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(Review Article)

Bivalve Mollusks as Biological Monitoring of Microplastic: A Review of *Anadara antiquata* and *Gafrarium sp.* in Indonesia

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Abstract

Existence of plastic waste has continued an increase in the environment. Plastic breaks into particles in the size range of 1-5000 µm called microplastics. Small plastic particles accumulate in aquatic biota, one of which is bivalves. Bivalves are used as sentinel organisms and bioindicators of marine pollution, as they can accumulate microplastics carried by seawater. In this context, two filter-feeding bivalve species are *Gafrarium sp.* and *Anadara antiquata*. The abundance of microplastics in A. *antiquata* and *Gafrarium sp.* in Indonesian coastal waters indicates that almost all bivalve species are contaminated with microplastics. The types of microplastics frequently found in A. *antiquata* and *Gafrarium sp.* are fibers, fragments, films, and pellets. The smaller the average size of microplastics, the more they can enter the aquatic food chain. Thus, the presence of plastic pollutants in seafood consumed by humans can pose a food safety risk. If microplastic particles enter the body continuously and accumulate in certain amounts and reach the maximum limit the body can tolerate, it will cause poisoning, tissue damage, disruption of vital organs, and cause death.

Keyword: *Anadara antiquata*; Biomonitoring; *Gafrarium sp.*; Microplastic

1. Introduction

Plastic waste remains a serious problem worldwide, due to its ever-increasing volume and its very slow degradation in the environment [1]. Global plastic production in 2020 reached approximately 367 million metric tons, with 4.8–12.7 million metric tons of plastic being dumped into the ocean every day, and this figure continues to rise [2]. The entry of plastic waste into marine environments is primarily due to poorly managed final disposal sites in coastal areas, as well as activities related to fishing and tourism [3][4]. Plastic waste in aquatic environments can degrade into small particles known as microplastics (MPs) [5].

Based on their sources, microplastics are categorized into two groups: primary and secondary MPs [6]. Primary microplastics are intentionally manufactured at microscopic sizes, such as microbeads found in skincare products, which enter water systems through drainage. Furthermore, these primary MPs can easily escape industrial wastewater treatment processes, eventually entering marine environments [7]. In contrast, secondary microplastics are fragments, pieces, or degradation products resulting from the breakdown of larger plastic waste into smaller particles [8]. This degradation is caused by exposure to high-intensity UV radiation and mechanical abrasion through physical, chemical, and biological processes [9]. Microplastic particles typically range in size from 1 µm to 5000 µm, formed through such degradation processes [10][11].

Microplastics can be found in water, sediments, and even in the air. They tend to accumulate in marine environments, particularly within sediment layers. Indirectly, the abundance and microscopic size of microplastics in the ocean make

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them ubiquitous and highly bioavailable to aquatic organisms, leading to their potential ingestion by marine biota [12][13]. Microplastics occur in various types, differing in size, shape, color, composition, density, and other physical characteristics [14]. Based on their shapes, MPs can be classified into five categories: fibers, fragments, films, pellets, and foams [15]. Morphological characteristics of microplastics can also serve as indicators of their origin [16].

These ingested plastic particles can cause physical damage and obstruct the digestive systems of organisms. Once ingested, microplastics may either remain in the gastrointestinal tract and be excreted via defecation, or be transferred across the intestinal epithelium into bodily tissues (translocation) [10]. Therefore, monitoring (biomonitoring) of MPs in coastal marine waters using organisms is necessary to assess environmental conditions in marine areas.

2. Bivalves as microplastic monitoring

Bivalves, as part of the macrozoobenthic community inhabiting coastal regions and contributing to Indonesia's biodiversity, are commonly employed as sentinel organisms in aquatic environmental biomonitoring. This is due to their sessile lifestyle, wide distribution, and high tolerance to pollutants [17]. There are over 7,500 known bivalve species across tropical, temperate, and polar ecosystems [18]. The sensitivity of bivalves to environmental changes is a key factor supporting their broad adaptability [19]. Consequently, bivalves are used as sentinel organisms and bioindicators of marine pollution, as they can accumulate microplastics carried by seawater [20].

Bivalves feed either as filter feeders or deposit feeders, using their gills. Their diet includes phytoplankton, bacteria, detritus, and zooplankton. They open their shells to allow large volumes of water to enter. The gills then filter the water through ciliary movement, capturing food particles and microplastics that adhere to mucus on the gills [18][21]. As filter feeders, bivalves can accumulate pollutants such as heavy metals in contaminated waters, which poses risks to human consumption and simultaneously highlights their suitability as bioindicators [22][23]. Their ability to accumulate microplastics also supports their potential role as microplastic bioindicators. This potential is reinforced by factors such as their wide distribution, pollutant tolerance, and sessile nature, which makes them easy to sample [24].

This is further supported by a study by Qu et al., which found a positive correlation between microplastic levels in water samples and in bivalves, with bivalves tending to ingest smaller microplastics than those present in the water [25]. Additionally, Gerhardt and D'costa et al. noted that bivalves live in close contact with sediments and feed by filtering suspended organic materials from the water, allowing microplastic pollutants in water or sediment to enter their bodies [26][27]. In this context, two filter-feeding bivalve species and widely distributed in Indonesian waters is *Gafrarium sp*. and *Anadara antiquata*.

Gafrarium sp. belongs to the family Veneridae, while *A. antiquata* is part of the family Arcidae. Both species are typically found in habitats with sandy or sandy-mud substrates. These substrates are rich in organic matter, making them suitable habitats for both species [28]. *Gafrarium sp*. and *A. antiquata* demonstrate potential as sentinel organisms for microplastic biomonitoring in marine environments. *Gafrarium* clams typically burrow into fine or muddy sand, although their entire bodies do not completely enter the substrate due to their short siphons. *Gafrarium sp*. resides in a vertical position, with its posterior often protruding above the sand surface, which is associated with its feeding behavior as a filter feeder [29]. The maximum shell length is 4.8 cm, but generally has a shell length of up to 3.5 cm [30]. This species plays an important ecological role in coastal ecosystems, serving as a bioindicator of water quality and contributing to ecosystem services. Its effectiveness as a filter feeder enables it to capture small particles, including microplastics, from the water. This was evidenced in a study by Lam et al., which found that *Gafrarium sp*. in Hong Kong accumulated microplastic contaminants in its body at levels of 0.79 ± 0.90 particles per individual [31].

On the other hand, *A. antiquata* is bivalve species from the family Arcidae. This clam burrows into sandy or muddy substrates and uses a structure called a siphon, which has separate channels for water intake and expulsion [32]. Known as the cockle, this benthic species fulfills its nutritional needs by filtering water from its surroundings using its siphon [33]. It is commonly found in muddy-bottomed substrates, in both intertidal and sublittoral zones, at depths of up to 25 meters. The shell length can grow up to 10.5 cm, although most individuals have shells around 7 cm in length [30]. This species has potential as a biological monitor for microplastics in marine waters due to its ability as a filter feeder. This was demonstrated in research by Mayoma et al., which showed that A. *antiquata* found in the Mtoni Kijichi River on the Tanzanian coast reported an average of 2.1±1.8 microplastic particles per individual [34].

3. Microplastic accumulation in *Anadara antiquata* and *Gafrarium sp.*

Microplastic consumption in *A. antiquata* and *Gafrarium sp*. collected from several coastal waters in Indonesia shows differences in the abundance and types of microplastics found in them. The abundance of microplastics in *A. antiquata* found in the coastal waters of Lamongan was 0.5 ± 0.37 items/g, while at Ujung Gersik Beach, Belitung Regency, it was 0.81–1.94 particles per individual. Additionally, the abundance of microplastics in *Gafrarium sp*. found in coastal waters of Lamongan was 3.2 ± 2.52 items/g, while at Pari Island, Seribu Islands, Jakarta, it was 9.1 items/g (Table 1).

Table 1 Comparison of microplastics contamination reported by other studies

Species	Location	Abundance of microplastics	Type of microplastics	References
A. antiquata	Coastal waters of Lamongan	0.5 ± 0.37 items/g	Fiber (92.31%), film (7.69%)	[35]
	Ujung Gersik Beach, Belitung Regency	0.81-1.94 particle per individual	Fiber (1.42 particle per individual), fragmen & film (0.43 particle per individual)	[36]
Gafrarium sp.	Coastal waters of Lamongan	3.2 ± 2.52 items/g	Fiber (74.28%), fragment (22.86%), pellet (2.85%)	[35]
	Pari Island, Seribu Islands, Jakarta	9.1 items/g	Fragment (66.91%), fiber (33.09%)	[37]

Table 1 above shows differences in microplastic abundance between *A. antiquata* and *Gafrarium sp*., which may be related to differences in pollution sources around those locations. Additionally, shellfish habitats belong to a group of marine organisms with slow movement and a sedentary lifestyle (in sediments or on the seabed), leading to more intensive bioaccumulation and bioconcentration [38]. Shellfish obtain food by filtering water (filter feeders), making them prone to pollution accumulation, which makes them an excellent indicator for monitoring environmental pollution.

The types of microplastics commonly found in *A. antiquata* and *Gafrarium sp*. are fibers, fragments, films, and pellets (Table 1). Fiber-type microplastics originate from boat ropes, fishing activities, and coastal communities, which undergo degradation into very small plastic particles in the water. As is known, coastal communities have a high potential for generating plastic waste, particularly plastic bags and food or beverage packaging made of plastic [39]. Fragments, on the other hand, have irregular shapes with a thick texture and can originate from thick plastic items such as bottles, plastic bags, and PVC pipe pieces that later break down into smaller sizes [40]. Film-type plastic is thin and transparent, resulting from the degradation of thin plastic waste like plastic bags, so this type has low density [36]. Pellet-type plastic is small in size because this type of microplastic typically originates from primary sources. Primary sources include scrubs used for bathing, which are already small in size (micrometers to millimeters) from the start, so when they fragment further, they become even smaller pieces [41]. Therefore, microplastic contamination in bivalves can reflect pollution in their habitat [42].

Microplastics in water pose a significant threat to marine organisms, particularly bivalves [43]. Bioaccumulation of microplastics in water can have impacts on the health of biota, including hormonal disruption, changes in feeding behavior, and potential mortality. The distribution of microplastics in water is highly dependent on polymer density and physical-chemical factors of the water, such as currents, wind, and tides. Particle density is a highly influential factor in the distribution of microplastics. Microplastics with lower density are more easily distributed by currents. Polymer types with lower density tend to occupy the water surface and environment [36].

Microplastics of very small size result in their ubiquitous nature and high bioavailability for aquatic organisms [44]. As a result, microplastics can be ingested by marine life such as fish and bivalves, allowing these pollutants to enter the aquatic food chain. Thus, the presence of these plastic pollutants in seafood consumed by humans can pose a food safety risk [45]. If microplastic particles continuously enter the body and accumulate to a certain amount, reaching the maximum limit the body can tolerate, it can cause poisoning, tissue damage, organ dysfunction, and death [46].

4. Conclusion

Microplastic consumption in *A.antiquata* and *Gafrarium sp.* in Indonesian coastal waters is widespread because almost all bivalve species are contaminated with microplastics. In this context, the most common types of microplastics consumed by mollusks are fibers, fragments, films, and particles. Therefore, this review provides additional evidence that microplastic contamination impacts marine organisms and has the potential to bioaccumulate to higher trophic levels through the food chain. If microplastic particles continue to enter the human body and accumulate beyond the body's tolerance threshold, microplastics can cause poisoning, tissue damage, organ dysfunction, and even death. Therefore, policies and regulations need to be implemented to reduce the release of synthetic fibers into the marine environment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclsoed.

References

[1] Aulia A, Azizah R, Sulistyorini L, Rizaldi M.A. Literature Review: The Impact of Microplastics on Coastal Environments, Marine Biota, and Potential Health Risks. Jurnal Kesehatan Lingkungan Indonesia. 2023; 22(3):328-341.

[2] Gola D, Kumar TP, Arya A, Chauhan N, Agarwal M, Singh SK, Gola S. The impact of microplastics on marine environment: A review. In Environmental Nanotechnology, Monitoring and Management. Elsevier B.V. 2021; 16.

[3] Wahyudin GD, Afriansyah A. Combating Marine Plastic Pollution Based on International Law. Jurnal IUS Kajian Hukum dan Keadilan. 2020;8(3):530-550.

[4] Nazriati, Utomo Y, Fajaroh F, Suharti, Danar, Ciptawati E. Balekambang Beach Clean-Up Movement from Plastic Waste. Jurnal Pengabdian Masyarkat Universitas Merdeka Malang. 2020;5(2):139-144.

[5] Rahim NF, Yaqin K, Rukminasari N. Effect of microplastic on green mussel Perna viridis: experimental approach. Jurnal Ilmu Kelautan. 2020;5(2):8.

[6] Zhang C, Wang S, Sun D, Pan Z, Zhou A, Xie S, Wang J, Zou J. Microplastic pollution in surface water from east coastal areas of Guangdong, South China and preliminary study on microplastics biomonitoring using two marine fish. Chemosphere. 2020; 256:127202.

[7] Wang W, Wang J. Investigation of microplastics in aquatic environments: An overview of the methods used, from field sampling to laboratory analysis. In TrAC-Trends in Analytical Chemistry. Elsevier B.V. 2018; 108:195-202.

[8] Hiwari H, Purba NP, Ihsan YN, Yuliadi LPS, Mulyani PG. Condition of Microplastic Garbage in Sea Surface Water at Around Kupang and Rote, East Nusa Tenggara Province. Pros Sem Nas Masy Biodiv Indonesia. 2019;5(2):165–171.

[9] Wright SL, Kelly FJ. Plastic and human health: A micro issue? Environmental Science and Technology. 2017;51(2):6634-6647.

[10] Browne MA, Dissanayake A, Galloway TS., Lowe DM, Thompson RC. Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus edulis (L.). Environmental Science & Technology. 2008;42(13):5026–5031.

[11] Kim YN, Yoon JH, Kim KH. Microplastic contamination in soil environment - A review. In Soil Science Annual. Soil Science Society of Poland. 2020;71(4):300-308.

[12] Melindo HL, Riani E, Sinambela MWC. Microplastics in Sand Sea Cucumber (Holothuria scabra) Cultivation: A Case Study of Pasaran Island, Bandar Lampung. Coastal and Ocean Journal. 2022;6(2):73-80.

[13] Boucher J, Friot D. Primary Microplastics in the Oceans: A Global Evaluation of Sources. IUCN. 2017.

[14] Mauludy MS, Yunanto A, Yona D. Microplastic Abundances in the Sediment of Coastal Beaches in Badung, Bali. Jurnal Perikanan Universitas Gadjah Mada. 2019;21(2):73–78.

[15] Lusher AL, Welden NA, Sobral P, Cole M. Sampling, isolating, and indetigying microplastics ingested by fish and invertebrates. Analytical Methods. 2017;9(9):1346-1360.

[16] Wu C, Zhang K, Xiong X. Microplastic Pollution in Inland Waters Focusing on Asia In Freshwater Microplastics. Springer International Publishing AG.2018.

[17] Lionetto MG, Caricato R, Giordano ME. Pollution Biomarkers in Environmental and Human Biomonitoring, The Open Biomarkers Journal. 2019; 9:1-9.

[18] Arapov J, Balic DE, Peharda M, Gladan NZ. Bivalve Feeding - How and What They Eat? Ribarstvo. 2010;68 (3):105-116.

[19] Wahyuni I, Sari IJ, Ekanara B. Mollusc Biodiversity (Gastropoda and Bivalves) as a Bioindicator of Water Quality in the Coastal Area of Tunda Island, Banten. Biodidaktika. 2017;12.

[20] OSPAR. OSPAR request on Development of a Common Monitoring Protocol for Plastic Particles in Fish Stomachs and Selected Shellfish on the Basis of Existing Fish Disease Surveys. In ICES Advice. Book 1, 2015.

[21] Giribet G. Bivalvia. In W. F. Ponder & D. R. Lindberg, ed. Phylogeny and Evolution of the Mollusca. Berkeley. Berkeley: University of California Press, pp. 105-141, 2008.

[22] WWF-Indonesia. Better Management Practices- Shellfish Fisheries: A Guide to Catching and Handling. Jakarta: WWF-Indonesia, 2015.

[23] Purbonegoro T. The Potential of Bivalves as Bioindicators of Metal Pollution in Coastal Areas. Oseana. 2018;43(3):61-71.

[24] Beyer J, Green NW, Brooks' S, Allan IJ, Ruus A, Gomes T, Schøyen M. Blue mussels (Mytilus edulis spp.) as sentinel organisms in coastal pollution monitoring: A review. Marine Environmental Research. 2017; 130:338 365.

[25] Qu X, Su L, Li H, Liang M, Shi H. Assessing the relationship between the abundance and properties of microplastics in water and in mussels. Science of the Total Environment. 2018; 621:679-686.

[26] Gerhardt A. Bioindicator species and their use in bio-monitoring. In: Environmental Monitoring. Vol. 1 (In-yang HI, Daniels JL, eds). Encyclopedia of Life Support Systems (EOLSS), Oxford. 2002.

[27] D'costa AH, Shyama SK, Praveen KMK, Furtado S. The Backwater Clam (Meretrix casta) as a bioindicator species for monitoring the pollution of an estuarine environment by genotoxic agents. Mutation Research: Genetic Toxicology and Environmental Mutagenesis. 2018; 825:8–14.

[28] Atlanta V, Ambarwati R, Rahayu DA, Mujiono N. Diversity of bivalves on the north coast of Lamongan, East Java, Indonesia. Biodiversitas Journal of Biological Diversity. 2022;23(8):4263-4271.

[29] Akhrianti I, Dietriech GB, Isdradjad S. Spatial Distribution and Habitat Preferences of Bivalves in the Coastal Waters of Simpang Pesak District, East Belitung Regency. Jurnal Ilmu dan Teknologi Kelautan Tropis. 2014;6(1):171-185.

[30] Poutiers JM. Bivalves (Acephala, Lamellibranchia, Pelecypoda). In: Carpenter K.E. & V.H. Niem (eds). FAO Spesies Identification Guide for Fishery Purposes; The Living Marine Resources of The Western Central Pacific. Volume 1. Rome: FAO. 1998.

[31] Lam TWL, Tsui YCJ, Cheng YL, Ma ATH, Fok L. Microplastic contamination in edible clams from popular recreational clam-digging sites in Hong Kong and implications for human health. Science of the Total Environment. 2023;875.

[32] Arwin B, Oetama D. Growth Patterns and Condition Factors of Feather Clams (*Anadara antiquata*) in Bungkutoko Waters, Kendari City. Jurnal Manajemen Sumber Daya Perairan. 2016;2(1):89-100.

[33] Silaban R, Silubun DT, Jamlean AAR. Ecological Aspects and Growth of Feather Clams (*Anadara antiquata*) in Letman Waters, Southeast Maluku Regency. Jurnal Kelautan. 2021;14(2):120-131.

[34] Mayoma BS, Sørensen C, Shashoua Y, Khan FR. Microplastics in beach sediments and cockles (*Anadara antiquata*) along the Tanzanian coastline. Bulletin of Environmental Contamination and Toxicology. 2020; 105:513-521.

[35] Asadi MA, Iranawati F, Nafidya F, Supriyadi S, Talukder A. Microplastics in Wild Clams Harvested from Coastal Waters of Lamongan, Indonesia. Journal Eng. Technol. Sci. 2022;54(5):936-950.

[36] Pratiwi N, Pratiwi FD, Kurniawan A. Analysis of Microplastic Content in Water, Sediment, and Feather Clams (*Anadara antiquata*) at Ujung Gersik Beach, Belitung Regency. Jurnal Laut Khatulistiwa. 2025;8(1).

[37] Tubagus W, Sunarto, Ismail MR, Yuliadi LPS. Identification of Microplastic Composition on Clams (Gafrarium tumidum) and Sediments in Pari Island, Seribu Islands, Jakarta. Indonesian Journal of Marine Science. 2020;25(3):115-120.

[38] GESAMP. Sources, Fate and Effects of Microplastics In The Marine Environment: Part 2 Of A Global Assessment Science For Sustainable Oceans (j Peter, Kershaw, & Chelsea M. Rochman, Eds.). International Martitime Organization. 2010.

[39] Tuhumury N, Ritonga A. Identification of existance and type of microplastics in cockle at Tanjung Tiram Waters, Ambon Bay (in Bahasa). TRITON: Jurnal Manajemen Sumberdaya Perairan. 2020;16(1):1–7.

[40] Ayuningtyas WC, Yona D, Julinda SHS, Irnawati F. Abundance of Microplastics in the Waters of Banyu Urip, Gresik, East Java. Journal of Fisheries and Marine Research. 2019;3(1):41–45.

[41] Makrima DB, Suprijanto J, Yulianto B. Microplastics in Tentacles and Digestion of Squid from TPI Tambak Lorok. Journal of Marine Research. 2022;11(3):467–474.

[42] Hossain MS, Sobhan F, Uddin MN, Sharifuzzaman SM, Chowdhury SR, Sarker S, Chowdhury MSN. Microplastics in Fishes from the Northern Bay of Bengal. Science of the Total Environment. 2019;690:821–830.

[43] Mattsson K, Jovic S, Doverbratt I, Hansson LA. Nanoplastics in the aquatic environment in Book Microplastic Contamination in Aquatic Environments. 2018;379-399.

[44] Lie S, Suyoko A, Effendi AR, Ahmada B, Aditya HW, Sallima IR, Arisudewi NPAN, Hadid NI, Rahmasari N, Reza A. Measurement of microplastic density in the Karimunjawa National Park, Central Java, Indonesia. Indo Pacific Journal of Ocean Life. 2018;2(2):54-58.

[45] Supusepa J, Hulopi M, Sahetapy JM, Kalay DA. Introduction to mollusk resources and seagrass ecosystems as well as introduction to microplastics and their impact on the coastal environment for students of SDN Negeri Lama, Teluk Baguala District, Ambon City. BALOBE: Jurnal Pengabdian Masyarakat. 2022:1(1):27-37.

[46] Wang Z, Qin Y, Li W, Yang W, Meng Q, Yang J. Microplastic Contamination in Freshwater: First Observation in Lake Ulansuhai, Yellow River Basin, China. Environmental Chemistry Letters. 2019;17(4):1821–1830.