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Microplastics in Lake Poso Sediments and Their Use as Educational Media

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Abstract: Microplastic pollution is an emerging environmental concern because these particles can accumulate in aquatic ecosystems but are difficult to detect visually. This study aimed to identify the morphological types and determine the density of microplastics in sediments from Lake Poso, Central Sulawesi, Indonesia, and to develop an educational poster based on the findings. A quantitative descriptive approach was applied. Sediment samples were collected from three categories of sites: an area with minimal human activity, a tourism area, and a residential area. Two sampling points were established at each site, yielding six sediment samples. At each sampling point, 200 mL of sediment was collected using the hand-collection method and analyzed at the Biology Laboratory, Faculty of Teacher Training and Education, Tadulako University. Organic matter was digested using a 10% KOH solution, after which the samples were filtered and examined microscopically. Suspected microplastic particles were classified as fibers, fragments, films, or pellets. Microplastics were detected in all sediment samples, although their density varied among sites. Fragments were the most abundant type, followed by fibers, films, and pellets. Microplastic densities were 170 particles/100 g of dry sediment at the site with minimal human activity, 281 particles/100 g at the tourism site, and 218.5 particles/100 g at the residential site. The educational poster developed from these findings was evaluated by content, design, and media experts, as well as student users, and was categorized as highly suitable for educational use. These findings indicate that Lake Poso sediments are contaminated with microplastics, potentially associated with tourism, fisheries, residential activities, and other anthropogenic inputs. Improved waste management and environmental monitoring are therefore needed to reduce microplastic contamination in the lake.
Keywords: Educational poster; Lake Poso; learning media; microplastics; sediment

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INTRODUCTION

Lake Poso is one of the largest lakes in Indonesia and supports a wide range of community activities, including hydroelectric power generation, fisheries, transportation, and tourism. These activities provide substantial socioeconomic benefits to surrounding communities. However, the intensive and continuous use of the lake may increase environmental pressures when it is not accompanied by effective and sustainable management. Lake Poso is therefore increasingly exposed to environmental disturbances that may threaten the long-term integrity and sustainability of its aquatic ecosystem (Fauziyyah & Arifin, 2023).

Communities surrounding Lake Poso depend on the lake as a major source of food and income, particularly through fishing activities involving fishing lines and nets. However, these activities may generate plastic waste from damaged fishing gear, fishing lines, food packaging, bottles, and other plastic products. When inadequately managed, this waste may enter the lake and undergo physical, chemical, and biological weathering, resulting in its gradual fragmentation into smaller plastic particles. Potential land-based inputs may also include synthetic fibers released during the washing of textiles, which have been identified as an important source of microfibers in aquatic environments (Napper & Thompson, 2016; De Falco et al., 2019). These particles may be transported through the water column and eventually deposited in bottom sediments.

Microplastics are commonly defined as plastic particles smaller than 5 mm and are generally classified as primary or secondary microplastics. Primary microplastics are intentionally manufactured at microscopic sizes, such as microbeads and industrial plastic pellets, whereas secondary microplastics are generated through the fragmentation of larger plastic materials while retaining their original polymer composition (Azizah et al., 2020). Plastic waste that remains in the environment may therefore become a persistent source of microplastic contamination in soil, water, sediments, and living organisms (Dewi et al., 2015).

Microplastic contamination has been documented in several Indonesian freshwater ecosystems. Adila and Windusari (2024) reported microplastics in the waters of the Musi River, while Seftianingrum et al. (2023) identified microplastics in water, sediments, and fish from the Porong River. Similar contamination has also been reported in freshwater lakes outside Indonesia, including Lake Winnipeg in Canada and Poyang Lake in China, demonstrating that lakes can act as important reservoirs of microplastic pollution (Anderson et al., 2017; Liu et al., 2019). Collectively, these findings indicate that microplastic pollution has become an important environmental issue in inland aquatic ecosystems and requires greater scientific and management attention.

Sediments consist of mineral particles, organic matter, and other materials transported by water before settling on the bottom of aquatic environments. They can serve as accumulation zones for various contaminants, including microplastics. Depending on their polymer density, size, shape, surface characteristics, and interactions with organic or mineral particles, microplastics may settle from the water column and become retained in sediments. Consequently, sediment analysis can provide valuable information on the spatial distribution and potential long-term accumulation of microplastic pollution in aquatic ecosystems (Liu et al., 2019; Zhao et al., 2019).

The accumulation of microplastics in sediments may alter sediment characteristics and increase the exposure of benthic organisms that feed on or live within bottom substrates. Experimental evidence has demonstrated that freshwater benthic macroinvertebrates can be exposed to and ingest microplastics present in sediments, although the magnitude of biological effects depends on particle characteristics, exposure concentrations, and organism sensitivity (Redondo-Hasselerharm et al., 2018). Microplastic particles may subsequently enter aquatic food webs through ingestion and may potentially be transferred to fish of ecological and economic importance. This issue is particularly relevant to Lake Poso because the lake provides habitat for diverse aquatic organisms that support local food security and livelihoods.

Although microplastic pollution has been widely investigated in various Indonesian aquatic environments, information regarding its occurrence and distribution in Lake Poso sediments remains limited. Furthermore, research findings concerning microplastic contamination in Lake Poso have not been systematically incorporated into locally contextualized biology learning media. This represents both an environmental knowledge gap and an opportunity to transform locally generated scientific evidence into educational material that is directly relevant to students' surroundings. An educational poster based on local research findings may provide a concise and visually accessible means of introducing students to the sources, characteristics, distribution, and ecological implications of microplastic pollution.

Accordingly, this study aimed to determine the occurrence of microplastics in Lake Poso sediments, characterize the forms of the detected particles, quantify their abundance, and develop an educational poster based on the research findings. It was hypothesized that sediments collected from tourism and residential areas would contain greater microplastic abundance than sediments collected from an area with minimal direct human activity. The resulting educational poster is expected to support locally contextualized biology learning by connecting scientific concepts with environmental problems occurring in the students' own region. In particular, the material may support learning topics related to environmental pollution, aquatic ecology, ecosystem interactions, environmental change, natural resource conservation, and the effects of human activities on aquatic ecosystems.

METHOD

Research Design and Study Area

This study employed a quantitative descriptive design consisting of sediment sampling followed by laboratory analysis of microplastic particles at the Biology Laboratory, Faculty of Teacher Training and Education, Tadulako University.

The study was conducted from January to March 2026. Sediment samples were collected from Lake Poso, Pamona District, Poso Regency, Central Sulawesi, Indonesia (approximately 1°54′–2°04′ S and 120°32′–120°43′ E). Sampling was conducted at three locations representing different levels of human activity: an area with minimal human activity, a tourist area, and a residential area. All sediment samples collected from the lake ecosystem were subsequently analyzed at the Biology Laboratory, Faculty of Teacher Training and Education, Tadulako University. The sampling locations are presented in Figure 1.

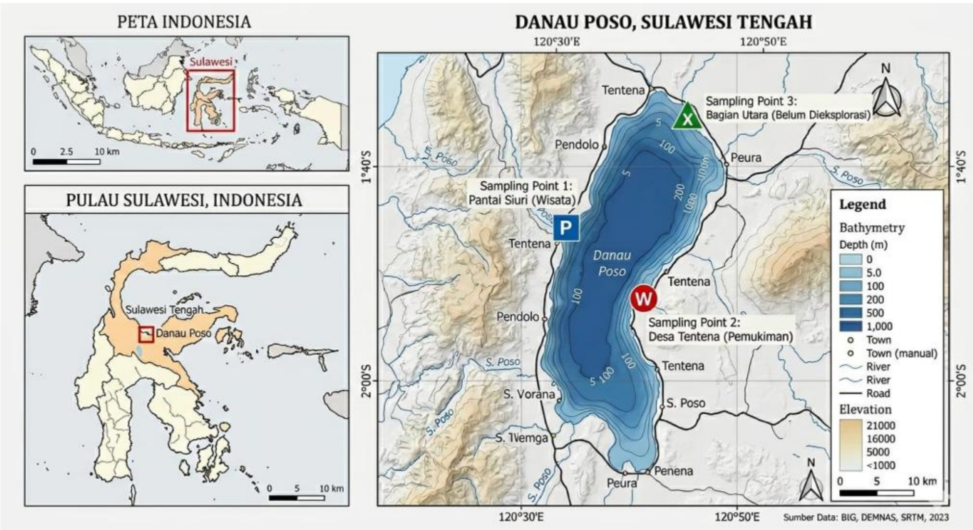

Figure 1. Study locations

Sediment Sampling

The samples consisted of sediment collected from the three study locations: the residential area, the tourist area, and the area with minimal human activity. A total of 200 mL of sediment was collected from each sampling point. The study used both primary and secondary data.

Sampling locations were selected using purposive sampling based on differences in the intensity of human activity. Sediment samples were collected manually using the hand-collection method and placed in 200-mL sampling bottles. During sampling, the researchers wore nitrile gloves, face masks, and cotton clothing to minimize contamination by synthetic microplastics. Before use, all sampling containers were rinsed with filtered distilled water and covered with aluminum foil.

Equipment and Materials

The equipment used in this study included 500-mL glass beakers for digesting sediment samples with 10% KOH, glass stirring rods for homogenizing the sediment–KOH mixture, Whatman No. 42 filter paper with a pore size of 2.5 μm for filtering particles separated from the sediment, an incubator for drying the samples, and a microscope for observing particle morphology.

The materials included sediment samples, 10% KOH solution for digesting organic matter, filtered distilled water for cleaning laboratory equipment, and aluminum foil for covering the beakers and wrapping sediment samples during incubation. All glassware was washed using plastic-free detergent, rinsed with filtered distilled water, and dried before use. Throughout the analytical procedures, the samples were covered with aluminum foil to prevent the deposition of airborne microplastics from the laboratory environment.

Sample Preparation and Microplastic Extraction

Sediment samples were collected directly from the three study locations, transferred into labeled 200-mL bottles, and transported to the laboratory for analysis. The samples were dried at 50°C for 72 h to remove moisture without altering the physical structure of the microplastic particles. A temperature of 50°C was selected because it is below the deformation temperature of most common microplastic polymers, including polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET).

The dried sediment samples were mixed with 10% KOH solution at a ratio of 1:3 (w/v) and incubated at 60°C for 24 h. KOH was used because it effectively degrades organic matter without damaging most microplastic polymers. Following digestion, density separation was performed using a saturated NaCl solution with a density of approximately 1.2 g/cm³. The mixture was left undisturbed for 24 h to allow the microplastic particles to float. The resulting supernatant was then filtered through Whatman No. 42 filter paper with a pore size of 2.5 μm.

Microplastic density was calculated according to Cole et al. (2011) using the following equation:

$$\mathbf{KR} = \frac{ni}{n}$$

Note:
RD = relative density;
n_i = number of microplastic particles detected; and
n = dry weight of the sediment analyzed.

Visual Identification of Microplastics

Particles retained on the filter paper were examined microscopically and classified according to their morphology as fibers, fragments, films, or pellets. Visual identification was based on the following criteria: the absence of biological cellular structures, a homogeneous or unnatural color, a morphology corresponding to fibers, films, fragments, or pellets, the absence of visible biological tissue on the particle surface, and resistance to disintegration when touched with a needle.

The number and morphological type of each identified particle were recorded and documented. After all observations and identifications had been completed, the data were organized according to the journal template.

Development and Validation of the Educational Media

The educational media were developed using a Research and Development approach adapted from the stages proposed by Borg and Gall. The development process included planning, product development, expert validation, revision, and limited-scale testing.

The validation instrument consisted of a Likert-scale questionnaire covering content suitability, language, presentation, and visual appearance. The validation data were analyzed using a percentage-based feasibility assessment according to the following equation:

$$\text{Mean feasibility score} = \frac{\text{Sum of all percentage scores}}{\text{Number of assessment aspects}} x100$$

The criteria used to interpret the feasibility percentage of the educational media are presented in Table 1.

Table 1. Feasibility criteria for the educational media

Percentage	Media feasibility category
81%–100%	Highly feasible
61%–80%	Feasible
41%–60%	Moderately feasible
21%–40%	Not feasible
<21%	Highly infeasible

Source: Arikunto (2014)

RESULTS AND DISCUSSION

Microscopic examination indicated the presence of particles visually identified as microplastics in all sediment samples collected from Lake Poso. Four morphological types were observed: fibers, fragments, films, and pellets. The number and distribution of the particles identified at each sampling point are presented in Table 2.

Table 2. Counts of particles visually identified as microplastics in sediments from Lake Poso

Sampling location	Sample type	Number of samples	Sampling point	Fibers	Fragments	Films	Pellets	Total particles	Mean particle count per sample
Area with minimal direct human activity	Sediment	2	1	27	257	16	17	317	170
			2	12	10	1	0	23	
Tourist area	Sediment	2	1	16	217	6	1	240	281
			2	14	299	8	1	322	
Residential area	Sediment	2	1	40	313	5	0	358	218.5
			2	18	60	1	0	79	

All sediment samples from Lake Poso contained particles visually identified as microplastics. Fragments were the dominant morphological type at all sampling locations, followed by fibers, films, and pellets. Based on the mean particle count per sample, the tourist area had the highest value, with 281 particles per sample, followed by the residential area with 218.5 particles per sample and the area with minimal direct human activity with 170 particles per sample.

The comparatively high particle counts in the tourist and residential areas suggest that anthropogenic activities may contribute to the accumulation of microplastics in Lake Poso sediments. Tourism, domestic activities, and fishing may increase the input of plastic waste into aquatic environments, where larger plastic materials can gradually fragment into smaller particles (Jambeck et al., 2015). This interpretation is consistent with Ibrahim et al. (2023), who reported that aquatic areas exposed to intensive human activity tend to contain greater microplastic accumulations than areas with lower levels of human activity.

Nevertheless, the distribution of the identified particles was spatially heterogeneous. Although the tourist area had the highest mean particle count, the highest count at an individual sampling point was recorded at the first residential sampling point, where 358 particles were identified. Considerable differences were also observed between the two sampling points within the same location. These findings indicate that particle distribution in Lake Poso sediments may be influenced by local environmental conditions in addition to the intensity of human activity.

The total number and relative proportion of each particle type are presented in Table 3.

Table 3. Distribution of particles visually identified as microplastics according to morphological type

Particle type	Total particles	Percentage (%)
Fibers	127	9.48
Fragments	1,156	86.33
Films	37	2.76
Pellets	19	1.42
Total	1,339	100

Fragments represented the most abundant morphological type, accounting for 86.33% of all identified particles. Fibers accounted for 9.48%, films for 2.76%, and pellets for 1.42%.

Area with Minimal Direct Human Activity

At the first sampling point in the area with minimal direct human activity, 317 particles were identified, consisting of 27 fibers, 257 fragments, 16 films, and 17 pellets. At the second sampling point, 23 particles were recorded, comprising 12 fibers, 10 fragments, and one film; no pellets were detected.

The presence of these particles in an area without direct human activity indicates that microplastic contamination is not necessarily restricted to locations adjacent to identifiable local pollution sources. Particles may be transported from other parts of the catchment through river inflows, surface runoff, and lake currents before being deposited in relatively undisturbed areas. Thus, the occurrence of microplastics in sediment may reflect both local inputs and hydrodynamic transport within the lake system.

Lebreton et al. (2017) demonstrated that plastic particles can be transported between locations through flowing-water systems and subsequently accumulate in sediments. Similarly, previous research has shown that microplastics may occur in sediments located far from major pollution sources because small particles are readily transported by water currents before settling on the bottom of aquatic environments (Putri & Rafi'i, 2023).

However, the substantial difference between the two sampling points at this location also indicates pronounced small-scale spatial variability. Differences in sediment texture, water movement, shoreline morphology, and particle-deposition processes may have contributed to the unequal distribution of particles between the sampling points.

Tourist Area

Microplastic particle counts were comparatively high in the tourist area. At the first sampling point, 240 particles were identified, including 16 fibers, 217 fragments, six films, and one pellet. At the second sampling point, 322 particles were recorded, comprising 14 fibers, 299 fragments, eight films, and one pellet.

The high mean particle count in this area may be associated with tourism-related activities and the use of disposable plastic products. Inadequately managed plastic waste may enter the lake directly or through surface runoff. Exposure to ultraviolet radiation, wave action, temperature fluctuations, and mechanical abrasion can subsequently cause larger plastic materials to fragment into microplastics. Nevertheless, the present study did not directly identify the sources or polymer composition of the particles; therefore, the association with tourism should be interpreted as a plausible explanation rather than as confirmed source attribution.

Previous studies have shown that aquatic tourism areas are particularly vulnerable to microplastic pollution because increased visitor activity is often accompanied by greater consumption and disposal of single-use plastic products. In the Wonorejo mangrove tourism area in Surabaya, sediment microplastics were dominated by films and fragments that were considered to originate from plastic bags and food packaging transported by water currents and deposited in sediments (Estina et al., 2025). Increasing tourism activity may therefore increase plastic-waste generation and the subsequent formation of microplastics in aquatic ecosystems (Ivar do Sul & Costa, 2014).

Residential Area

The highest count at an individual sampling point was recorded in the residential area. At the first sampling point, 358 particles were identified, consisting of 40 fibers, 313 fragments, and five films; no pellets were detected. At the second sampling point, 79 particles were recorded, comprising 18 fibers, 60 fragments, and one film, with no pellets detected.

The presence of relatively high particle counts in the residential area may be associated with domestic activities that generate plastic waste, including shopping bags, food packaging, beverage bottles, and plastic household products. When such materials enter the aquatic environment, they may gradually degrade and fragment into smaller particles that eventually accumulate in sediments.

However, the marked difference between the two residential sampling points demonstrates that microplastics were not uniformly distributed within the sediment. This variation may have resulted from differences in sediment grain size, local circulation, proximity to waste-discharge pathways, shoreline characteristics, and particle-deposition processes. The limited number of sampling points may also have contributed to the observed variability and restricts broader statistical generalization across the lake.

Distribution and Possible Origins of Particle Types

Fragments were the dominant particle type at all sampling locations, representing 86.33% of the total particles identified. Their predominance suggests that much of the observed contamination may consist of secondary microplastics produced through the breakdown of larger plastic materials. Similar findings were reported by Ibrahim et al. (2023) and Liu et al. (2019), who identified fragments as the most abundant microplastic type in aquatic sediments. The accumulation of fragments may result from prolonged physical, chemical, and biological weathering of plastic waste in aquatic environments (Andrady, 2011).

Fibers were the second most abundant morphological type. Their occurrence in sediment is commonly associated with synthetic textiles, ropes, fishing lines, and fishing nets. Browne et al. (2011) reported that synthetic fibers released through domestic activities and the use of fishing equipment constitute important sources of fiber-shaped microplastics in aquatic environments. However, because polymer composition was not confirmed in the present study, the specific sources of the observed fibers cannot be established conclusively.

Films were detected at all sampling locations, although their abundance was considerably lower than that of fragments and fibers. Film-shaped particles are commonly associated with the degradation of thin plastic materials, including shopping bags, food wrappers, and other forms of disposable packaging. Estina et al. (2025) similarly reported the occurrence of films in sediments from the Wonorejo mangrove tourism area in Surabaya. Their presence in Lake Poso may indicate inputs from degraded flexible plastic products, although this interpretation requires confirmation through polymer analysis.

Pellets were the least abundant particle type. Plastic pellets are generally small, rounded materials used as raw materials in plastic manufacturing. Their low abundance suggests that contamination in Lake Poso may be more strongly associated with the fragmentation of discarded consumer plastics than with direct inputs of industrial plastic feedstock (Guerranti et al., 2019). This interpretation should nevertheless be treated cautiously because the particles were classified according to visual morphology rather than chemical composition.

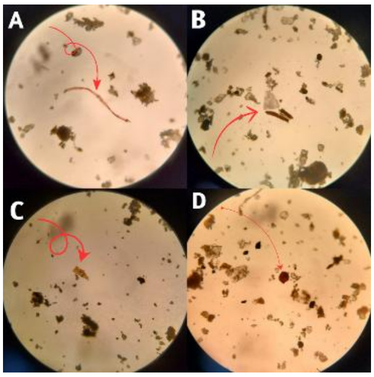

Figure 2. Representative particles visually identified as microplastics in sediments from Lake Poso under 40× microscopic magnification, with a scale of 500 µm: (a) fiber; (b) fragment; (c) film; and (d) pellet. Source: Research findings, 2026.

Development and Validation of the Educational Poster

The findings on microplastic contamination in Lake Poso sediments were incorporated into an educational poster for use in biology learning. The poster format was selected because visual media can transform complex research findings into concise, contextualized, and readily understandable information.

The poster presents information on potential sources of plastic pollution, the morphological characteristics of the identified particles—fibers, fragments, films, and pellets—and the possible implications of plastic pollution for the Lake Poso ecosystem. This approach is consistent with Mashuri (2019), who stated that posters can communicate educational information concisely, attractively, and accessibly. The poster may therefore serve as a contextual learning resource while promoting awareness of plastic-waste management in schools and local communities.

The results of the validation process conducted by content experts, design experts, media experts, and student users are summarized in Table 4.

Table 4. Validation results for the educational poster

Validator	Percentage (%)	Suitability category
Content expert	88	Highly suitable
Design expert	91	Highly suitable
Media expert	80	Suitable
University students	90	Highly suitable
Mean	**87.25**	**Highly suitable**

The educational poster obtained a mean validation score of 87.25%, placing it in the highly suitable category. The content expert awarded a score of 88%, the design expert 91%, the media expert 80%, and the university-student users 90%. Based on the predetermined assessment criteria, the score of 80% awarded by the media expert falls within the suitable category rather than the highly suitable category.

The media expert recommended improvements to several visual components, particularly image arrangement, font size, and color composition. These revisions were intended to improve the visual hierarchy and ensure that the information could be communicated more clearly. After the poster was revised in accordance with the validator's recommendations, its presentation became more coherent, communicative, and accessible to users.

The validation results indicate that the poster is suitable for presenting scientific information on microplastic contamination in an engaging and contextually relevant format. The use of research findings from Lake Poso provides additional educational value because learners can examine an environmental problem occurring within their own region. Such locally contextualized content may support biology learning related to environmental pollution, ecosystems, environmental change, and natural-resource conservation.

However, the validation procedure assessed the poster's suitability rather than its effectiveness in improving learning outcomes or environmental awareness. Therefore, the findings support the conclusion that the poster is appropriate for use as a learning medium, but they do not yet demonstrate that it significantly improves students' knowledge, attitudes, or behavior. Further research using pretest–posttest assessments or comparative learning designs is required to evaluate its educational effectiveness.

Study Limitations

The findings of this study should be interpreted in light of several limitations. First, particle identification was based on visual and morphological characteristics and was not confirmed using spectroscopic methods such as Fourier-transform infrared spectroscopy or Raman spectroscopy. The identified particles should therefore be regarded as suspected microplastics. Second, only two sediment samples were collected from each location, limiting the ability to represent the spatial variability of microplastic contamination throughout Lake Poso. Third, differences in particle counts among locations were interpreted descriptively because no inferential statistical analysis was conducted. Future studies should include more sampling points, contamination blanks, polymer confirmation, and measurements of relevant environmental variables to provide a more comprehensive assessment of microplastic contamination in Lake Poso.

CONCLUSION

The results demonstrate that sediments throughout Lake Poso were contaminated with microplastic particles. Microplastic densities were 170 particles per 100 g of dry sediment in the area with minimal human activity, 281 particles per 100 g of dry sediment in the tourist area, and 218.5 particles per 100 g of dry sediment in the residential area. These findings indicate that microplastics are widely distributed throughout the aquatic environment and may accumulate in sediments as a result of human activities and the environmental degradation of plastic waste.

The identified microplastics consisted of fibers (9.48%), fragments (86.33%), films (2.76%), and pellets (1.42%). Fragments were the most dominant form, suggesting that most of the microplastics originated from the fragmentation of larger plastic materials. The relatively high microplastic densities observed in the residential and tourist areas further indicate that anthropogenic activities may contribute substantially to microplastic pollution in Lake Poso. The educational poster developed from the research findings was classified as highly feasible and has the potential to serve as a locally contextualized biology learning medium to enhance students' understanding of environmental pollution and aquatic ecosystem conservation.

RECOMMENDATION

Future studies should investigate microplastics not only in sediments but also in the water column and aquatic organisms to provide a more comprehensive assessment of microplastic pollution in Lake Poso. More accurate analytical methods should also be employed to identify polymer types and confirm the chemical composition of the suspected microplastic particles. In addition, environmental education programs should be strengthened to increase public awareness of responsible plastic waste management and prevent the disposal of plastic waste into Lake Poso.

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