DEVELOPING A RAPID ASSESSMENT TOOL FOR MISMANAGED PLASTIC WASTE ENTERING WATER BODIES

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ABSTRACT

The rapid assessment tool for evaluating the impact of plastic waste on water bodies is a valuable approach for safeguarding human health, aquatic habitats, and other natural resources. This tool, based on the established protocols for assessing and monitoring floatable debris of the United State Environmental Protection Agency and the California Regional Water Quality Control Board's rapid trash assessment methodology. The research group has refined this assessment tool to enhance user accessibility and practicality. The research results have determined six key assessment criteria. Each survey site using this tool receives a composite score from 6 to 54, reflecting the cumulative impact across all six criteria. The score provides a clear classification of the site's condition regarding plastic waste impact. In detail, Poor (6 – 18): Indicates severe impact from plastic waste, requiring immediate and significant intervention. Moderate (19 – 36): Reflects a moderate level of impact, suggesting that the site is affected but not critically, necessitating targeted mitigation efforts. Good (37 – 54): Shows minimal impact, suggesting effective control measures are in place and the site is relatively healthy with respect to plastic waste pollution. This method has also been tested in practice and shown to be effective when applied to assess the impact of plastic waste discharge in water bodies. The rapid assessment tool supports timely and informed actions to mitigate pollution, protect ecosystems, and improve water quality. The tool's adaptability and efficiency make it a crucial asset in the ongoing efforts to combat plastic waste pollution in various water bodies.

1. INTRODUCTION

Growing awareness of the accumulation of marine debris, particularly plastic waste, has prompted a surge in studies analyzing its environmental impacts and the pathways by which waste reached the water bodies (*Lavoie* et al., 2021). Recent research suggested that a significant portion of aquatic debris was associated with terrestrial activities and poor waste management in coastal cities (*Eunomia*, 2016). However, geographical differences persisted, mainly between developed countries and emerging and developing countries (*Jambeck* et al., 2015). While plastic waste in Europe and the United States were mainly related to tire wear, microplastics in wastewater, or coastal litter, in the Global South, the lack of fully integrated municipal solid waste treatment systems was a major contributor (*Napper & Thompson*, 2018). In fact, *Margallo* et al. (2019) highlighted that although most municipal solid waste (over 90%) in Latin America and the Caribbean was properly collected, it was not treated with adequate waste treatment processes. This resulted in a large proportion of waste being sent to open dumps or poorly managed landfills (*Ziegler-Rodriguez* et al., 2019).

There was a strong causal relationship between increasing amount of marine litter and cities, especially when located in riparian countries or coastal areas (*Meijer* et al., 2021). This correlation increased when waste collection systems were poor (*Roebroek* et al., 2021). Two studies conducted in the past decade have estimated the amount of solid waste, specifically plastic, transported to the sea by large rivers or coastal cities (*Lebreton* et al., 2017; *Schmidt* et al., 2017), identifying rivers as major contributors.

The rapid assessment of plastic waste impact on water bodies has served several critical purposes including baseline monitoring; early warning; impact assessment; comparison between locations; and effectiveness of management activities. So, this study was aimed to: (1) develop a rapid assessment method to control the impact of plastic waste on aquatic life and water quality in various water bodies; and, (2) contribute the development and refinement of a comprehensive set of monitoring tools and indicators, particularly for field research and rapid assessments.

2. METHODS

2.1. Methodology

The rapid assessment tool for mismanaged plastic pollution entering water bodies leveraged the protocols for assessing and monitoring floatable debris of the United State Environmental Protection Agency (*U.S. EPA*, 2002) and the California Regional Water Quality Control Board's rapid trash assessment methodology (*U.S. EPA*, 2002). This method was refined through author's field experience and conferring with representatives from various stakeholders in environmental resource research and management (*Pham & Nguyen*, 2015).

2.2. Considerations for choosing a rapid assessment tool

The rapid assessment methodology for the impact of plastic waste on water bodies included a visual survey of the water bodies and adjacent areas from which plastic elements could be carried to the water body by wind, water, gravity or trash. The worksheet of rapid plastic pollution assessment was designed to represent the range of effects that plastic had on the physical, biological, and chemical integrity of water bodies. The worksheet has also provided a record for evaluation of the management of plastic discharges, by documenting sites that received direct discharges and those that accumulated trash from various locations. The specific items on the tally sheet were determined based on common items retrieved during numerous pilot surveys (*U.S. EPA*, 2002; *Pham & Nguyen*, 2010).

2.3. Developing the criteria for rapid assessment tool

The rapid assessment methodology for the impact of plastic waste on water bodies was based on six key criteria: (i) Level of plastic waste; (ii) Actual number of plastic items found; (iii) Threat to aquatic life; (iv) Threat to human health; (v) Illegal dumping and littering; and, (vi) Accumulation of plastic waste (*U.S. EPA*, 2002). The rapid assessment focused on evaluating the impact of plastic waste on aquatic bodies through a series of indicators related to waste and water quality. These criteria were divided into three categories: waste discharge levels, threats to aquatic life and water quality, and sources of plastic waste entry.

2.4. Designing the scoring scales for rapid assessment tool

Designing a scale to assess the impact of plastic waste discharge on water bodies, the research team adjusted the scale according to the amount of discharge to increase the quantity and level to suit the conditions of plastic waste use as well as the environmental protection awareness of the local people. Given the scoring system where each criteria was rated from 1 to 9. So the rapid assessment results generated site-specific scores on a scale from 6 to 54 for six criteria, here was a breakdown of the rating scale:

- Poor (6 – 18): 1. Worst impact of plastic waste; 2. Slightly better than 1 but still poor; and, 3. Marginally better but still in the poor category.
- Moderate (19 – 36): 4. Lowest level of moderate impact; 5. Mid-level of moderate impact; and, 6. Highest level of moderate impact.
- Good (37 – 54): 7. Lowest level of good impact; 8. Mid-level of good impact; and 9. Best impact, indicating the least impact of plastic waste on water bodies.

3. FINDINGS AND DISCUSSION

3.1. Site selection and locations

At each predetermined survey site, a tape was used to measure 100 m of the river length (Figure 1). The length of the cross-section did not have to be measured in a straight line, but could be measured along the winding curves of a river, stream or coastline. The starting and ending points would be selected so that they are easy to see, for example: tree roots, bushes, rocks, banks. The research team would consult and record the upper boundary of the riverbank or tidal flat for the survey. In addition, it was necessary to determine the characteristics of the survey site such as the low or hight water level limit; for tidal sea or river areas, it was necessary to determine the high and low tide boundaries. Determining these characteristics was to support comparison of assessments over time of year at the same survey location.

Figure 1. Survey length at each site

3.2. Conducting the rapid assessment criteria and scale

The rapid assessment criteria and scale of the impact of plastic waste on water bodies were presented in Table 1. By utilizing these indicators, it was possible to identify critical areas for intervention, develop targeted mitigation strategies, and improve overall management of plastic pollution in aquatic environments.

Table 1. The criteria and scale for rapid assessment of the impact of plastic waste on water bodies

No.	Criteria	Rapid assessment scale		
		Good (7 – 9)	**Moderate (4 – 6)**	**Poor (1 – 3)**
1	Level of plastic waste	At first observation, no plastic waste is found; upon closer inspection, there is no or very little plastic waste on the shore or in the river.	At first observation, very little plastic waste is found; upon closer inspection, there are some bottles, jars, food containers on the shore or in the river.	At first observation, plastic waste is found scattered in some places; upon closer inspection, there are many bottles, jars, food containers on the shore or in the river.
2	Actual number of plastic items found	There are from 0 – 15 pieces of plastic waste per length of surveyed river section.	There are from 16 – 45 pieces of plastic waste per surveyed river section.	There are more than 45 pieces of plastic waste per surveyed river section.
3	Threat to aquatic life	There is no types of plastic waste that threat biodiversity such as plastic bottles containing chemicals, food tray/box, or nylon bags.	There are some types of plastic waste that threat biodiversity such as plastic bottles containing chemicals, food tray/box, or nylon bags.	There are many types of plastic waste that that threat biodiversity such as plastic bottles containing chemicals, food tray/box, or nylon bags. Among them, there are types that are toxic to aquatic life.
4	Threat to human health	There is no plastic waste such as plastic bottles containing chemicals, grease, or medical waste (pathogenic microorganisms, chemicals).	There is no plastic waste such as plastic bottles containing chemicals, grease, or medical waste (pathogenic microorganisms, chemicals). But there is no highly toxic plastic waste such as pesticides, bandages, batteries.	There are more than 3 pieces of plastic waste such as plastic bottles containing chemicals and grease, or medical waste (pathogenic microorganisms, chemicals). In addition, there is highly toxic plastic waste such as pesticides, bandages, batteries.
5	Illegal dumping and littering	There is no evidence of illegal dumping of plastic waste. It may be just pieces of plastic waste from passersby.	There is evidence of illegal dumping of plastic waste, but no more than 3 small piles of plastic waste (diameter less than 50 cm with height less than 20 cm).	There are more than 3 small piles. Furthermore, it can be seen that plastic waste is piled up in large piles, including hazardous waste.
6	Accumulation of plastic waste	There is no accumulation of plastic waste in the river or no more than 5 pieces of plastic waste.	There is accumulation of plastic waste in the river from 6 – 20 pieces of plastic waste.	There is more than 20 pieces of plastic waste accumulated in the river.

3.3. Establishment of Plastic Waste Impact Index

It was estimated that the lower the calculated value for the Plastic Waste Impact Index (PWII), the stronger the impact of plastic waste on aquatic life and water quality of water bodies. In summary, from the calculated value of each criterion, then for convenience of calculation, it can be calculated according to the formula (1):

$$PWII = \frac{\sum_{i=1}^{6}(Ni \times Ti)}{Nmax} \times 100 \quad (1)$$

In which, N_i: score achieved for criterion i when assessing in each site; T_i: weight of criterion i; $\Sigma(N_i \times T_i)$: sum of score for each criteria and weight of criteria; N_{max}: maximum total score of all criteria (54 point).

Table 2 showed the weights of the evaluation criteria. The higher the weight assigned to a criterion, the greater its contribution to the overall assessment.

Table 2. The weight of the evaluation criteria

No.	Criteria	Weight
1	Level of plastic waste	0.13
2	Actual number of plastic items found	0.22
3	Threat to aquatic life	0.16
4	Threat to human health	0.12
5	Illegal dumping and littering	0.18
6	Accumulation of plastic waste	0.19

The proposed scoring scale for the PWII was presented in Table 3. To clarify, if a site had a high PWII percentage, it suggested that effective waste management practices, lower plastic waste generation, or higher efficiency in handling and recycling plastic waste in that area. Conversely, a lower PWII percentage could indicate a higher impact, meaning that the site contributed more significantly to plastic waste problems.

Table 3. The proposed scoring scale for PWII

No.	Scoring scale	Ranking
1	PWII≥80%	Very low impact
2	60%≤PWII<80%	Low impact
3	40%≤PWII<60 %	Moderate impact
4	20%≤PWII<40%	High impact
5	PWII<20%	Very high impact

3.4. Validation of the rapid assessment method

To validate the proposed rapid assessment tool for mismanaged plastic waste entering water bodies, a survey and testing was conducted at four specific locations along the Cai River of Khanh Hoa Province in June 2024. The chosen sites represent different segments of the river, offering a comprehensive view of plastic waste impact in varying conditions, including the sites as Site 1 (about 200 m upstream from the Thac Ngua Suspension bridge); Site 2 (about 200 m upstream from the Phuoc Kieng bridge); Site 3 (about 200 m downstream from the salt dam at the Cai River bridge); and, Site 4. (about 200 m downstream from the Xom Bong bridge) (Figure 2).

Figure 2. Sites of validation for the rapid assessment method in June 2024. (a) Site 1; (b) Site 2; (c) Site 3; and (d) Site 4

The PWII values, as shown in Table 4, fluctuated between 38% and 75% in June 2024. These values classified the plastic waste impact into three levels: (i) low, (ii) moderate, and (iii) high. The values of PWII indicated the low plastic waste impact at the site 1; the moderate impact at the Site 2 and Site 3; and the high impact at the Site 4.

Table 4. Results of the assessment of the impact of plastic waste on water bodies recorded in the Cai River, Khanh Hoa Province (06/2024)

Sites	PWII	Ranking
1	75%	Low impact
2	52%	Moderate impact
3	48%	Moderate impact
4	38%	High impact

4. CONCLUSION

This structured and systematic approach provided for rapid, accurate assessments that could inform management strategies, prioritized actions, and tracked progress over time in addressing plastic waste pollution in various water bodies. The results from this fast, easy-to-learn, and easy-to-implement method could be utilized for below purposes:

- Use the tool to establish initial conditions and track changes over time;
- Quickly identify areas where plastic waste levels are rising, allowing for prompt intervention;
- Assess how plastic waste impacts evolve over different seasons or years at a particular site;
- Compare different locations within the same water body type to identify areas needing more attention or those showing improvement; and,
- Measure the outcomes of implemented plastic waste management strategies to

determine their success and areas for improvement.

To ensure the most accurate assessment results, this rapid assessment method should be further validated across different types of water bodies. This would help refine the tool, ensuring it is robust and adaptable to various aquatic environments. By incorporating this tool into regular monitoring and management practices, stakeholders could make more informed decisions, prioritize interventions, and effectively combat plastic waste pollution, ultimately protecting aquatic ecosystems and human health.

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