducting beach cleaning is necessary but costly for local government administrations. Considering that public funds typically fund beach cleaning, the budget allocated by municipal governments for this matter is often much smaller than what is allocated for other activities, making it a lower priority (Cruz et al., 2020). Funding applications or proposals for beach cleaning activities need to be made to support the overall program costs. Having consistent and sustainable partnerships to solve the marine waste problem is essential in these activities. On the other hand, the potential of CCUs could facilitate the identification and measurement of the quantitative abundance of marine debris in the environment. The evidence of outcomes derived from clean-ups demonstrates a commitment to environmental responsibility and collaboration with experts and NGOs (Hong et al., 2014). The continuation of CCU must be integrated into policies and regulations aimed at holding industries and other contributors to litter pollution accountable for their environmental impact. Furthermore, CCU is described in the NAP (National Action Plans) across SEA. A fairer distribution of both costs and responsibilities can help to maintain a clean and sustainable environment.

3.4 Future action and recommendation

To support the reduction of plastic waste worldwide, several recommendations for coastal clean-up activities on the beach include the following:

1. Scaling up citizenship action on coastal clean-up in Southeast Asia, including the need for stronger partnerships between governments, civil society, and the private sector. International regulations, national policies, public rules, and consumer behavior are not strong or comprehensive enough to protect the environment globally (DeSombre et al., 2018). Governments have a significant role in fostering and optimizing cooperation with nonprofit associations (Sur et al., 2018). Only with the involvement of all stakeholders can effective solutions for CCU activities be created.
2. Embracing the potential of technology and innovation is needed because it is not only highly effective but also a novelty that may attract public attention, ultimately increasing public awareness of the escalating issue of plastic waste, particularly in the oceans (Falk-Andersson et al., 2020). This can also be done by receiving direct feedback from participants for future actions.
3. The importance of building local capacity and empowerment where community involvement in coastal management issues is active is crucial for the success of coastal area management, as it instills environmental responsibility in participants (Urbina et al., 2021; Graham, 2023). Uneputty et al. (1998) found that community engagement in beach clean-ups has effectively changed local behavior, leading to short-term positive impacts on local environmental quality. Involving local community members in beach cleaning events increases awareness of the local impacts of marine litter by allowing

participants to witness the issue firsthand (Ornell et al., 2011; Zahari et al., 2022).

4. Establishing an effective waste management system and infrastructure is an important approach to combatting littering and preventing waste from ending up in landfills and being transferred into the ocean. An effective management system is an alternative for reducing marine litter.
5. It is crucial to recognize that the need for clean-up extends beyond beaches to include mangroves and coastal ecosystems as well. Mangroves and other coastal ecosystems (coral reefs and seagrass) serve as effective traps for marine debris, and addressing this issue requires increased efforts from society, including government intervention.

4 Conclusion

The problem of marine debris, including coastal debris, has been a critical issue in countries in SEA. Addressing this kind of pollution is a complex and extensive challenge that requires multifaceted solutions. Numerous studies have highlighted the vital role of citizen action in reducing marine debris. It is crucial to acknowledge that continuous efforts are being made in countries in SEA to enhance beach cleanliness and mitigate marine debris. Various stakeholders, including government agencies, NGOs, private companies, and local communities, are actively involved in tackling this problem through beach clean-up campaigns, public education, awareness initiatives, and policy and regulatory reforms to improve waste management practices. Strengthening partnerships among governments, civil society, NGOs, universities, and the private sector and embracing the potential of technology and innovation are crucial to managing and reducing debris that comes from terrestrials, including rivers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

NP: concept, data analysis, and lead writing. BP: writing and literature review. IF: editing and concept. MM: editing and finalizing the manuscript. MI: literature review and writing, CF: writing and data collection. RR: layout and data analysis. All authors contributed to the article and approved the submitted version.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Universitas Padjadjaran and Komitmen Grants funded some coastal beach clean-up in this research.

Acknowledgments

We thank the Komitmen Research Group (KGR) for providing the marine debris database. Universitas Padjadjaran supported most of the data collection from 2012 to 2020 in Indonesia. We would like to express our sincere thanks to the reviewers for their valuable input and insightful comments.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1250736/full#supplementary-material

References

Akbar, M. R. A., Junianto,, Faizal, I., and Purba, N. P. (2022). The trajectory of marine debris from Cirebon City Estuary, West Java, Indonesia. *AACL Bioflux* 15 (5), 2620–2628.

Apriliani, I. M., Purba, N. P., Dewanti, L. P., Herawati, H., and Faizal, I. (2021). Citizen-based marine debris collection training: study case in Pangandaran. *Farmers: J. Comm. Serv.* 2 (1), 56–61. doi: 10.24198/fjcs.v2i1.31927

Arumdani, (2021). Keberadaan Plastik di Lingkungan, Bahaya terhadap Kesehatan Manusia, dan Upaya Mitigasi: Studi Literatur. *Jurnal Serambi Eng.* 6 (4), 2279–2285. doi: 10.32672/jse.v6i4.3471

Barnardo, T., and Ribbink, A. J. (2020). *African marine litter monitoring manual.port elizabeth, south africa, african marine waste network, sustainable seas trust*. 158. doi: 10.25607/OBP-923

Battisti, C., Poeta, G., Romiti, F., and Picciolo, L. (2020). Small environmental actions need of problem-solving approach: Applying project management tools to beach litter clean-UPS. *Environ. MDPI* 7 (10), 1–15. doi: 10.3390/environments7100087

Burgess, H. K., Herring, C. E., Lippiatt, S., Lowe, S., and Uhrin, A. V. (2021). NOAA marine debris monitoring and assessment project shoreline survey guide. *NOAA Tech. Memorandum NOS OR&R* 56, 20. doi: 10.25923/g720-2n18

Catarino, A. I., Mahu, E., Severin, M. I., Akpetou, L. K., Annasawmy, P., Asuquo, F. E., et al. (2023). Addressing data gaps in marine litter distribution: Citizen science observation of plastics in coastal ecosystems by high-school students. *Front. Mar. Sci.* 10 (February). doi: 10.3389/fmars.2023.1126895

Cheshire, A. C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., et al. (2009). *UNEP / IOC Guidelines on Survey and Monitoring of Marine Litter. UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83*. (Nairobi: UNEP).

COBSEA and CSIRO (2022). *Marine litter monitoring methods handbook. Part 1* (Bangkok: United Nations Environment Programme), 77 pp.

Conchubhair, D. O., Fitzhenry, D., Lusher, A., King, A. L., van Emmerik, T., Lebreton, L., et al. (2019). Join effort among research infrastructure to quantify the impact of plastic debris in the ocean. *Environ. Res. Lett.* 14 (6), 065001. doi: 10.1088/1748-9326/ab17ed

Cordova, M. R., Nurhati, I. S., Riani, E., Nurhasanah,, and Iswari, M. Y. (2021). Unprecedented plastic-made personal protective equipment (PPE) debris in river outlets into Jakarta Bay during COVID-19 pandemic. *Chemosphere* 268, (129360). doi: 10.1016/j.chemosphere.2020.129360

Cruz, C. J., Muñoz-Perez, J. J., Carrasco-Braganza, M., Poullet, P., Lopez-Garcia, P., Contreras, A., et al. (2020). Beach cleaning costs. *Ocean Coast. Manage.* 188, 1–14 (April 2019). doi: 10.1016/j.ocecoaman.2020.105118

DeSombre, E. R., Dauvergne, P., and Alger, J. (2018). *A Research Agenda for Global Environmental Politics* (Cheltenham: Edward Elgar Publishing, Ltd., Pp. Ocean Governance.), 114–125. doi: 10.4337/9781788110952

Faizal, I., Anna, Z., Utami, S. T., Mulyani, P. G., and Purba, N. P. (2022). Baseline data of marine debris in the Indonesia beaches. *Data Brief* 41, 107871. doi: 10.1016/j.dib.2022.107871

Faizal, I., Purba, N. P., Cordova, M. R., Abimanyu, A., Afandi, N. K. A., Indriawan, D., et al. (2021). Marine debris pathway across Indonesian boundary seas. *J. Ecol. Eng.* 22 (3), 82–98. doi: 10.12911/22998993/132428

Falk-Andersson, J., Larsen Haarr, M., and Havas, V. (2020). Basic principles for development and implementation of plastic clean-up technologies: What can we learn from fisheries management? *Sci. Total Environ.* 745, 141117. doi: 10.1016/j.scitotenv.2020.141117

Fauziah, S. H., Rizman-Idid, M., Cheah, W., Loh, K. H., Sharma, S., Noor, N. M., et al. (2021). Marine debris in Malaysia: A review on the pollution intensity and mitigating measures. *Mar. pollut. Bull.* 167 (November 2020), 112258. doi: 10.1016/j.marpolbul.2021.112258

Galgani, F. (2015). Marine litter, future prospects for research. *Front. Mar. Sci.* 2. doi: 10.3389/fmars.2015.00087

Gall, S. C., and Thompson, R. C. (2015). The impact of debris on marine life. *Mar. pollut. Bull.* 92, 170–179. doi: 10.1016/j.marpolbul.2014.12.041

GESAMP (2019). *Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean*. Eds. P. J. Kershaw, A. Turra and F. Galgani (Nairobi: IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 130p. Rep. Stud. GESAMP No. 99.

Graham, R. E. D. (2023). Proposed solutions for marine debris in the Windward Islands- perspectives from key policy makers and policy influencers. *Front. Mar. Sci.* 10 (January). doi: 10.3389/fmars.2023.1065299

Harris, P. T., Westerveld, L., Nyberg, B., Maes, T., Macmillan-Lawler, M., and Appelquist, L. R. (2021). Exposure of coastal environments to river-sourced plastic pollution. *Sci. Total Environ.* 769 (14522), 1–15. doi: 10.1016/j.scitotenv.2021.145222

Harzing, A. W. (2007) *Publish or perish*. Available at: http://www.harzing.com/pop.htm.

Herdiansyah, H., Saiya, H. G., Afkarina, K. I. I., and Indra, T. L. (2021). Coastal community perspective, waste density, and spatial area toward sustainable waste management (Case study: Ambon bay, Indonesia). *Sustain. (Switzerland)* 13, 1–14. doi: 10.3390/su131910947

Hiwari, H., Purba, N. P., Ihsan, Y. N., Yuliadi, L. P. S., and Mulyani, P. G. (2019). Condition of microplastic garbage in sea surface water at around Kupang and Rote, East Nusa Tenggara Province. *Pros. Semnas. Masyarakat Biodiv. Indonesia* 5, 165–171. doi: 10.13057/psnmbi/m050204

Hong, S., Lee, J., Kang, D., Choi, H. W., and Ko, S. H. (2014). Quantities, composition, and sources of beach debris in Korea from the results of nationwide monitoring. *Mar. pollut. Bull.* 84 (1–2), 27–34. doi: 10.1016/j.marpolbul.2014.05.051

Irwin, K. (2012). The impacts of marine debris: A review and synthesis of existing research. *Living Oceans Soc.* 38, 1–38.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perrryman, M., Andrady, A., et al. (2015). Plastic waste inputs from land into the ocean. *Sci. (1979)* 347, 768–771. doi: 10.1017/CBO9781107415386.010

Kandziora, J. H., van Toulon, N., Sobral, P., Taylor, H. L., Ribbink, A. J., Jambeck, J. R., et al. (2019). The important role of marine debris networks to prevent and reduce ocean plastic pollution. *Mar. pollut. Bull.* 141, 657–662. doi: 10.1016/j.marpolbul.2019.01.034

Kong, T., Li, X., Pan, K., Zhang, W., and Li, R. (2023). Changes in sources and composition of beach waste in coastal cities around the bohai sea of china during the tourist peak and off-peak seasons. *Int. J. Env. Res. Public Health* 20 (3), 2573. doi: 10.3390/ijerph20032573

Ku-Yusof, K. M., Anuar, S. T., Mohamad, Y., and Maisarah, J. (2023). First evidence of microplastic pollution in the surface water of Malaysian Marine Park islands, South China Sea during COVID-19. *Mar. pollut. Bull.* 194, 115268. doi: 10.1016/j.marpolbul.2023.115268

Lechthaler, S., Waldschläger, K., Stauch, G., and Schüttrumpf, H. (2020). The way of macroplastic through the environment. *MDPI* 7 (10), 1–30. doi: 10.3390/environments7100073

Maharani, A., Purba, N. P., and Faizal, I. (2018). Occurrence of beach debris in Tunda Island. *E3S Web Conferences* 04006, 1–12. doi: 10.1051/e3sconf/20184704006

Martin, C., Almahasheer,, and Duarte, C. M. (2019). Mangrove forests as traps for marine litter. *Env. pollut.* 247, 499–508. doi: 10.1016/j.envpol.2019.01.067

Maximenko, N., Hafner, J., Kamachi, M., and MacFadyen, A. (2018). Numerical simulations of debris drift from the Great Japan Tsunami of 2011 and their verification with observational reports. *Mar. pollut. Bull. 132(June* 2017), 5–25. doi: 10.1016/j.marpolbul.2018.03.056

Ng, C. H., Mistoh, M. A., Teo, S. H., Galassi, A., Ibrahim, A., Sipaut, C. S., et al. (2023). Plastic waste and microplastic issues in Southeast Asia. *Front. Environ. Sci.* 11. doi: 10.3389/fenvs.2023.1142071

OECD (2019a). *Marine plastics pollution myanmar* (Paris: The Organisation for Economic Co-operation and Development), 4. Available at: https://www.oecd.org/ocean/topics/oceanpollution/marine-plastics-pollution-Myanmar.pdf.

OECD (2019b). *Marine plastics pollution cambodia* (Paris: The Organisation for Economic Co-operation and Development), 4. Available at: https://www.oecd.org/ocean/topics/oceanpollution/marine-plastics-pollution-Cambodia.pdf.

Okuku, E. O., Kombo, M., Mwalugha, C., Owato, G., Otieno, K., Mbuche, M., et al. (2023).). Are tropical mangroves a sink for litter leaking from land-and sea-based sources? Evidence from selected Kenyan mangroves. *Mar. pollut. Bull.* 187, 114590. doi: 10.1016/j.marpolbul.2023.114590

Omeyer, L. C. M., Duncan, E. M., Aiemsomboon, K., Beaumont, N., Bureekul, S., Cao, B., et al. (2022). Priorities to inform research on marine plastic pollution in Southeast Asia. *Sci. Total Environ.* 841, 1–18 (June). doi: 10.1016/j.scitotenv.2022.156704

Opfer, S., Arthur, C., and Lippiatt, S. (2012). *NOAA Marine Debris Shoreline Survey Field Guide* (Silver Spring: NOAA Marine Debris Programm), 19.

Ornell, C., Finn, S., and Basurto, X. (2011). A holistic approach to reducing plastic marine debris in coastal North Carolina. *Nicholas School of the Environment of Duke University*. 1–64.

Owusu-Ansah, P., Obiri-Yeboah, A. A., Nyantakyi, E. K., Woangbah, S. K., and Yeboah, S. I. I. K. (2022). Ghanaian inclination towards household waste segregation for sustainable waste management. *Sci. Afr.* 17, e01335. doi: 10.1016/j.sciaf.2022.e01335

Pérez-Guevara, F., Roy, P. D., Kutralam-Muniasamy, G., and Shruti, V. C. (2022). Coverage of microplastic data underreporting and progress toward standardization. *Sci. Total Environ.* 829, 154727. doi: 10.1016/j.scitotenv.2022.154727

PRIF (2018). *Solid waste management and recycling* (New South Wales: Pacific Regional Infrastructure Facility, Asian Development Bank), 103.

Purba, N., Faizal, I., Cordova, M., Abimanyu, A., Afandi, N., Indriawan, D., et al. (2021). Marine debris pathway across indonesian boundary seas. *J. Ecol. Eng.* 22 (3), 82–98. doi: 10.12911/22998993/132428

Putri, R. A., and Hudaya, M. (2022). The establishment of ASEAN framework of action on marine debris: the role of shared knowledge. *Global: J. Pol. Int.* 24 (1), 63–84. doi: 10.7454/global.v24i1.668

Ryan, P. G., Moore, C. J., Van Franeker, J. A., and Moloney, C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Philos. Trans. R. Soc. B: Biol. Sci.* 364, 1999–2012. doi: 10.1098/rstb.2008.0207

Ryan, P. G., and Swanepoel, D. (1996). Cleaning beaches: Sweeping the rubbish under the carpet. *South Afr. J. Sci.* 92 (6), 275–276.

Schmaltz, E., Melvin, E. C., Diana, Z., Gunady, E. F., Rittschof, D., Somarelli, J. A., et al. (2020). Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. *Environ. Int.* 144, 106067. doi: 10.1016/j.envint.2020.106067

Schuyler, Q., Willis, K., Lawson, T. J., Mann, V., Wilcox, C., and Hardesty, B. D. (2017). *Handbook of Survey Methodology: Plastics Leakage* (Canberra: CSIRO). Available at: http://hdl.handle.net/102.100.100/389141?index=1.

Seltenrich, N. (2015). New link in the food chain? : marine PLastic and seafood saftey. *Safety. Environ. Health Persp.* 123 (2), 34–42. doi: 10.1289/ehp.123-A34

Sur, C., Abbott, J. M., Ambo-Rappe, R., Asriani, N., Hameed, S. O., Jellison, B. M., et al. (2018). Marine debris on small Islands: Insights from an educational outreach program in the spermonde archipelago, Indonesia. *Front. Mar. Sci.* 5 (FEB). doi: 10.3389/fmars.2018.00035

Thang, L. D. (2019). *Overview of marine plastic debris in vietnam in relation to international context* (Hanoi, Vietnam: FIG Working Week 2019: Geospatial Information for a Smarter Life and Environmental Resilience). Available at: https://www.fig.net/resources/proceedings/fig_proceedings/fig2019/papers/ts01d/TS01D_le_dai_10174.pdf.

UNEP (2016). *Marine plastic debris and microplastics – global lessons and research to inspire action and guide policy change* (Nairobi: United Nations Environment Programme), 274.

Uneputty, P., Evans, S. M., and Suyoso, A. (1998). The effectiveness of a community education programme in reducing litter pollution on shores of Ambon Bay (eastern Indonesia). *J. Biol. Educ.* 32 (2), 143–147. doi: 10.1080/00219266.1998.9655611

Urbina, M. A., Luna-Jorquera, G., Thiel, M., Acuña-Ruz, T., Amenábar Cristi, M. A., Andrade, C., et al. (2021). A country's response to tackling plastic pollution in aquatic ecosystems: The Chilean way. *Aquat. Conserv.: Mar. Freshw. Ecosyst.* 31 (2), 420–440. doi: 10.1002/aqc.3469

Urbina, M. A., Luna-Jorquera, G., Thiel, M., Acuña-Ruz, T., Amenábar Cristi, M. A., Andrade, C., et al. (2020). A country's response to tackling plastic pollution in aquatic ecosystems: The chilean way. *Aquat. Conserv.: Mar. Freshw. Ecosyst.* 31 (2), 420–440. doi: 10.1002/aqc.3469

van der Velde, T., Milton, D. A., Lawson, T. J., Wilcox, C., Lansdell, M., Davis, G., et al. (2017). Comparison of marine debris data collected by researchers and citizen scientists: Is citizen science data worth the effort? *Biol. Conserv.* 208, 127–138. doi: 10.1016/j.biocon.2016.05.025

Van Dyck, I. P., Nunoo, F. K. E., and Lawson, E. T. (2016). An empirical assessment of marine debris, seawater quality and littering in Ghana. *J. Geosci. Environ. Prot.* 04, 21–36. doi: 10.4236/gep.2016.45003

Vince, J., and Hardesty, B. D. (2016). Plastic pollution challenges in marine and coastal environments: From local to global governance. *Restor. Ecol.* 25, 123–128. doi: 10.1111/rec.12388

Vince, J., and Hardesty, B. D. (2018). Governance solutions to the tragedy of the commons that marine plastics have become. *Front. Mar. Sci.* 5. doi: 10.3389/fmars.2018.00214

Vriend, P., Hidayat, H., van Leeuwen, J., Cordova, M. R., Purba, N. P., Löhr, A. J., et al. (2021). Plastic pollution research in Indonesia: state of science and future research directions to reduce impacts. *Front. Environ. Sci.* 9 (June). doi: 10.3389/fenvs.2021.692907

Wenneker, B., Oosterbaan, L.Intersessional Correspondence Group on Marine Litter (ICGML) (2010). *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area. Edition 1.0* (London, UK: OSPAR Commission), 15. doi: 10.25607/OBP-968

Williams, A. T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., and Perales, J. A. (2016). Distribution of beach litter along the coastline of Cadiz, Spain. *Mar. pollut. Bull.* 107, 77–87. doi: 10.1016/J.MARPOLBUL.2016.04.015

World Bank (2020). *Plastic Waste Discharges from Rivers and Coastlines in Indonesia. Plastic Waste Discharges from Rivers and Coastlines in Indonesia*. (Jakarta: World Bank). doi: 10.1596/35607

World Bank (2021). *Market study for vietnam: Plastics circularity opportunities and barriers. marine plastics series, east asia and pacific region* (Washington DC: World Bank), 116.

World Bank (2022). *Plastic waste material flow analysis for thailand: Summary report (English). marine plastic series* Vol. 1 (Washington DC: World Bank), 72.

Zahari, N. Z., Rafidi, F. J., Cleophas, F. N., Budin, K., and Musta, B. (2022). Distribution and abundance of marine debris on intertidal zone at three selected small island, Sabah. *J. Physics: Conf. Series IOP Publishing* 2314, 12001. doi: 10.1088/1742-6596/2314/1/012001