Bioscientist: Jurnal Ilmiah Biologi
https://e-journal.undikma.ac.id/index.php/bioscientist

June 2026 Vol. 14, No. 2
e-ISSN: 2654-4571
pp. 1067-1077

Microplastic Analysis in the Digestive Tract of Squid (*Loligo* sp.) Sold at a Traditional Market in Palu City and Its Application as an Educational Medium

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Received: April 2026; Revised: May 2026; Accepted: June 2026; Published: June 2026

Abstract: This study aimed to identify the morphological types of microplastics present in the digestive tracts of squid (*Loligo* sp.) sold at a traditional market in Palu City. A descriptive approach combining quantitative and qualitative analyses was employed. A total of 10 fresh squid specimens were randomly selected from a single vendor at Lasowani Traditional Market. The digestive tracts were isolated, digested using 10% potassium hydroxide (KOH), and incubated at 40°C for 96 h. The recovered particles were subsequently classified and counted, and microplastic abundance was calculated. Three morphological types of microplastics—fibers, films, and fragments—were detected in the digestive tracts of the 10 squid specimens. A total of 948 particles were recorded, corresponding to a mean abundance of 94.8 particles per individual. Films were the most prevalent type, accounting for 48.4% of the total particles, followed by fragments at 26.7% and fibers at 24.9%. These findings indicate that film-type microplastics were dominant in the digestive tracts of the examined squid. Based on the research findings, an educational poster was also developed and subjected to expert validation. The poster achieved a feasibility score of 82.23%, indicating that it was highly suitable, based on the validation results, for use as a learning resource in biology education.

Keywords: Abundance; microplastics; squid (*Loligo* sp.)

How to Cite: Apriyani, N. K., Dhafir, F., Rauf, A., Ramadhan, A., Sabran, M., & Masrianih. (2026). Microplastic Analysis in the Digestive Tract of Squid (Loligo sp.) Sold at a Traditional Market in Palu City and Its Application as an Educational Medium. *Bioscientist: Jurnal Ilmiah Biologi*, *14*(2), 1067–1077. https://doi.org/10.33394/bioscientist.v14i2.20735

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INTRODUCTION

Plastic waste is a widespread environmental problem in Indonesia, including Palu City. Rather than arising solely from limited public awareness, plastic pollution is associated with improper disposal practices, inadequate waste management, and the transport of land-based waste into aquatic environments. Plastic debris discarded on land can enter rivers and coastal waters through drainage systems, river flow, and stormwater runoff (Sukarna, 2020). Rivers are recognized as important pathways through which plastic waste is transported from terrestrial environments to the ocean (Lebreton et al., 2017). Once released into aquatic environments, larger plastic items may persist, undergo physical and chemical weathering, and gradually fragment into smaller particles.

Microplastics are generally defined as plastic particles measuring less than 5 mm (Labibah et al., 2020). They can be classified as either primary or secondary microplastics. Primary microplastics are intentionally manufactured at microscopic sizes, whereas secondary microplastics are formed through the fragmentation and degradation of larger plastic products. Their small size and broad environmental distribution make them readily available to aquatic organisms. In addition, similarities in size, shape, or appearance between microplastic particles and natural prey may increase the likelihood of accidental ingestion by marine organisms (Neves et al., 2015). Purnama et al. (2021) documented microplastic contamination in the digestive tracts of 30 kawakawa tuna (*Euthynnus affinis*), indicating that commercially important marine organisms may be exposed to plastic particles. Once ingested, these particles may be expelled, temporarily retained in the gastrointestinal tract, or interact physically and chemically with the organism (Browne et al., 2015).

The presence of anthropogenic debris in seafood is particularly relevant because marine organisms sold for human consumption may reflect the entry of plastic particles into marine food webs. Rochman et al. (2015), for example, detected anthropogenic debris in fish and shellfish obtained from markets in Indonesia and the United States. Their study also emphasized the importance of distinguishing confirmed plastic particles from visually identified fibers when polymer composition has not been verified using spectroscopic techniques.

Squid provisionally identified as *Loligo* sp. are widely consumed marine organisms and occupy an important trophic position in marine food webs. As active predators of small fish, crustaceans, and zooplankton, squid may be exposed to plastic particles either directly from the surrounding environment or indirectly through contaminated prey. These feeding characteristics make squid relevant organisms for investigating the occurrence of plastic particles at higher trophic levels. Squid are soft-bodied invertebrates belonging to the phylum Mollusca and class Cephalopoda. They exhibit bilateral symmetry and possess a well-developed digestive system that may retain ingested materials for a certain period (Lumenta, 2017; Wulandari, 2018). However, when specimens are obtained from markets and their capture locations are unknown, the findings should be interpreted as evidence of contamination in the examined seafood products rather than as direct evidence of pollution at a particular marine location.

Microplastic contamination in marine organisms, including squid, has been investigated in previous studies. Makrima et al. (2022), in their study entitled "Microplastics in the Tentacles and Digestive Tracts of Squid from the Tambak Lorok Fish Auction Site," reported 343 particles in the digestive tract and 212 particles in the tentacles. The identified particle forms included fibers, films, fragments, and pellets. Nevertheless, information on suspected microplastic particles in squid marketed in Palu City remains limited. Furthermore, the use of locally generated evidence on microplastic contamination as contextual material for biology education has received relatively little attention. The present study addresses these gaps by combining an environmental investigation with the development of an educational resource based on a local environmental issue.

Accordingly, this study aimed to identify the morphological forms and determine the abundance of particles suspected to be microplastics in the digestive tracts of squid provisionally identified as *Loligo* sp. and purchased from Lasowani Traditional Market, Palu City. The study also aimed to develop an educational poster based on the research findings and evaluate its feasibility as a biology learning resource. The poster format was selected to communicate information on microplastic contamination in a concise, visually accessible, and contextually relevant manner for students.

METHOD

The study was conducted from January to June 2026. Squid specimens were randomly purchased from one vendor at Lasowani Traditional Market, Palu City, whereas analysis of the digestive tracts was performed at the Biology Laboratory, Faculty of Teacher Training and Education, Tadulako University.

This study employed qualitative and quantitative descriptive approaches. The qualitative approach was used to characterize microplastic particles, defined as plastic particles smaller than 5 mm. These particles may occur in various morphological forms, including fine fibers, irregular fragments, thin films, and spherical particles, and may be white, black, blue, red, transparent, or colorless (Fitria et al., 2021). The quantitative approach was used to determine the number and abundance of microplastic particles identified in the digestive tracts of the squid specimens. The resulting data were presented numerically and summarized in tables.

A total of 10 fresh squid specimens, provisionally identified as *Loligo* sp., were used in this study. The equipment and materials included 250-mL Erlenmeyer flasks, an incubator, a binocular microscope, dissection instruments, a camera, a cool box, Pasteur pipettes, Petri dishes, 10% potassium hydroxide (KOH), distilled water, Whatman No. 42 filter paper with an approximate pore size of 2.5 μm, and aluminum foil.

Before microplastic identification, all laboratory equipment was thoroughly washed, dried, and sterilized. Materials, including the 10% KOH solution, were prepared under clean conditions. All sample-containing vessels were tightly covered with aluminum foil, and the researchers wore gloves and masks throughout the analytical procedures to minimize potential contamination (Hafsan, 2014).

Microplastic Extraction and Identification

Microplastics in the digestive tracts of *Loligo* sp. were extracted and identified using the following procedure:

1. A complete set of dissection instruments was prepared;
2. Each squid specimen was dissected longitudinally to remove its digestive tract;
3. The digestive tract was transferred into a 250-mL Erlenmeyer flask;
4. A total of 150 mL of 10% KOH solution was added to each sample to digest the biological tissue;
5. Each Erlenmeyer flask was tightly covered with aluminum foil;
6. The samples were incubated at 40°C for 96 h;
7. After incubation, each sample was filtered through Whatman No. 42 filter paper with an approximate pore size of 2.5 μm to separate the microplastic particles from the remaining tissue residues;
8. The retained material was rinsed with distilled water and filtered again to remove residual biological material;
9. The samples were covered with aluminum foil and dried in an incubator at 50°C for 48 h;
10. The particles retained on the filter paper were identified and counted using a binocular microscope at 10× magnification;
11. Microplastic abundance was calculated to determine the average number of particles detected per squid specimen.

Microplastic abundance was calculated according to Cordova (2021) using the following equation:

$$\mathbf{KR} = \frac{(Ni)}{n}$$

Note:
KR : microplastic abundance (particles/individual);
Ni : total number of microplastic particles detected; and
N : total number of squid specimens analyzed.

The detected particles were subsequently classified according to their morphological forms, including fibers, fragments, films, and small spherical particles. This classification was performed to determine the dominant microplastic type. The results were summarized in tabular form to facilitate interpretation.

Development and Validation of the Learning Media

The learning media were developed using a Research and Development approach adapted from the stages proposed by Borg and Gall. The development process included preliminary planning, media design, expert validation, revision based on expert feedback, and testing involving 25 university students.

The validation instrument consisted of a questionnaire assessing the suitability of the content, clarity and appropriateness of language, organization of information, and overall visual presentation of the media. The assessment results were analyzed by calculating the feasibility percentage. According to Afriyadi et al. (2018), the feasibility of the developed learning media was calculated using the following equation:

$$\textbf{Feasibility percentage} = \frac{\text{Total score obtained}}{\text{Total possible score}} \times 100$$

Table 1. Feasibility criteria for the learning media

Feasibility Percentage	Feasibility Category
81–100%	Highly feasible
61–80%	Feasible
41–60%	Moderately feasible
21–40%	Not feasible
0–20%	Highly infeasible

RESULTS AND DISCUSSION

The examination revealed particles morphologically consistent with microplastics in the digestive tracts of all squid specimens obtained from a traditional market in Palu. The abundance and morphological types of the suspected microplastic particles detected in each specimen are presented in Table 2.

Table 2. Suspected microplastic particles detected in the digestive tracts of squid (*Loligo* sp.)

Sample	Length (cm)	Weight (kg)	Number of specimens	Fiber	Film	Fragment	Total particles
Loligo sp. 1	10.5	0.04	1	30	12	10	52
Loligo sp. 2	10.9	0.04	1	22	30	6	58
Loligo sp. 3	11.7	0.04	1	23	40	30	93
Loligo sp. 4	12.3	0.05	1	54	70	33	157
Loligo sp. 5	11.8	0.04	1	48	45	23	116
Loligo sp. 6	11.1	0.03	1	6	40	23	69
Loligo sp. 7	11.9	0.04	1	8	47	31	86
Loligo sp. 8	11.5	0.04	1	12	37	28	77
Loligo sp. 9	11.6	0.04	1	18	62	27	107
Loligo sp. 10	12.2	0.05	1	15	76	42	133
Total			10	236	459	253	948
Mean abundance							94.8 particles/individual

The total abundance and relative proportions of the three particle types are summarized in Table 3.

Table 3. Distribution of suspected microplastic particles according to morphological type

Particle type	Total number	Percentage (%)
Fiber	236	24.9
Fragment	253	26.7
Film	459	48.4
Total	948	100.0

Occurrence and Abundance of Suspected Microplastics

Particles classified as fibers, films, and fragments were detected in the digestive tracts of all 10 squid specimens. The total number of particles varied among individuals, ranging from 52 particles in Sample 1 to 157 particles in Sample 4. Overall, 948 particles were recorded, corresponding to a mean abundance of 94.8 particles per individual.

The detection of particles in all specimens indicates that the sampled squid had been exposed to anthropogenic particulate material before being marketed. However, because the specimens were obtained from a single market trader and their precise capture locations were not documented, these findings cannot be used to determine the contamination level of a specific marine area in Palu. Therefore, the results should be interpreted as preliminary evidence of suspected microplastic ingestion in market-sourced squid rather than direct evidence of pollution in a particular water body.

Particle identification was based on visual morphological characteristics observed using a binocular microscope. Films were identified as thin, irregular, sheet-like particles; fibers as elongated, thread-like particles; and fragments as relatively thick particles with irregular edges. Visual examination is commonly used as an initial microplastic-screening method, but it may result in the misclassification of natural fibers, organic residues, pigments, or other non-plastic materials as plastics, particularly when particles are small or weathered (Hidalgo-Ruz et al., 2012; Hermsen et al., 2018).

Because polymer composition was not confirmed using Fourier-transform infrared spectroscopy, Raman spectroscopy, or another chemical-identification technique, the detected particles are referred to throughout this study as “suspected microplastics.” This terminology follows recommendations that researchers explicitly distinguish visually suspected particles from chemically confirmed plastic particles (Hartmann et al., 2019).

The number of suspected microplastic particles differed considerably among specimens. Sample 4 contained the highest total abundance, comprising 54 fibers, 70 films, and 33 fragments, whereas Sample 1 contained the lowest abundance, comprising 30 fibers, 12 films, and 10 fragments. Variation among individual organisms may be influenced by differences in feeding history, prey selection, habitat use, gastrointestinal retention, exposure duration, and the ability to eliminate previously ingested particles (Yona et al., 2020).

Sample 4 was also one of the largest specimens examined. However, the present descriptive results do not provide sufficient evidence to conclude that specimen length or weight caused the higher particle abundance. Establishing such a relationship would require a larger sample size and an appropriate statistical analysis, such as correlation or regression analysis.

The detection of suspected plastic particles in squid is consistent with previous findings in cephalopods. Makrima et al. (2022) reported fibers, films, fragments, and pellets in the digestive tracts and tentacles of squid obtained from the Tambak Lorok fish-landing site. Plastic debris has also been reported in the stomach contents of the jumbo squid *Dosidicus gigas*, indicating that cephalopods can ingest plastic particles either directly from the surrounding environment or indirectly through contaminated prey (Rosas-Luis, 2016).

Nevertheless, numerical comparisons among studies must be made cautiously because reported particle abundances are influenced by differences in sample size, organism size, digestive tissue examined, digestion procedures, filter pore size, microscope resolution, contamination-control procedures, minimum particle-size thresholds, and the use or absence of spectroscopic confirmation (Hidalgo-Ruz et al., 2012; Hermsen et al., 2018). Thus, differences in recorded particle abundance do not necessarily represent actual differences in environmental contamination.

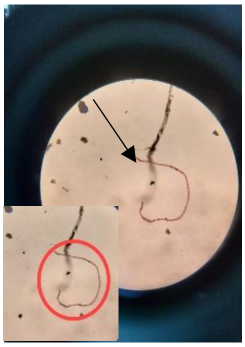
Distribution and Possible Origins of Particle Types

As shown in Table 3, film particles were the dominant morphological type, accounting for 459 particles or 48.4% of the total. Fragments represented 253 particles or 26.7%, whereas fibers accounted for 236 particles or 24.9%.

The predominance of films is consistent with the findings of Nurkhasanah and Nasution (2024), who reported film as the most frequently identified microplastic type in giant snakehead, *Channa micropeltes*, and silver rasbora, *Rasbora argyrotaenia*. Film particles are commonly associated with the degradation of thin plastic products, including disposable plastic bags, wrappers, and flexible food packaging. Under microscopic observation, films generally appear thin, flexible, asymmetrical, angular, and partly transparent (Claessens et al., 2011).

However, the origin of a particle cannot be determined solely from its morphological shape. Although the predominance of films may indicate exposure to degraded flexible plastic packaging, this interpretation remains tentative because the polymer composition and potential pollution sources in the squid capture areas were not investigated.

Suwartiningsih and Nafi'a (2023) suggested that film-like particles may resemble components of natural food, including planktonic organisms, thereby increasing the likelihood of accidental ingestion. Squid may encounter microplastics through direct ingestion of particles suspended in the water column or indirectly through the consumption of contaminated prey. Because environmental samples and prey remains were not examined in the present study, the dominant exposure pathway could not be determined.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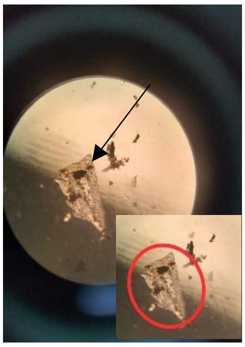
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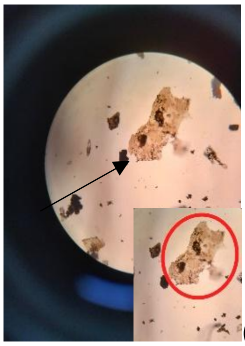
(c)

Figure 1. Particles suspected to be microplastics based on visual morphological characteristics observed using a binocular microscope at 10× magnification: (a) fiber, (b) film, and (c) fragment

Fragments were the second most abundant particle type, accounting for 26.7% of the total. These particles may originate from the physical degradation of relatively rigid plastic products, such as beverage bottles, detergent containers, rigid food containers, and other plastic packaging. Fragments generally differ from films because they are thicker, less flexible, and more irregular in shape. Their coloration may vary depending on the original material and the extent of environmental weathering (Gray et al., 2018).

The proposed sources of fragments remain presumptive because morphological observations alone cannot identify the original plastic product or polymer. Polymer characterization and comparison with potential environmental sources would be required to verify their origin.

Fibers represented 24.9% of all detected particles. Fibers may originate from synthetic textiles, fishing nets, ropes, fishing lines, and other plastic-based materials. Under microscopic observation, fibers typically appear as elongated, thread-like structures with relatively uniform thickness and may be transparent or colored (Hiwari et al., 2019).

Fiber abundance should be interpreted with particular caution because airborne textile fibers are a common source of contamination during sample preparation, filtration, and microscopic examination. Although aluminum foil, gloves, and masks were used to minimize contamination, the results of procedural or airborne blanks were not reported. The absence of blank-corrected data may have resulted in an overestimation of the number of fibers (Hermsen et al., 2018).

Future studies should therefore include procedural blanks, airborne-deposition controls, filtered reagents, non-synthetic laboratory clothing, and blank correction for each analytical batch. These quality-assurance procedures are essential for distinguishing particles originating from the samples from those introduced during laboratory processing (Hermsen et al., 2018).

Ecological and Food-Safety Implications

The occurrence of suspected microplastics in squid digestive tracts demonstrates that anthropogenic particles were biologically available to the sampled organisms. The types and quantities retained in the digestive tract may be influenced by the feeding behavior of the organism, habitat characteristics, particle properties, gastrointestinal retention time, and the ability to eliminate ingested particles (Yona et al., 2020).

Previous laboratory and field studies have associated microplastic exposure with reduced feeding, physical irritation, altered energy allocation, oxidative stress, and inflammatory responses in marine organisms. Microplastic surfaces may also carry plastic additives or environmental contaminants (Wright et al., 2013). However, none of these biological effects was measured in the present study. Therefore, the detection of particles in the digestive tract should not be interpreted as evidence that the sampled squid experienced physiological damage.

The presence of suspected microplastics in commercially sold squid is relevant to studies of plastic-particle transfer through marine food webs. Anthropogenic debris has previously been detected in fish and bivalves marketed for human consumption, demonstrating that seafood may represent one pathway of human exposure to plastic particles (Rochman et al., 2015).

Nevertheless, the current results cannot be directly converted into an estimate of human dietary exposure. Only the digestive tracts were examined, and the study did not determine whether particles had translocated into edible muscle or other tissues. Moreover, squid digestive organs are commonly removed during food preparation.

Consequently, the findings demonstrate ingestion by squid but do not establish the number of particles that would be consumed by humans.

Microplastic exposure through seafood has raised concerns regarding potential human-health effects. However, current evidence remains insufficient to establish the clinical consequences of typical dietary exposure. Available studies differ substantially in particle size, polymer type, concentration, and exposure conditions, while standardized methods for assessing human exposure and risk remain limited (Smith et al., 2018; Vethaak & Legler, 2021).

Therefore, no specific human-health risk can be inferred from the abundance values recorded in this study. Further research should examine chemically confirmed particles in edible tissues, realistic dietary exposure levels, and potential biological responses using standardized analytical procedures.

Educational-Poster Validation

The biological findings were used to develop an educational poster intended to communicate information about suspected microplastic contamination in squid digestive tracts to students and the wider community. The poster was evaluated by a content expert, a design expert, a media expert, and students. The evaluated components included content suitability, visual presentation, readability, organization, and clarity of communication. The validation results are presented in Table 4.

Table 4. Validation results for the educational poster

Validator	Percentage (%)	Feasibility category
Content expert	82.22	Highly feasible
Design expert	91.42	Highly feasible
Media expert	76.66	Feasible
Students	78.62	Feasible
Mean	82.23	Highly feasible

The educational poster obtained a mean validation score of 82.23%, placing it in the highly feasible category based on the criteria of Arikunto (2014). This result indicates that the poster was considered appropriate in terms of content, visual design, readability, and suitability as a supplementary biology learning resource. Expert validation is essential for identifying weaknesses in the content, language, presentation, and design of instructional media before classroom implementation (Afriyadi et al., 2018).

The design and content experts awarded scores of 91.42% and 82.22%, respectively, indicating that the poster presented the research findings accurately and used an appropriate visual structure. Clear integration of text and images can improve information processing and reduce unnecessary cognitive load (Mayer, 2008). In contrast, the media expert and students awarded lower scores of 76.66% and 78.62%, suggesting that aspects such as layout, color contrast, font size, and information density still required improvement. Placing related text and images close together may also improve comprehension (Schroeder & Cenkci, 2018).

Following revisions based on expert and student feedback, the poster met the feasibility criteria for use as a supplementary learning resource. However, the validation results indicate product feasibility rather than instructional effectiveness (Nieveen, 1999; Plomp & Nieveen, 2013). Further studies should therefore assess its effect on students' knowledge or environmental awareness using a pretest–posttest design.

CONCLUSION

This study identified 948 particles morphologically suspected to be microplastics in the digestive tracts of 10 squid (*Loligo* sp.) obtained from Lasowani Traditional Market, Palu City, corresponding to a mean abundance of 94.8 particles per individual. The particles were classified as fibers, films, and fragments, representing 24.9%, 48.4%, and 26.7% of the total particles, respectively. Films were the predominant particle type. Because the particles were identified solely on the basis of visual morphological characteristics without spectroscopic confirmation, these findings should be interpreted as evidence of suspected microplastic contamination. An educational poster developed from the research findings obtained an overall feasibility score of 82.23% based on evaluations by expert validators and students. This result indicates that the poster is highly feasible for use as a biology learning resource addressing microplastic pollution, although further research is required to evaluate its effectiveness in improving learning outcomes.

RECOMMENDATION

Future studies should expand the scope of the investigation by comparing or examining the relationship between microplastic contamination in squid and shrimp sold at traditional markets in Palu City. Such comparative research would provide a more comprehensive understanding of microplastic contamination in commercially important marine organisms.

ACKNOWLEDGMENT

The authors sincerely thank the academic supervisors, research team, and all individuals who contributed facilities, guidance, assistance, and encouragement throughout the study. The authors also acknowledge everyone involved in the successful completion of the research entitled “Analysis of Microplastics in the Digestive Tract of Squid (*Loligo* sp.) Sold at Traditional Markets in Palu City and Its Use as an Educational Medium,” which supported the preparation of this scientific article.

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