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Microplastic accumulation and reduction in shellfish (*Polymesoda bengalensis*) using NaCl solution

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Abstract: This study investigates microplastic (MP) contamination in shellfish (*Polymesoda bengalensis*) and evaluates the effectiveness of NaCl treatment in reducing MP levels in consumed shellfish. Samples were collected from three estuaries in West Sumatra, Indonesia: Batang Arau, Bungo Pasang and North Punggasan. The samples were analyzed using trinocular microscopy and attenuated total reflectance-Fourier transform infrared (ATR-FTIR) to quantify MP abundance and identify polymer types. MP concentrations ranged between 750–1000 particles/kg in shellfish and 400–500 particles/kg in sediments, with Batang Arau exhibiting the highest levels. The predominant MP forms detected were fragments (82.36 %), films (13.72 %) and fibers (3.92 %), with sizes primarily between 100–300 μm. The primary polymers identified included polyvinyl chloride (PVC), polyamide (PA) and polyethylene terephthalate (PET). A series of treatments using NaCl solutions at varying concentrations (10, 20 and 30 %) and immersion durations (10, 20 and 30 min) demonstrated that a 30 % NaCl solution for 30 min effectively reduced MP levels by 85 %, decreasing MP concentration in shellfish flesh to 150 particles/kg. These findings highlight the potential of NaCl treatment as a cost-effective method for reducing MP contamination in shellfish, contributing to improved seafood safety and providing insights into MP pollution management in aquatic ecosystems.

Keywords: bioindicators; microplastics; salt solutions; shellfish; types of polymers.

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INTRODUCTION

Plastic is a synthetic organic polymer often used because it is light, cheap and versatile, for example, in food packaging, medical devices, medicines and construction tools. The resulting plastic waste is a problem that attracts public attention because of its slow decomposition rate. In Indonesia, plastic waste is estimated to reach 187.2 Mt/year.[1] Plastics are composed of long-chain molecules called macromolecules. Plastic cannot decompose quickly because of its long chain of constituents. Plastic particles come in various sizes, including microplastic (MP). MPs are particles less than 5 mm in size. This MP can be formed from large plastic tears caused by biota bites and degradation due to sunlight.[2,3]

MPs are divided into two based on their origin, namely primary MP and secondary MP. Primary MP refer to MP that are intentionally produced in microscopic sizes, while secondary MP are MP that are formed through fragmentation of large plastics.[4] MPs can spread into aquatic environments, including rivers, lakes, seas, air and soil. They are an environmental problem because of their ability to absorb chemical pollutants and because they can enter the food chain, from small organisms to humans. MPs float and accumulate in sediments, allowing these particles to be accidentally ingested by marine organisms. Shellfish, as filter feeder organisms, have a way of eating by filtering plankton so that microplastic particles that float and settle in the sediment will accumulate in the shellfish's body through the activity of filtering these particles while eating.[5–7]

Shellfishes are mollusks that are sessile, filter feeders and more tolerant of changes in environmental conditions.[8,9] These filter-feeder organisms can be used as monitoring agents (bio-monitoring) of the aquatic environment because they settle at the bottom of the water and are directly exposed to contaminants. These properties support environmental monitoring, so shellfish are widely used as indicators of microplastic pollution.[10] Several previous studies have been conducted to identify MP in mussels in various waters, including 22 mussels in coastal China. The average abundance of MP obtained was 2200 particles/kg. Then shellfish in UK waters. The abundance of MP obtained ranged from 700––2900 particles/kg of shellfish.[11] Furthermore, for 25 mussels in China Beach, the MP abundance obtained ranged from 1520–5360 particles/kg of mussels[12] and research on 4 species of mussels in China, the MP abundance obtained ranged from 300–201000 particles/kg.[13] Later, MP studied mussels and sediments in Batang Arau, Bungo Pasang and Padang Sarai River Estuary, West Sumatra, Indonesia.

Humans widely consume shellfish because they have high economic value and are very good for consumption.[11] However, their vulnerability to the uptake of pollutants allows MP to enter the food chain and accumulate at higher trophic levels, becoming a concern for marine predators and human health.[14] Therefore, a strategy is needed to reduce MP pollutants in shellfish by using NaCl salt solutions.

NaCl salt is thought to reduce MP in shellfish by exploiting the difference in density between the plastic particles and the NaCl salt solution. Interaction with the NaCl salt solution causes low-density pollutants to rise to the surface of the NaCl salt solution. NaCl can attract particles along with water and then float them to the surface if the density of the particles is lower than NaCl. Previous research on using NaCl salt to reduce MP abundance in blood clams (*Tegillarca granosa*) has also been reported.[15] Based on the explanation above, research was conducted to analyze the abundance of MP in shellfish and sediment from three different locations in the waters of West Sumatra, Indonesia and study the effect of variations in the concentration of NaCl salt solution and optimal soaking time to reduce the abundance of MP in consumed shellfish. by society. MP identification begins[16] with MP separation to obtain MP particles. Next, visual identification (size and shape) and abundance of MP were carried out using a microscope and continued with a characterization of the MP functional group types using ATR--FTIR.

EXPERIMENTAL

Materials

The materials used were doubly distilled water, which served as a purified solvent to prevent contamination during sample preparation and microplastic (MP) extraction. 30 % H_2O_2 was utilized to oxidize and break down organic matter in samples, ensuring that only MPs remained for analysis. 25 % NaCl and table salt solution with zero or minimum MP were employed for density separation, exploiting the difference in density between MPs and the saline solution to facilitate particle flotation and isolation. Whatman filter paper no. 42 was selected for its fine pore size, enabling effective filtration of MPs without losing smaller particles. Shellfish samples were the primary subject of study for MP bioaccumulation, while sediment samples served to assess environmental MP load and its correlation to bioaccumulation in shellfish. Aluminum foil was used to cover samples during heating or storage, preventing airborne contamination.

Instruments

The instruments used were a food processor, which ground shellfish meat into smaller particles to enhance the efficiency of MP extraction. A cooler box maintained the integrity of samples during field collection and transport, preserving their original state before analysis. Plastic ziplock bags were used for secure sample storage to avoid any cross-contamination. A camera (Realme 6) documented each stage of the study, providing visual records for sample collection and laboratory procedures. A scalpel carefully opened shellfish shells, preserving the internal tissue for analysis. A metal shovel collected sediment samples, ensuring consistency in sample depth and area. A 5 mm filter was used to sieve and homogenize sediment samples. Various glassware was employed for handling, storing and processing samples. An oven (Memmert, Schwabach, Germany) dried sediment and activated reagents at consistent temperatures. A vacuum pump facilitated efficient sample filtration and an analytical balance provided precise measurements of sample weight. ATR-FTIR (Perkin Elmer, Waltham, MA, USA) identified polymer types of MPs based on spectral characteristics and a trinocular mic-

roscope (Optika B-350, Bergamo, Italy) enabled the visual identification of MP shapes and sizes, critical to characterizing particle morphology.

Sample preparation

Shellfish samples were frozen in a freezer at –20 °C for two days. After freezing, the shell is opened using surgical tools.[11] Sediment samples were homogenized with the help of a 5 mm mess filter. Wet sediment (100 g) was weighed using an analytical balance and dried in an oven for two days at a temperature of 65 °C.

Sample separation

20 g of dried shellfish meat was weighed and ground using a food processor, then added with 30 % H_2O_2 solution, 300 mL each. The sample was homogenized, heated for 24 h at 65 °C and then covered with aluminum foil. Next, the solution was heated and left at room temperature in the oven for 24 h. 200 mL of NaCl solution (250 g L^{-1}) was added to the sample, homogenized using a magnetic stirrer and left for 24 h.[17] The solution was then filtered through the supernatant using Whatman No. 42 filter paper with the help of a vacuum pump. MP filtered on Whatman paper are then identified visually (shape and size) with a microscope and then calculated in abundance and type of polymer using FTIR.

The dry sediment sample was weighed as much as 20 g and put into a beaker. 300 mL of 30 % H_2O_2 solution was added and the solution was heated at 65 °C for 24 h using an oven. Then 200 mL of NaCl was added and homogenized using a magnetic stirrer, covered with aluminum and left for 24 h. Next, it was filtered using Whatman filter paper No. 42. MP that have been filtered on Whatman paper are then identified visually (shape and size) using a microscope and then the abundance and type of polymer are calculated using FTIR.[17-21]

Soaking in NaCl salt solution

Soaking in a salt solution utilizes the density of NaCl and MP and the flow rate of salt water through the meat's pores to separate the MP from the shellfish meat. A total of 20 g of shellfish meat that had been frozen was slowly put into a 250 mL beaker and weighed. Then, it is put in solutions with various concentrations (0, 10, 20 and 30 %). The soaking time was varied (10, 20 and 30 min). Particles with a lighter density, for example, MP, will float to the surface of the solution. Then, the shellfish meat is separated from the solution and ground using a food processor.[22]

Shellfish meat (20 g) was weighed and ground using a food processor and then 300 mL of 30 % H_2O_2 solution was added. The sample was homogenized, heated for 24 h at 65 °C and then covered with aluminum foil. After heating, the solution was left at room temperature for 24 h. 200 mL of NaCl solution (250 g L^{-1}) was added to the sample, homogenized using a magnetic stirrer and left for 24 h.[17] The solution was then filtered through the supernatant using Whatman filter paper No. 42 with the help of a vacuum pump. MP filtered on Whatman paper are then identified visually (shape and size) using a microscope and then the abundance and type of polymer are calculated using FTIR.

Microplastic identification

Visual identification, such as shape and size, was done using a B-350 Optika trinocular microscope with 100× magnification. Next, the MP abundance in shellfish and sediment was calculated using the formula.[23-25] Identification of MP polymer types using ATR-FTIR:

$$K = \frac{n}{m} \tag{1}$$

where *K*= MP abundance (particles/kg), *n* = number of MP (particles) and *m* = dry weight of sample (kg).

Experimental design

The experimental design was a completely randomized (factorial CRD) design. The factors used consist of two factors, namely NaCl concentration (%) and soaking time (min). There are three levels of NaCl concentration, namely 10, 20 and 30 %. There are three soaking times, namely 10, 20 and 30 min. Data on the effect of the two factors and interactions between factors on the abundance of shellfish MP were analyzed using analysis of variance (ANOVA) and a Duncan test was carried out to analyze the differences. This analysis used a significance level of 0.05 with SPSS v26 software.

RESULTS AND DISCUSSION

Microplastic abundance

The identification of MP abundance in shellfish and sediment from the Batang Anai River Estuary, Bungo Pasang River Estuary and North Punggasan River Estuary, West Sumatra, Indonesia, can be seen in Fig. 1. The average MP abundance detected in shellfish ranged between 750±41 and 1000±71 particles/ /kg, whereas in sediment, it ranged between 400±108 and 500±82 particles/kg.

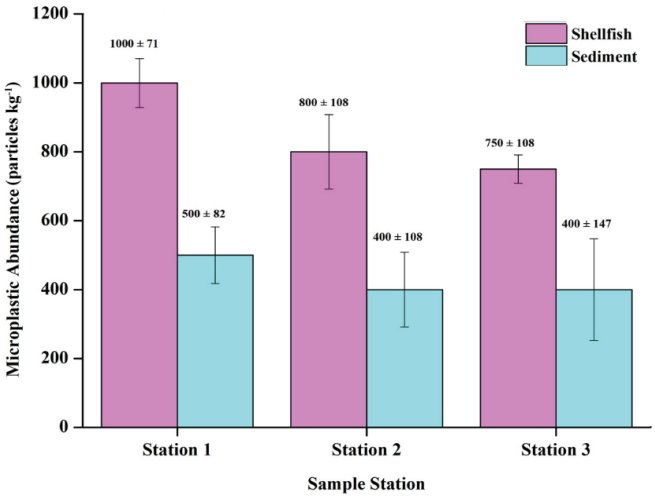

Fig. 1. Microplastic abundance (particles/kg) in shellfish and sediment samples (n=3).

In Fig. 1, it can be seen that the highest abundance of MP particles was found in shellfish samples (1000±71 particles/kg) and sediment (500±82 particles/kg) from station 1 (Batang Arau River Estuary). This is because the Batang Arau River Estuary is a tourist area busy with visitors, a densely populated residential area and a sea transportation area (such as fishing activities and ports) and the sampling location is close to the Fish Auction Place (FCP).

Generally, the higher the MP abundance in sediment, the higher the MP abundance in shellfish. The reduced abundance of MP in both sediment and shellfish at stations 2 and 3 is thought to be due to reduced disposal of plastic waste originating from household waste, fewer tourist visits and distance from sea transportation.[26,27]

Shellfish and sediments have a close relationship in marine geology and ecology. Shellfish are mollusks that generally live in sea waters. Conversely, sediment is small particles of rocks, minerals, dead organisms and other organic materials deposited on the bottom of water. Shellfish often play an important role in sediment formation and can influence the composition and structure of the sediments around them. Mussels and sediments have a close relationship that involves processes such as: 1) some types of shellfish, especially those with calcium carbonate shells, can contribute significantly to the formation of limestone; 2) shellfish generally live on the seabed or the substrate. During their lives, they can collect sediment from their surroundings. Some types of shellfish, such as oyster shells, use their gill organs to filter food particles from the water, resulting in sedimentation of surrounding particles; 3) several shellfish live with sediment on the seabed. Mussels may hide in sediment to protect themselves from predators or search for food; 4) shellfish are often an important part of marine ecosystems. They can interact with other organisms, including organisms that live in or around sediments, such as microorganisms, snails and macroalgae; 5) sediment pollution by chemicals or waste can harm the health of shellfish and sediment ecosystems; 6) several types of shellfish can be used as environmental indicators to evaluate water and sediment quality. They can show whether the environment is clean or polluted.[28]

Microplastic shape

The MP shape at three stations, both in shellfish and sediments, is dominated by fragments in the order fragment > film > fiber (Fig. 2). In this study, fragments dominated all sampling stations in shellfish and sediments because many macro plastics, such as plastic bottles, containers and other plastic packaging, can experience physical degradation due to exposure to UV light, temperature changes and friction. This decomposition process turns plastic into smaller fragments. Microplastics themselves can become smaller fragments due to environmental degradation processes. Exposure to UV light, oxidation and mechanical forces can cause MP to break down into smaller fragments. Abrasion is rubbing or scratching plastic on other objects, such as rocks, sand and other surfaces. In this process, small pieces can be separated from the plastic surface and become MP fragments.[19,29] Some plastic products, especially those susceptible to wear and tear and repeated use, may develop fragments during use. For example, car tires, brake pads and other plastic products can produce MP fragments due to friction and wear.

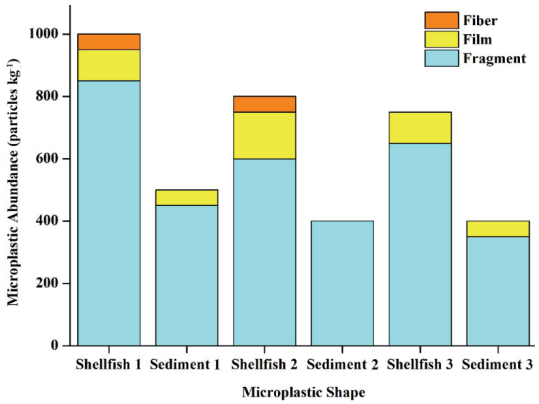

Fig. 2. Abundance of microplastic shapes in shellfish and sediment samples.

MPs in fragments are found more in shellfish than sediments for several reasons, including: 1) MPs often degrade into very small fragments, less than 5 mm. These particles are more likely to accumulate in shellfish tissue because they are similar in size to natural food particles that filter-feeding organisms, such as mussels, can filter; 2) shellfish are filter-feeder animals that eat plankton and small particles from the water. This filtering process makes shellfish susceptible to capturing MP in the water, including small fragments; 3) MPs can be widely distributed in the marine environment and reach various habitats, including seawater and sediment. However, shellfish often reside in shallow areas with higher MP concentrations; 4) shellfish often contact marine sediments while searching for food and burrowing on the sea floor. MP fragments can interact with sediments and shellfish that feed on sediments tend to incorporate MP into their bodies; 5) the chemical properties of MP can also influence how easily organisms absorb them. Some MP can absorb toxic chemical compounds from the surrounding environment, accumulating in organisms' tissues, including shellfish.[30]

Furthermore, in the second sequence, both shellfish and sediments were dominated by MP in the shape of films, except for sediments in the Bungo Pasang River Estuary (station 2), where no films were found. The film is thought to originate from the fragmentation of plastic bags and has a low density. The film is a type of secondary MP whose source comes from the fragmentation process of plastic packaging and plastic bags made from polyethylene polymer. Particle films also come from fragile plastic fragments.[31] Microbeads (pellets), MP in granular form, are one type of primary MP. Primary MP are made in microforms in beauty and hygiene products. MP microbeads usually come from polymers such as polyethylene, polystyrene and polymethyl methyl acrylate.[29] MP in pellet form is produced from raw materials from industrial activities, toiletries, soap and facial cleansers, while the foam is made from packaging and plastic bags. The form of fragments, films and fibers shows that the MP found in this study is a secondary MP formed through the photolysis process. At station 2, no film was

found in the sediment. It is suspected that a small amount of film has been consumed by shellfish and another possibility is the hydrodynamic process of water so that the current carries the MP in the sediment to other places.[32]

Fiber is only found in shellfish at stations 1 and 2. Fiber is a type of MP whose sources are nylon, polyvinyl and polypropylene. People use nylon to make clothes, carpets and ropes. Polyvinyl alcohol is usually used as a basic material for making fishing equipment, while polypropylene is often used to make carpets and ropes, which are widely used on ships.

Microplastic size

The results of the MP size study in shellfish and sediment at three sampling stations can be seen in Fig 3. Fig 3 shows that the abundance of shellfish and sediments based on MP size tends to be dominated by sizes 101–300 μm > 301––500 μm > 501–1000 μm and the other sizes are small in number. MPs with very small sizes, such as nanoplastics, can be easily inhaled, enter the respiratory systems of humans and animals and can be absorbed through the digestive tract. These particles can pose a health risk because they can penetrate tissues and organs in the body and have the potential to lose their buoyancy and sink in waters due to biofouling. Furthermore, differences in the size of MP waste are closely related to wind direction and speed,[33] the presence of biofouling[34] and hydrodynamic water conditions such as currents, waves and tides. Larger MP become trapped in larger living organisms such as fish, seabirds and marine mammals. However, MP with smaller sizes can easily enter organisms through contaminated food and water. Microplastics accumulating in organisms can cause dangerous effects, including organ damage, hormonal changes and reproductive disorders.

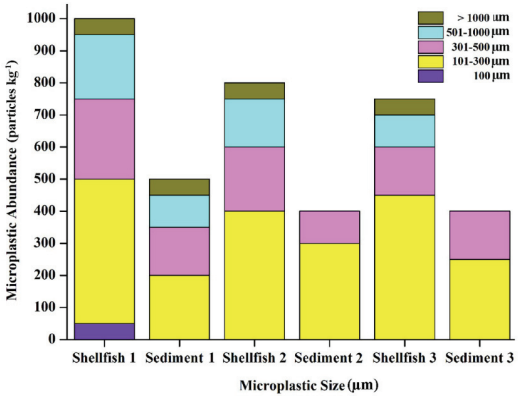

Fig. 3. Abundance of microplastic size in shellfish and sediment samples.

The size of the MP can directly affect its level of toxicity. Several studies have shown that smaller MP particles can contain harmful chemical compounds,

such as persistent organic pollutants (POPs), that can leach into the environment or the body of organisms. The content of these chemical compounds can cause poisoning and other negative impacts on living organisms.[35] MPs, especially large ones, can also act as vectors or carriers of other pollutants. MP can absorb toxic chemical compounds from the surrounding environment, such as pesticides or heavy metals and transport them to the organisms that consume them. Thus, MP may increase the exposure of organisms to harmful pollutants.

MPs are plastic fragments that are less than 5 mm in size. More specific MP sizes, such as 101–300 μm, fall into the very small MP category. The presence of MP in shellfish can be caused by various factors:[37] 1) filter-feeder organisms, such as mussels, may be more likely to consume MP measuring 101–300 μm because this size can match the particle size usually taken by these organisms; 2) biological processes in the body of mussels or other organisms may cause the separation or accumulation of MP of a certain size; 3) some MP may have certain chemical properties that make them more attractive to certain organisms. Chemical interactions between MP and filter feeder organisms can influence consumption rates; 4) small-sized MPs (*e.g.*, 101–300 μm) are more easily absorbed by shellfish through feeding and filtration processes, as these sizes resemble natural food particles. MPs of this size can become trapped in the tissue of shellfish flesh, making them more prone to accumulation within the organism. As shellfish continuously process water, they tend to filter out more of these smaller particles, leading to an increased amount of MP within their tissue; 5) once MPs are absorbed by the shellfish, these particles can become lodged within internal tissues, such as around the digestive organs or gills. Due to the continuous filtration system of shellfish, MPs accumulated within their bodies tend to persist and accumulate, especially in soft tissues like the flesh. This results in higher concentrations of MP within shellfish tissue compared to their surrounding environment; 6) sediment deposition processes in a region can influence the extent to which certain MP accumulate in organisms. Factors such as deposition velocity and sedimentation characteristics can play an important role.

Strategies for reducing microplastics in shellfish meat

Shellfish are marine organisms that are often the target of exposure to MP. Based on Fig. 4, the abundance of MP in shellfish before treatment (as control = treatment A) was 1000±71 particles/kg. The effects of MP in shellfish on their health and survival may pose a risk to higher organisms that consume them, including humans. Here are some of the effects of MP on shellfish: 1) shellfish tend to accumulate MP from the surrounding environment. These particles can penetrate the shellfish's body tissue, including vital organs such as gills and intestines; 2) MPs can affect the digestive system of shellfish. They can clog the intestines and hinder the digestive process, hindering nutrient absorption and potentially

causing health problems; 3) some types of MP contain toxic chemicals. When shellfish consume MP, these chemicals can escape and enter the shellfish's body, causing toxic effects.[37]

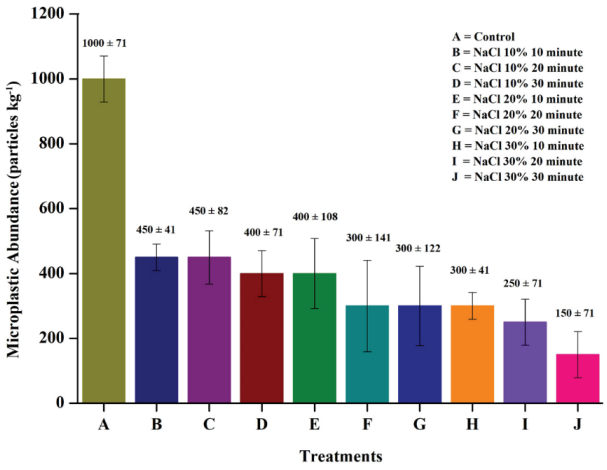

Fig. 4. Abundance of MP in shellfish meat with variations in soaking time (min) and salt concentration (%).

Therefore, to anticipate the negative impact of MP on shellfish, an experiment was carried out with a completely randomized factorial design combining two factors, namely NaCl salt solution (%) and soaking time (min), which can be seen in Table I and Fig. 4, showing that two factors, namely the concentration of NaCl solution (%) and soaking time (min) resulted in a decrease in the abundance of MP in shellfish meat.

TABLE I. Decrease in the amount of microplastics (MP shellfish abundance values) at NaCl concentration and soaking time; different superscript letters in the same row and column indicate significant differences ($p < 0.05$) in the decrease in MP abundance (ab is not significantly different from groups having a and/or b; abc is not significantly different from all groups; ac is not significantly different from groups a and/or c)

Soaking time (*B*), min	NaCl concentration (*A*), %		
	10	20	30
10	450 ± 41^{ab}	400 ± 108^{abc}	300 ± 41^{ac}
20	450 ± 82^{ab}	300 ± 141^{abc}	250 ± 71^{ac}
30	400 ± 71^{ab}	300 ± 122^{abc}	150 ± 71^{ac}

Based on Table I, the results of factorial testing show that NaCl concentration (Factor A) has a significant effect ($p < 0.05$) on reducing the abundance of MP in shellfish meat while soaking time (Factor *B*) and the interaction between NaCl concentration (Factor *A*) and soaking time (Factor *B*) had no significant

effect ($p > 0.05$) on reducing the abundance of shellfish MP. Duncan's further test showed that a 30 % NaCl solution and a soaking time of 30 min were optimal results, with a decrease in MP abundance in shellfish meat obtained by 150±71 particles/kg (85 %). In a 30 % NaCl solution and a soaking time of 20 min, MP particles were reduced to 250±71 particles/kg. 30 % NaCl solution and a soaking time of 10 min reduced the MP particles in shellfish meat to 300±41 particles/kg, as seen in Fig. 4.

Several mechanisms involve NaCl and MP: 1) NaCl can influence MP transport in the water environment. When water contains salt, the water's density increases, which can affect MP movement and transport. However, this effect may be small and influenced by various other factors; 2) although NaCl itself does not decompose MP, water containing salt can change the physical and chemical properties of MP. Environmental conditions involving salt, temperature and pressure can influence the MP degradation process; 3) ions and molecules in the salt solution can interact with the MP surface through the adsorption process. This can influence MP' surface properties, behavior and transport; 4) salts such as NaCl can be involved in MP biogeochemical cycles. These include interactions with living organisms, absorption by soil and the potential to enter the food chain.[33]

Based on Fig. 5, before treatment (control), there was MP in the form of films, fibers and fragments. However, after treatment, the MP concentration decreases as fragments, but the MP in films and fibers disappears. This shows that combining NaCl salt solution (%) and soaking time (min) effectively removes MP in films and fibers and reduces MP in fragments. The presence of salt, NaCl, in the environment, can influence the fate and transport of MPs. For example: 1) MPs can interact with salt through absorption and desorption processes. Salts in the environment can be absorbed onto the surface of MP, thereby affecting their

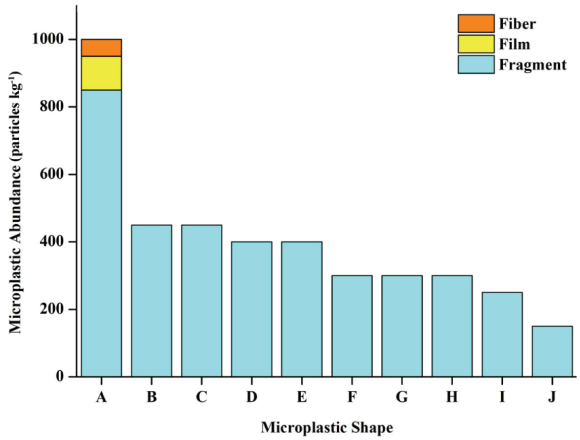

Fig. 5. Abundance of microplastic shapes in shellfish meat samples with variations in soaking time (min) and salt concentration (%).

properties and behavior; 2) the presence of salt can cause aggregation of MP particles. This aggregation can affect its transport in aquatic systems and its potential for ingestion by organisms.

The relationship between MP size, salt solution (%) and soaking time (min) involves various factors and interactions. From Fig. 6, as the salt solution (%) and soaking time (min) increase, the microplastic concentration decreases, some of the MP sizes disappear (≤ 100 μm, 501–1000 μm, > 1000 μm) and decrease (101–300 μm, 301–500 μm). When MP come into contact with a salt solution, several processes can occur: 1) the size of the MP can affect its buoyancy in salt water. Smaller MP may remain suspended in the water column for longer due to less settling due to gravity. Larger MP may settle more quickly; 2) MPs can aggregate or clump and particle size can influence this process. Smaller particles may aggregate more easily due to increased surface area and interparticle interactions; 3) the size of MP can influence their interactions with salt ions and other chemicals in solution. For example, smaller particles may have a greater surface area relative to their volume, thereby providing more opportunities for chemical reactions or adsorption of substances from the surrounding environment; 4) the size of MP can affect their bioavailability to marine organisms. Smaller particles may be more easily digested by smaller organisms, potentially leading to biomagnification through the food chain; 5) the size of MP can influence their transportation and distribution in water systems. Smaller particles may be more easily transported by water currents and distributed over a wider area.[40,41]

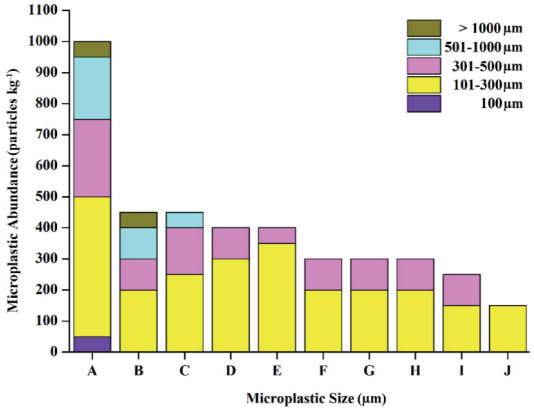

Fig. 6. Abundance of microplastic size in shellfish meat samples with variations in soaking time (min) and salt concentration (%).

Identification of MP polymer types

FTIR results before and after treatment, Fig. 7 shows the FTIR spectrum of standard polyvinylchloride (PVC) MP with MP spectra from shellfish without and with treatment with 30 % NaCl solution for 30 min. The FTIR results show that the type of polymer found is polyvinyl chloride (PVC), as evidenced by the

discovery of several main peaks characteristic of polyvinyl chloride polymers. In the standard PVC spectrum, the peak wave number was found at 2919.47 cm^{-1}, indicating C–H stretching vibrations (3000–2840 cm^{-1}); 1082.35 cm^{-1} indicates C–C bending vibration (1100–1000 cm^{-1}); and wave numbers of 686.17 and 617.41 cm^{-1} indicate C–Cl stretching vibrations (850–550 cm^{-1}). In the untreated MP spectrum, wave number peaks were found at 2916.46 and 2850.34 cm^{-1}, indicating C–H stretching vibrations; wave number 1048.78 cm^{-1} indicates C–C bending vibration; and the wave number 715.82 cm^{-1} indicates C–Cl stretching vibrations. Meanwhile, in the spectrum of MP in shellfish treated with 30 % NaCl solution for 30 min, a wave number peak was found at 2926.14 cm^{-1} indicating C–H stretching vibrations; wave number 1006.71 cm^{-1} indicates C–C bending vibration and the wave number 828.10 cm^{-1} indicates C–Cl stretching vibrations.[42,43]

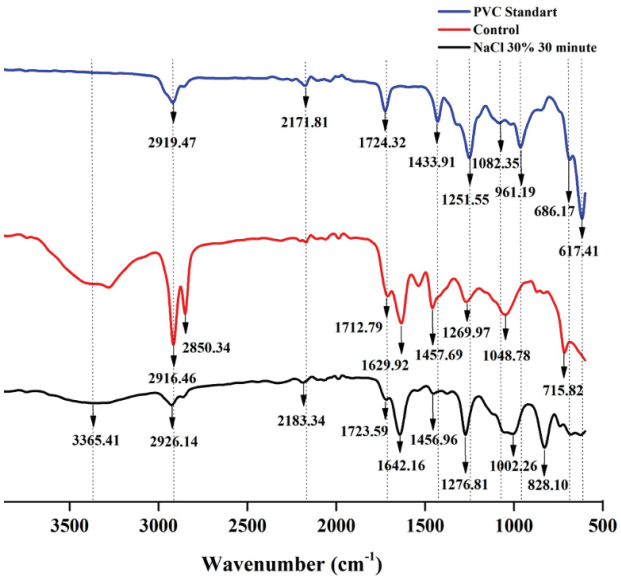

Fig. 7. Standard FTIR spectrum of PVC, without and with 30 % NaCl solution treatment for 30 min.

In Fig 7 and Table II, it can be seen that there is a missing peak (C–H vibration) in the spectrum of microplastics in shellfish treated with 30 % NaCl solution for 30 min compared to the microplastic spectrum in shellfish samples without treatment, such as C–H vibration. The peak spectrum of microplastics treated with 30 % NaCl solution for 30 min, such as C–H and C–O vibrations, tends to be weaker in intensity and not as sharp as the peaks of microplastics without treatment.

TABLE II. Wave number shift of PVC before and after treatment with NaCl

Wavenumber, cm^{-1}			Characteristics	Functional group
PVC standard	Control	NaCl 30 %, 30-min		
–	–	3365.41	N–H stretching	Aliphatic primary amine
2919.47	2916.46	2926.14	C–H stretching	Alkane
–	2850.34	–	C–H stretching	Alkane
2171.81	–	2183.34	S–C≡N stretching	Thiocyanate
1724.32	1712.79	1723.59	C=O stretching	Carboxylic acid
–	1629.92	1642.16	C=C stretching	Alkene
1433.91	1457.69	1456.96	C–H bending	Alkane
1251.55	1269.97	1276.81	C–O stretching	Aromatic ester
1082.35	1048.78	–	C–O stretching	Primary alcohol
961.19	–	1002.26	C=C bending	Alkene
–	–	828.10	C–Cl stretching	Halo compound
686.17	715.82	–	C=C bending	Alkene
617.41	–	–	C–Br stretching	Halo compound

Polyvinyl chloride (PVC) is a type of polymer that can be used in various products, including MP. Interactions between MP, NaCl and PVC functional groups may occur in certain environments, especially if the MP are exposed to water or electrolyte solutions. In PVC, the main functional group involved in the interaction is the polymer chain's chlorine group. PVC MP will open these groups to reaction with surrounding substances, including NaCl in solution.[44] Some potential interactions between NaCl and PVC on MP involve: 1) ion adsorption; Na^+ and Cl^- can be adsorbed on the surface of PVC MP through electrostatic interaction with the open chlorine groups on PVC; 2) ion exchange; Na^+ may exchange with other ions bound to PVC, affecting the surface properties of MP; 3) dissolution of PVC; under certain conditions, NaCl in solution can cause dissolution or degradation of PVC, especially if the solution concentration is high enough or other factors favor the chemical reaction; 4) physical changes; the interaction between NaCl and PVC can affect the physical properties of MP, such as surface structure, hardness or solubility.[22,44,46]

However, it is important to note that these interactions can be complex and highly dependent on specific environmental conditions, such as temperature, pH and NaCl concentration.[47]

In addition, the consequences of these interactions on MP and the environment still require further research. Fig. 8 compares the FTIR spectrum of MP between standard polyamide (PA) and the spectrum of MP in shellfish without and with treatment with 30 % NaCl solution for 30 min.

The FTIR results show that the type of polymer found is polyamide (PA), as evidenced by the discovery of several main peaks characteristic of polyamide polymers. In the standard PA MP spectrum, a wave number peak was found at 3292.84 cm^{-1} indicating N–H stretching vibrations (3330–3250 cm^{-1}); 2920.91

cm^{-1} indicates C–H stretching vibrations (3000–2840 cm^{-1}); wave number 1640.39 cm^{-1} indicates C=O stretching vibrations (1680–1630 cm^{-1}); wave numbers 1240.56 and 1029.94 cm^{-1} indicate C–N stretching vibrations (1250–1020 cm^{-1}). In the untreated MP spectrum, the wave number peak was found at 3277.24 cm^{-1} indicating N–H stretching vibrations; wave number 2924.31 cm^{-1} indicates C–H stretching vibrations; wave number 1637.05 cm^{-1} indicates C=O stretching vibrations (1680–1630 cm^{-1}); wave numbers 1247.35 and 1020.72 cm^{-1} indicate C–N stretching vibrations (1250–1020 cm^{-1}). In the spectrum of MP treated with 30 % NaCl solution for 30 min, the wave number peak was found at 3327.84 cm^{-1}, indicating N–H stretching vibrations; wave number 2892.39 cm^{-1} indicates C–H stretching vibrations; wave number 1320.44 cm^{-1} indicates C–N stretching vibrations; wave number 1020.56 cm^{-1} indicates C–N stretching vibrations.[26,27]

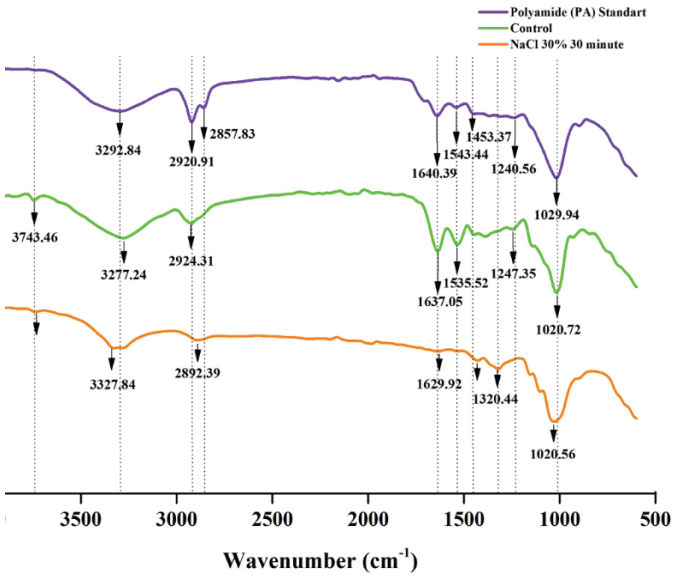

Fig. 8. FTIR spectrum of standard PA, without and with 30 % NaCl solution treatment for 30 min.

In Fig. 8 and Table III, it can be seen that there is a missing peak in the MP spectrum treated with 30 % NaCl solution for 30 min compared to the MP spectrum without treatment, such as C=O vibration. Apart from that, all the MP spectrum peaks in shellfish samples treated with 30 % NaCl solution for 30 min tended to be gentler and not as sharp as those without treatment, such as the N–H, C–H, C=O and C–N vibrations. This is due to the interaction between NaCl (table salt) and MP polyamide polymers through several mechanisms, especially due to their chemical properties. Polyamides are a group of polymers commonly

known as nylons and MP made from polyamides can interact with NaCl in water or other environments.

TABLE III. PA wave number shift before and after treatment with NaCl

Wavenumber, cm^{-1}			Characteristics	Functional group
PA standard	Control	NaCl 30%, 30 min		
–	3743.46	–	O–H stretching	Alcohol
3292.84	3277.24	3327.84	O–H stretching	Alcohol
2920.91	2924.31	2892.39	C–H stretching	Alkane
2857.83	–	–	C–H stretching	Alkane
1640.39	1637.05	1629.92	N–H bending	Amine
1543.44	1535.52	–	N–O stretching	Nitro compound
1453.37	–	1320.44	O–H bending	Phenol
1240.56	1247.35	–	C–N stretching	Amine
1029.94	1020.72	1020.56	C–O stretching	Vinyl ether

Some interactions that may occur are: 1) partial dissolution; salts such as NaCl can affect the partial dissolution of polyamide MP because NaCl dissolves in water. Its presence can modify the physical and chemical properties of the surrounding water. This can impact the solubility of polyamide MP; 2) ionic interactions; NaCl dissociates into Na^+ and Cl^- in water. These ions can interact with functional groups on polyamide that have certain charges. These ionic interactions can influence MP stability and physical properties; 3) ion adsorption; the surface of polyamide MP can adsorb ions. This adsorption can influence the surface properties and interaction of MP with their environment; 4) formation of hydrogen bonds; polyamides have amide groups that can form hydrogen bonds. The interaction between NaCl and the amide group can influence the structure and strength of polyamide MP.

CONCLUSION

The abundance of MP detected in shellfish ranged from (750 ± 41) and (1000 ± 71) particles/kg and the abundance of MP detected in sediment ranged from (400 ± 108) and (500 ± 82) particles/kg. The most frequently detected MP forms were fragments (82.36 %) > films (13.72 %) > fibers (3.92 %). The most commonly detected MP size was ≥ 100–300 μm (50.98 %). The types of polymers detected were polyvinylchloride (PVC), polyamide (PA) and polyethylene terephthalate (PET). Treatments varying the concentration of NaCl salt solution (0, 10, 20 and 30 %) and the effect of soaking time (10, 20 and 30 min) were carried out to reduce the abundance of MP in shellfish meat. The interaction of a NaCl concentration of 30 % and a soaking time of 30 min was the best result, with a reduction in MP abundance in shellfish meat of 85 %, from an MP abundance of 1000 to 150 particles/kg.

SUPPLEMENTARY MATERIAL

Additional data and information are available electronically at the pages of journal website: https://www.shd-pub.org.rs/index.php/JSCS/article/view/12882, or from the corresponding author on request.

ИЗВОД

АКУМУЛАЦИЈА И СМАЊЕЊЕ МИКРОПЛАСТИКЕ У ШКОЉКАМА (*Polymesoda bengalensis*) КОРИШЋЕЊЕМ РАСТВОРА NaCl

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Ова студија истражује контаминацију микропластиком (MP) у шкољкама (*Polymesoda bengalensis*) и процењује ефикасност третмана NaCl у смањењу нивоа MP у конзумираним шкољкама. Узорци су прикупљени из три ушћа у Западној Суматри, Индонезија: Батанг Арау, Бунго Пасанг и Нортх Пунггасан. Узорци су анализирани коришћењем тринокуларне микроскопије и инфрацрвене спектроскопије са ослабљеном тоталном рефлексијом и Фуриеровом трансформацијом (ATR-FTIR), да би се квантификовала количина MP и идентификовали типови полимера. Концентрације MP су се кретале између 750—1000 честица/kg^{-1} у шкољкама и 400—500 честица/kg^{-1} у седиментима, при чему је Батанг Арау показао највише нивое. Међу откривеним облицима MP преовладавали су фрагменти (82,36 %), филмови (13,72 %) и влакна (3,92 %), са величинама између 100–300 μм. Примарни идентификовани полимери укључивали су поливинил хлорид (PVC), полиамид (PA) и полиетилен-терефталат (PET). Серија третмана коришћењем раствора NaCl различитих концентрација (10, 20 и 30 %) и времена потапања (10, 20 и 30 min) показала је да 30 % раствор NaCl током 30 min ефикасно смањује нивое MP за 85 %, смањујући концентрацију MP у месу шкољки на 150 честица/kg^{-1}. Ови налази наглашавају потенцијал третмана NaCl као исплативе методе за смањење контаминације MP у шкољкама, доприносећи побољшаној сигурности морских плодова и пружајући увид у управљање загађењем MP у воденим екосистемима.

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