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MICROPLASTIC ACCUMULATION IN *Saccostrea cucullata* ALONG SRI LANKA'S WEST COASTAL BELT: IMPLICATIONS FOR SEAFOOD SAFETY POLICY RECOMMENDATIONS

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Abstract: Microplastics (MPs) are pervasive pollutants in marine environments, posing significant threats to ecosystems and human health. This study investigates the accumulation of MPs in *Saccostrea cucullata* (Rock Oysters) along the West coast of Sri Lanka from August 2021 to July 2022. Six sampling sites were selected to represent areas with varying anthropogenic activity, such as urbanization and tourism. MPs were extracted using alkaline digestion, and identified through hot needle tests and Fourier-Transform Infrared (FTIR) spectroscopy. The results revealed significant spatial variations in MPs concentrations, with the highest mean concentration recorded at Galleface (5.11 ± 2.2 MPs/g w.w.) and the lowest at Negombo Beach (2.60 ± 0.77 MPs/g w.w.). Filamentous blue particles were the most common, and particles smaller than 1 mm comprised nearly 25% of the total MPs. Seasonal factors, particularly the monsoon, influenced the temporal distribution of MPs. This study underscores the urgent need for pollution mitigation strategies, including waste management interventions and public awareness, to protect marine ecosystems and safeguard seafood safety in Sri Lanka.

Keywords: Microplastics, *Saccostrea cucullata*, seafood safety, microplastic contamination, public health, Sri Lanka

Introduction

Plastic pollution in marine environments has become one of the most pressing environmental challenges of the 21st century. With the rapid increase in plastic production over the past few decades, the disposal of plastic waste has overcome natural systems, contributing an estimated 8 million tons of plastic to the oceans annually (Jambeck et al., 2015). This pollution threatens marine biodiversity, disrupts ecosystems, and poses potential health risks to humans. Of particular concern is the rise of microplastics (MPs) plastic particles smaller than 5 mm. MPs can originate from the breakdown of larger plastic debris (secondary microplastics) or be intentionally manufactured for industrial applications (primary microplastics) (Andrady, 2011). The growing ubiquity of MPs in marine ecosystems has raised alarm due to their potential to infiltrate various levels of the food web, which ultimately threatens both marine organisms and human health.

Filter-feeding organisms such as molluscs, which rely on filtering large volumes of water for food particles, are especially vulnerable to microplastic contamination. As a result, they are ideal

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bioindicators for assessing MP pollution in marine environments. Furthermore, the consumption of molluscs by humans introduces the potential for microplastic ingestion, creating a direct pathway for human exposure through seafood (Rochman et al., 2015). Studies, such as Thushari et al. (2017), have highlighted the significant impact of microplastics on sessile invertebrates, warning of the far-reaching consequences for marine biodiversity and the health of coastal communities that depend on these species for sustenance.

Sri Lanka, an island nation with a coastline extending over 1,300 km, relies heavily on its marine resources for both economic and nutritional purposes. The western coastal belt, in particular, is ecologically and commercially vital, hosting important fishing grounds, tourism hubs, and urban centers. However, this region is also a hotspot for marine pollution, with waste materials, including plastic debris, entering the sea from land-based sources (Kumara et al., 2023). With rapid urbanization and increased industrial activity along the coast, understanding the extent and impact of MP pollution is crucial to developing effective management strategies that safeguard marine biodiversity and public health.

Recent studies have highlighted the detrimental effects of microplastic pollution on marine organisms, including research conducted along Sri Lanka's southern coastal belt, which found that MPs significantly impact selected invertebrate species (Wijethunga et al., 2019). However, despite these findings, a significant research gap remains regarding the spatial and temporal distribution of MPs in key coastal species, such as *Saccostrea cucullata* (Rock Oysters). Specifically, no study has yet addressed the accumulation of MPs in *S. cucullata* along Sri Lanka's western coastal belt. This gap in the literature calls for the first-ever spatial and temporal analysis of MPs in this species, which is critical to understanding how microplastic pollution is affecting local marine life and seafood safety.

This study focuses on *S. cucullata*, a species of Rock Oyster found in the intertidal zones of Sri Lanka's western coast. As a sessile filter feeder, *S. cucullata* is particularly susceptible to MP ingestion, making it an ideal bioindicator of microplastic pollution. The study aims to,

- Quantify MP concentrations in *S. cucullata* across six coastal sites.
- Examine spatial and temporal variations in MP accumulation.
- Assess the implications of microplastic contamination for seafood safety.
- Propose long-term mitigation strategies and policy recommendations to manage microplastic pollution in the region.

By addressing these objectives, the study aims not only to fill the gap in current knowledge regarding microplastic contamination in *S. cucullata* but also to provide actionable insights for policymakers, environmentalists, and public health authorities. The proposed policy recommendations will focus on strengthening waste management strategies, promoting public awareness, and implementing regulatory measures to reduce microplastic pollution, ensuring the protection of both marine ecosystems and public health.

Materials and Methods

Study Area

The study was conducted along the West coast of Sri Lanka, a region known for its rich biodiversity, extensive fishing grounds, and high levels of anthropogenic activity. Six sampling sites were selected to represent different levels of human activity and environmental conditions. These sites include,

Negombo Beach (7.2638100° N, 79.8408132° E): A bustling fishing area and popular tourist destination. Negombo is characterized by high levels of commercial activity, with a mix of fishing and tourism contributing to local pollution levels.

Sarakkuwa Beach (7.1165511° N, 79.8396166° E): A mixed-use beach with both tourism and fishing activities. Sarakkuwa experiences moderate levels of pollution due to its proximity to urban centers and commercial fishing operations.

Galleface (6.9244494° N, 79.8440188° E): An urban recreational beach located in the heart of Colombo, Sri Lanka's largest city. Galleface is frequented by both locals and tourists, and is heavily impacted by urban runoff and waste discharge from nearby industries.

Dehiwala (6.8476476° N, 79.8616093° E): A highly urbanized coastal region that lies just south of Colombo. Dehiwala is a densely populated area with significant commercial and industrial activity, contributing to high levels of plastic pollution.

Panadura (6.7162754° N, 79.8985551° E): A commercial hub known for its thriving fishing industry. Panadura is situated along a stretch of coast that is heavily trafficked by fishing vessels, which are a major source of plastic debris.

Beruwela (6.4785919° N, 79.9827386° E): A coastal town known for both fishing and tourism. Beruwela is a less urbanized area compared to other sites in this study, but it still experiences pollution from fishing activities and waste runoff from inland areas.

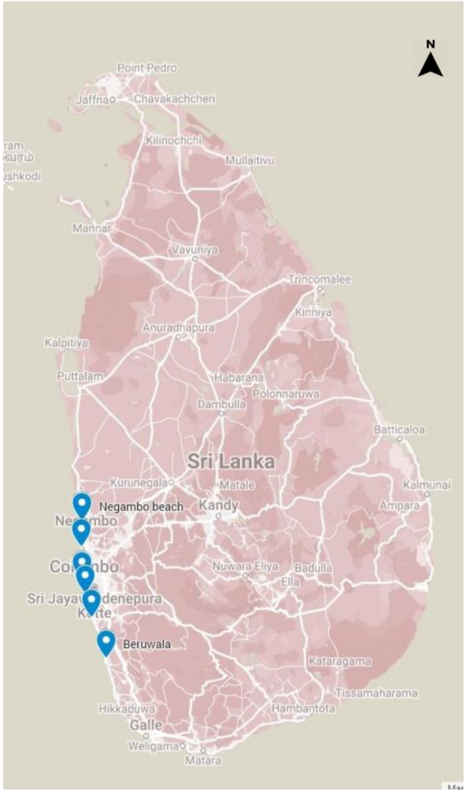

Figure 1: Six selected sites representing 3 districts of Western Province in Sri Lanka

Figure 2: Six selected sites representing 3 districts of Western Province

These sites were selected to capture a range of environmental conditions and anthropogenic influences, allowing for a comprehensive analysis of MP pollution along the West coast of Sri Lanka.

Seasonal Influences on Sampling Design

The study on microplastics in marine ecosystems takes into account seasonal variations in environmental factors that affect the distribution and accumulation of microplastics. Conducted from August 2021 to July 2022, the study aimed to capture both spatial and temporal fluctuations in microplastic concentrations. Key factors influencing the sampling strategy included the monsoon seasons, tourism seasons, and changes in temperature and ocean currents.

Sri Lanka experiences two monsoon seasons (Southwest from May to September and Northeast from October to February), which affect ocean currents, rainfall, and runoff, potentially increasing microplastic influx, particularly near urban and industrial areas. The study also considered tourism seasons, as peak tourist activity can lead to more plastic waste, impacting microplastic levels in coastal areas. Additionally, temperature changes and ocean currents may affect the movement and accumulation of microplastics, particularly in intertidal zones where marine species like oysters are located.

By sampling during both monsoon and dry periods, as well as peak and off-peak tourist seasons, the study aimed to provide a comprehensive understanding of how climatic, ecological, and anthropogenic factors influence microplastic contamination over time.

Sampling and Sample Preparation

Sampling was conducted over a 12-month period from August 2021 to July 2022, covering three distinct climatic seasons. The first, the South-west Monsoon (July-August 2021), is characterized by heavy rainfall and rough seas, which contribute to increased surface runoff from inland areas, often carrying plastic waste into the ocean. The second season, the Inter-Monsoonal Period (October 2021), serves as a transitional phase between monsoons and is marked by periodic changes in weather and sea conditions. Random collections were performed at three-month intervals, specifically in August 2021, November 2021, February 2022, and May 2022. During this time, the seas are typically calmer and less influenced by rainfall, affecting the movement and deposition of microplastics. Lastly, the North-east Monsoon (December 2021-January 2022) is associated with even calmer seas and reduced rainfall, further impacting the distribution and settlement of microplastics along the coastal areas. Each of these seasons provided unique environmental conditions that influenced microplastic transport and accumulation, offering a comprehensive understanding of their temporal variation in marine environments.

Specimens of *Saccostrea cucullata* were collected during low tide intervals at each sampling site. Individual specimens from each species were collected with attention to separation and labeling, ensuring no mixing of samples. To preserve the integrity of the samples, each molluscs ware individually wrapped in aluminum foil to prevent contamination during handling and transportation. The samples were then stored in ice boxes to maintain their condition before being transferred to the University of Peradeniya for further analysis. The samples were then placed in sterile containers and transported to the laboratory for analysis. In the laboratory, the oyster samples were washed with distilled water to eliminate any external contaminants, and two grams of tissue were separated from each sample using an analytical balance in preparation for microplastic extraction.

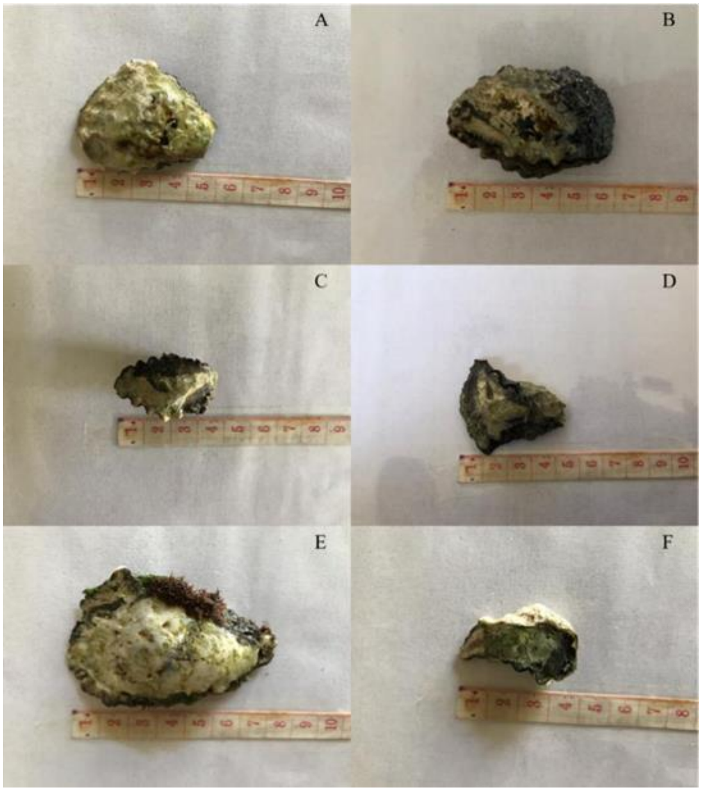

Figure 3: Images of collected Saccostrea cucullata samples in six different sites: (A), Negambo Beach,(B) Sarakkuwa, (C) Galle Face, (D) Dehiwela, (E) Panadura, (F) Beruwela in West coastal of Sri Lanka.

Microplastic Extraction and Identification

The collected samples underwent a meticulous preparation process to ensure accurate analysis of microplastics in organism. Subsequently, samples were dissected using specialized tools, and flesh samples were isolated and precisely weighed using a top loading balance (0.1g, Radwag WLC 6/A2, UK) for subsequent chemical analysis.

Stringent protective measures were implemented to prevent cross-contamination. Researchers utilized protective gear such as gloves, masks, cotton clothing, and laboratory coats during sample analysis. To mitigate any potential sources of contamination, all glassware and sieve sets were meticulously rinsed with distilled water in the laboratory. Before laboratory examinations, work surfaces, laboratory equipment, and instruments were meticulously cleaned with alcohol. Furthermore, the researcher's hands and forearms were thoroughly washed and scrubbed to minimize the risk of introducing contamination.

For the subsequent analysis, the flesh tissues were ground using a mortar and pestle. Subsequently, 2g of the ground flesh was precisely measured using the aforementioned top loading balance. The digestion process involved the utilization of 20 mL of a 10% w/w potassium hydroxide (KOH) solution, following triplicate replicates. Boiling tubes containing the measured flesh and KOH solution were covered with aluminum foil and then incubated at varying temperatures: room temperature (25°C), 40°C, and 55°C in a water bath (WB-4MS) for a duration of 96 hours. Visual examinations were carried out at 12-hour intervals throughout the incubation period.

The resultant digestates were filtered using 1.6µm (diameter 25 mm) Whatman glass microfiber filter papers (Masura et al., 2015) through a Buchner funnel. Following filtration, the filter membranes were allowed to air dry for 12 hours at 50°C. The filters containing microplastics were meticulously examined under a high-powered trinocular microscope (10 × 10 magnification) equipped with a five-megapixel camera (B-500TPL, OPTIKA Microscope, Italy). During the examination, the filter papers housing microplastics were placed within Petri dishes to prevent airborne contamination. Initial identification of microplastics was based on their texture and flexibility, following the sorting criteria established by Hidalgo-Ruz et al. (2012). To confirm the identity of microplastics, an alternative method—the Hot needle test— was employed, as outlined by De Witte et al. (2014). as having a smaller size (largest dimension <5mm) without having any visible cellular or organic structures, similar thickness throughout their entire length and clear and homogeneous color throughout were used as identical characters with in plastic during microscopic identification.

Visual identification and quantification of MPs

The air-dried filter papers were meticulously examined to identify MPs using an Olympus B×43 photomicroscope (Olympus B×43, Olympus photo microscope camera with screen, Made in Japan). Various power objective lenses, ranging from 4× to 100×, were utilized during the observation process.

Once identified, the MPs were categorized based on color and shape and photographed using a 50 µm scale. To determine the length of the identified MPs. ToupView software (ToupTek TopView, Copyright © 2023 – 2021, Version: ×64, 4.11.19728.20211022) was laboring with an accuracy of 0.01 µm.

In brief, captured MPs images were saved in JPG mode with a pixel size of 1600 × 1200. Subsequently, these images were documented separately based on the species, sites, and time (month). The documented MPs images were then dragged and dropped into the ToupView software. The 50 µm scale bar in the image was zoomed and calibrated using the ToupView software tool by aligning between 50 µm to count related pixels (Figure 4). Using the calibrated scale bar, the length and size of the MP images were measured, as shown in Figure 4. This protocol was followed for Figure 4 to measure the size of MPs.

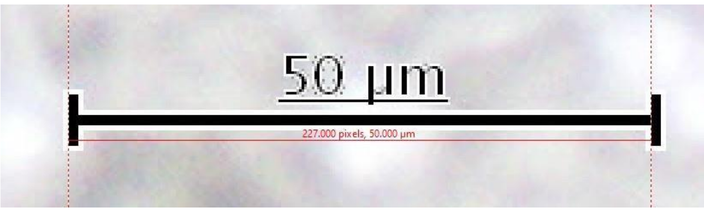

Figure 4: Image of calibrating protocol, aligning 50 µm scale bar and related pixel count using ToupView software.

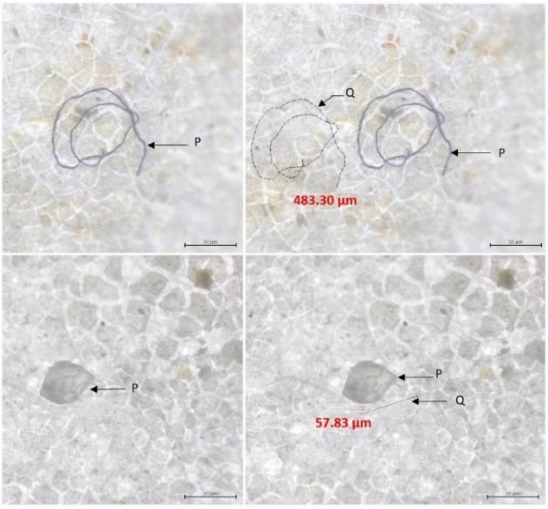

Figure 5: Images of (P) MP particles, (Q) Measuring MP plastic length using ToupView software.

Average MPs per gram based on rock oysters was calculated using the equation,

Average MPs per gram = Total No. of MPs/Total weight (g)

The average percentage of different characteristics of MPs in selected species calculated using the equation,

Average percentage of different types of MPs=(No. of MPs in each type/Total No. of MPs)×100

Quantification & classification of microplastics in the extracted samples

The process of microplastic analysis in oyster species was executed with meticulous precision, following a comprehensive and systematic approach to ensure accurate and robust results. After extraction, microplastics were first identified and classified based on their diversity in shapes and colors. This initial categorization laid the foundation for subsequent quantification and characterization efforts, with plastic debris being separated into distinct categories for focused analysis. The quantification process involved counting the plastic debris within each category and expressing the microplastic count per gram of oyster tissue, allowing for meaningful comparisons across different sampling locations and time periods. Additionally, the size and dimensions of microplastics were thoroughly examined using image processing software, specifically Optika View, ensuring precise measurements of each particle. Beyond simple enumeration, microplastics were systematically categorized by shape, including fibers/filaments, films, sheets, fragments, granules, polystyrene (PS) foams, and rod shapes, providing deeper insights into the diverse forms of particles present. Moreover, recognizing the importance of color as a characteristic identifier, microplastics were further classified into color categories such as blue, black, brown, green, orange, pink, purple, red, transparent, yellow, and white. This detailed classification based on shape and color offered a comprehensive understanding of the diversity and characteristics of microplastics found within the oyster samples.

Verification of MPs

The MPs extracted from the samples were separated using a sharp-end wooden pick to identify the identity of the type of polymer via the ATR-FTIR mode. The separation process was carriedout while observing the dissecting microscope, based on the color and shape of the MPs. This separation protocol was able to collect all samples according to colors, types, and shapes. These samples were then labeled, covered with aluminum foil, and stored for analysis.

ATR-FTIR instruments, Bruker OPTIK GmbH Rudolf-Plank-Str. 27D 76275 Ettlingen, Model: ALPHA II, Germany which was at Marine Environmental Protection Authority(MEPA) in the Galle, was used for the identification of polymer types. The melted point of the needle was transformed into a particle of MP with shape (fragment) into a different shape.

In brief, before analyzing MP samples, the working surface of the ATR-FTIR instrument was cleared using 70% alcohol, including the sample holder. Afterward, the background spectrum was taken by running the instrument using air. Subsequently, MPs were carefully transferred to the sampling holder. Once the sample was carefully placed on the measuring surface, the absorbance spectrum was recorded. The ATR-FTIR instrument, located at MEPA, utilized an FTIR spectrometer coupled with an Attenuated Total Reflection (ATR) accessory was used forthe confirmation. Each MPs underwent 32 scans, with a spectrum range set from 4000 to 500 cm^{-1}. The output spectra data were analyzed in OMNIC v8.3 software (Thermo Fisher Scientific, Made in USA). All spectra were later compared with library data to verify the polymer type. In the ATR-FTIR instrument, at MEPA, an FTIR spectrometer coupled with anAttenuated Total Reflection (ATR) accessory was used. Each MP particle underwent 23 scans,with a spectrum range of 4000 to 400 cm^{-1}. The output spectra data were analyzed in OPUS v8.5 software (Bruker OPTIK GmbH Rudolf-Plank-Str. 27D 76275 Ettlingen, Made in Germany). Some unidentifiable MPs particles were pooled and identified. Then, all spectra were compared with library data to verify the polymer types.

Confirmation and validation- To ensure the accuracy and reliability of the observed peaks, a comparison was conducted between the obtained peaks and the characteristic graphs associatedwith commercially available plastics. The FTIR procedure played a pivotal role in validating the identified polymers within the observed plastic particles.

Spectrum verification and comparison- For the spectrum verification process, the extracted microplastic particles were analyzed using the KBr pellet technique under the attenuated totalreflectance (ATR) mode of the ALPHA-T FTIR spectrophotometer. This approach ensured theacquisition of precise and representative spectra for each sample. The obtained spectra were then meticulously compared with reference plastic spectra corresponding to each polymer category.

Confirmation of polymer type- The comparative analysis of the spectra enabled the confirmation of the polymer type within the microplastic particles. Utilizing Bruker's OPUS 23 spectroscopy software, the observed spectra were matched against reference plastic spectrafor conclusive identification of polymer composition.

After the identification Fourier transfer Spectro photo meter (ALPHA –T, South Africa) in relation to the identical peaks obtained, graphical explanation is done using OPUS software. The obtained peaks were then compared with the characteristic graphs of the commercially available plastic for the further confirmation. The FTIR was performed to validate polymers of identified plastic particles. These particles were analyzed by the KBr pellet technique under the attenuated total reflectance mode of the FTIR (ALPHA-T, South Africa). Bruker's OPUS 23 spectroscopy software was used to verify the spectrum. The spectra obtained for each sample were compared with the reference plastic spectra in each category, and polymer type was confirmed accordingly.

Statistical analysis

The statistical data analyses were performed using the IBM SPSS Statistics v25 software. Data of evaluated criteria were initially checked for normality by using the Shapiro-Wilk test method.Normally distributed length data were compared with six sites and 12 months using one-way ANOVA tests separately for each species. Also, length variation was compared with six sites and 12 months using a two-way ANOVA test. Subsequently, the normality tests were done separately for different shapes and types of MPs levels. Due to failure of normality ($p < 0.05$),independent samples Kruskal-Walli's test was performed to investigate the significance between sampling sites and the months for shape and level of MPs found in rock oysters. Counted different shapes of MP levels were compared in the six sites between the 12 months using two-way ANOVA tests after the normality tests. Normal distributed data were compared separately for the rock oysters. Pearson correlation analysis was done to evaluate the relationship between tissue weights and tested species. Average values were expressed as mean ± SD (standard deviation on the mean), and statistical analysis was set atthe 5% significance level ($p < 0.05$).

Results and Discussion

Spatial Variations in Microplastic Accumulation

Microplastics were detected in all samples of analyzed *Saccostrea cucullate* (Table 1). The analysis also reveals a significant impact of location (p=0.001) on microplastic accumulation. The highest mean microplastic concentration 5.11±2.2 MPs/gw.w (Table 1) was observed in *Saccostrea cucullata* collected from Galle face, followed by Negambo, Sarakkuwa, Dehiwala,Panadura, and Beruwela. In contrast, the lowest mean concentration 2.60±0.77 MPs/gw.w(Table1) was recorded at Negombo Beach

Table 1: Count for Saccostrea cucullata versus location

Location	N	Mean	Grouping	
Galleface (GAL)	12	5.11	A	
Dehiwela (DEH)	12	4.87	A	
Panadura (PAN)	12	4.76	A	
Sarakkuwa(SAR)	12	4.01	A	B
Beruwela (BAR)	12	3.64	A	B
Negambo (NEG)	12	2.60		B

Means that do not share a letter are significantly different

Table 2: Average of microplastic (particles/g) found in Saccostrea cucullate in six study sites.

Saccoctrea cucullate	Location											
Time	NEG	± SD	SAR	± SD	GAL	± SD	DEH	± SD	PAN	± SD	BER	± SD
Aug- Oct (1)	2.74	0.45	5.06	1.26	6.51	1.51	5.69	0.77	4.41	0.80	3.53	1.01
Nov- Jan (2)	2.60	0.55	2.63	1.28	4.16	1.17	4.97	0.66	4.76	0.79	2.64	1.23
Feb- Apr (3)	2.00	0.77	3.28	1.29	3.03	1.66	3.84	0.82	5.03	0.85	3.37	1.18
May- Jul (4)	3.09	1.48	5.11	2.20	5.37	1.68	5.00	0.71	6.24	0.88	5.04	0.68

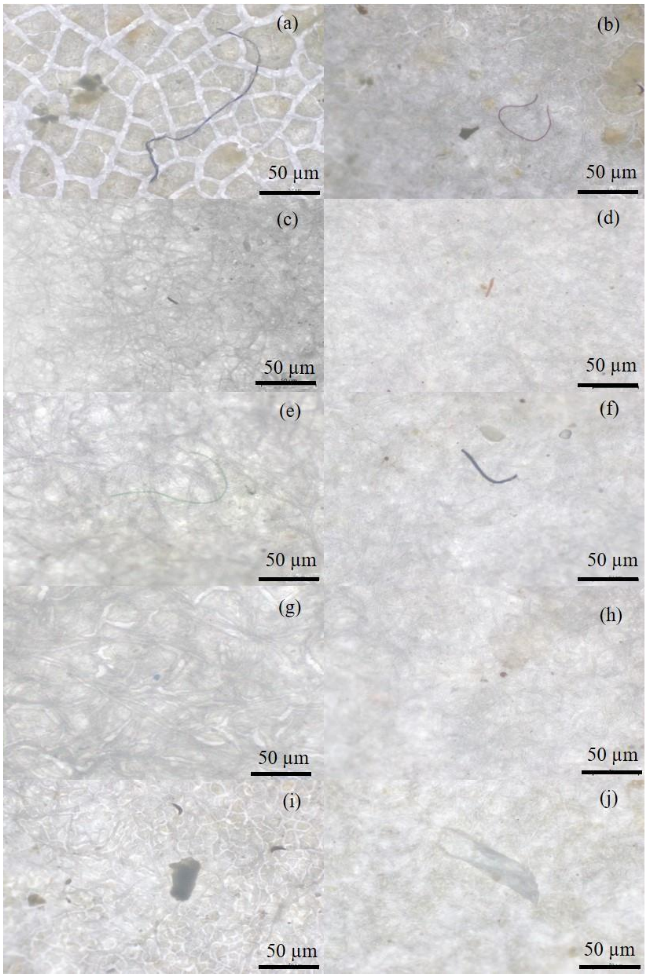

Figure 6: Different types and colors of images of (a) Blue filament, (b) Red filament, (c) Blue fragment, (d) Red fragment, (e) Other (Green filament), (f) Other (Black fragment), (g) Blue sphere, (h) Red sphere, (i) Foam and (j) Film type of identified under Photomicroscope in studied Species samples (Scale bar 50 µm).

Temporal Variations in Microplastic Accumulation

The ANOVA results indicate a significant effect of time (p=0.007) on microplastic accumulation in S*accostrea cucullata.* Tukey pairwise comparisons reveal that the mean microplastic concentration during May -2022 to July - 2022 was significantly higher than during other time periods.

Table 3: Count for Saccostrea cucullata versus time

Time	N	Mean	Grouping
May- Jul (4)	18	4.97	A
Aug- Oct (1)	18	4.65	A B
Nov- Jan (2)	18	3.63	B
Feb- Apr (3)	18	3.43	B

Means that do not share a letter are significantly different

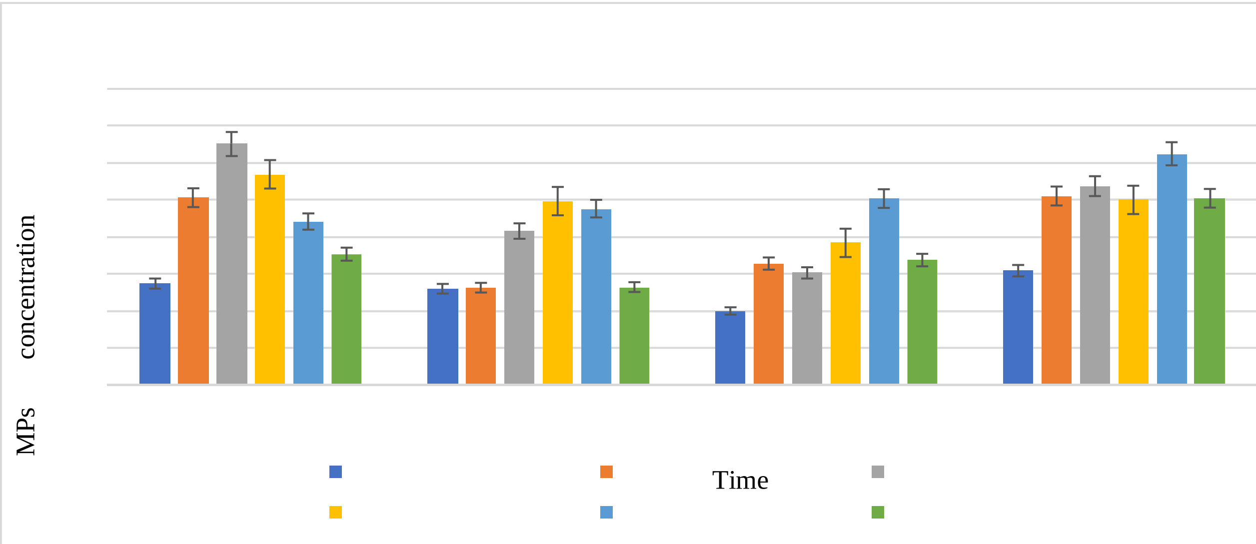

Figure 7: Average of microplastic (particles/g) found in Saccostrea cucullate in six study sites.

The results of this study provide compelling evidence of spatial variations in microplastic accumulation within the *Saccostrea cucullata* population across 6 different coastal locations inthe Western Province of Sri Lanka. The observed differences can be attributed to a myriad of factors that influence microplastic distribution and deposition, including local hydrodynamics,proximity to pollution sources, and waste management practices.

The notably higher mean microplastic concentration in S*accostrea cucullata* from Panadura, Dehiwala, and Galle Face suggests the influence of urban centers and industrial activities in these areas. Urban runoff, untreated wastewater discharge, and improper waste disposal practices may contribute to the higher microplastic loads in these locations. Panadura's prominence as a commercial hub and its proximity to densely populated urban regions may exacerbate microplastic pollution in its adjacent waters.

On the other hand, Negombo Beach's significantly lower microplastic accumulation raises questions about the effectiveness of waste management practices or the presence of natural barriers that limit microplastic transport. The difference in microplastic levels at Negombo beach compared to the other locations could be attributed to its unique coastal dynamics, hydrological patterns, and potential differences in local pollution sources.

The observed significant differences in microplastic accumulation across time periods suggest influence of seasonal variations. Factors such as weather patterns, rainfall, and ocean currents could contribute to the temporal fluctuations in microplastic loads. The higherconcentration during May to October (Time 1 and 4) might be associated with increased, human activities, tourism, or specific South West monsoon weather conditions leading to higher microplastic inputs into the coastal waters.

Characteristics and Types of Microplastics

The MPs identified in this study were predominantly filamentous (33.25%), followed by fragments (24.89%), pellets (15.32%), foam (11.17%), and film (9.37%). The dominance of filamentous MPs suggests that fishing gear, ropes, and textiles may be significant sources of plastic pollution in these regions, particularly in areas like Panadura and Beruwela, where fishing is a major economic activity. The prevalence of small particles (<1 mm) in the samples is of particular concern, as these particles are more easily ingested by marine organisms and have the potential to bioaccumulate within the food chain.

In terms of color, blue MPs were the most common (29.47%), followed by white (24.29%) and transparent (16.85%) particles. These findings are consistent with other studies that have reported a high prevalence of blue and white MPs in marine environments, likely due to the widespread use of these colors in fishing gear and plastic packaging materials (Cole et al., 2014).

Confirmation and Identification of Microplastics

Verification of microplastics using hot needle test

With the hot needle microplastic fibers showed curly behavior by separating from other particles in the sample. At the presence of a very hot needle plastic pieces melted or curled. Most of the detected microplastics were confirmed as plastics with the use of hot needle.

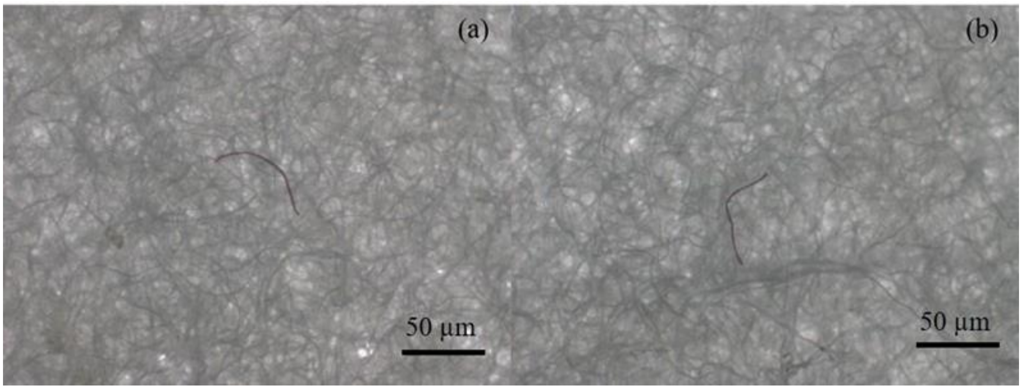

Figure 8: Images of Hot needle test (a) before and (b) after for a MP particle

Verification of microplatics using FTIR Spectroscopy

The confirmation of polymer types in the identified microplastics was conducted using FTIR spectroscopy. To determine the polymer composition of the microplastic samples, Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy was employed. Reference spectra from well-known polymer types were used as benchmarks, and a minimum of three absorption bands needed to match the sample spectra for confirmation the FTIR spectra derived from the microplastic samples exhibited resonance with reference spectra associated with High-Density Polyethylene (HDPE), Polypropylene (PP), and Polystyrene (PS) polymers. For the HDPE polymer, distinct absorption bands were observed at wave numbers 2850–2960 cm^{-1}, 1450–1470 cm^{-1}, and 720–730 cm^{-1}, corresponding to CeHstretch, CH_2 bend, and CH_2 rock bonds, respectively (Chércoles Asensio et al., 2009; Jung et al., 2018; Ng and Obbard, 2006).Similarly, the FTIR spectra of the Polypropylene (PP) plasticsamples displayed characteristic peaks at wave numbers 2850–2960 cm^{-1}, 1450–1470 cm^{-1}, 1360–1380 cm^{-1}, 968–997 cm^{-1}, and 800–840 cm^{-1}. These bands correspond to CeH stretch, CH_2 bend, CH_3 bend, CeC stretch, CH bend, C-CH_3 stretch, C-CH stretch, and methyl rocking mode combined with CH_3 and CH_2 rocking vibrations (Chércoles Asensio et al., 2009; Jung etal., 2018; Ng and Obbard, 2006).

The distinctive absorption bands at 3000–3030 cm^{-1}, 2840–2850 cm^{-1}, 1450–1495 cm^{-1}, 1027cm^{-1}, and 530–695 cm^{-1} verified the presence of Polystyrene (PS) polymer in the samples. These bands correspond to aromatic CeH stretch, CeH stretch, aromatic ring, and aromatic CeH, respectively. In concurrence with the FTIR analysis, the detected microplastics exhibitedspectra akin to those of commercially available synthetic plastics. This correspondence in functional groups between microplastics and their synthetic counterparts substantiates the identification of microplastic types.

The FTIR validation of polymer types in the identified plastic particles was carried out using the KBr pellet technique under the attenuated total reflectance mode of the FTIR instrument (ALPHA-T, South Africa). The spectra obtained for each microplastic sample were meticulously compared with the reference plastic spectra in each respective category, leading to the confident confirmation of the polymer types present.

In summary, the utilization of ATR-FTIR spectroscopy enabled the accurate determination ofpolymer types within the microplastic samples extracted from the Western Province. The resonance of spectra with well-established reference materials provides a robust basis for the identification and classification of microplastic polymers, enhancing our understanding of theplastic pollution landscape in the region.

Each type of plastic polymer has a unique absorption spectrum in the 900 - 1700nm wavelengthrange. Identified MPs were illustrated in Figure 9 and Figure 10 by using an FT-IR machine. Figure 9 was given spectra identified by (a) filaments (red and blue) + fragments(red and blue) and others in Negambo, (b) filaments (red and blue) in Sarakkuwa, (c) filaments(blue and red) in Galle Face, (d) filaments (red and blue) in Dehiwela, (e) fragments (red and blue) in Panadura, (f) fragments(red and blue) in Beruwela and they were respectively match with spectra percentages of (a) Polypropylene 99.4%, (b) Polypropylene 98.9%, (c) Polyvinyl Chloride-Hard 96.8%, (d) Polyvinyl Chloride-Un plasticized 93.8%, (e) Polyvinyl Chloride- Un plasticized 52.0%, (f) Polyphenylene Ether + High Impact Polystyrene 66.8%. And Figure 10 illustrated spectra matched with the tested samples (g) Polypropylene 70.1%, (h) Polypropylene Copolymer 57.6%, (i) Blend of Polypropylene and Ethylene / Propylene 17.3%,(j) Blend of Polypropylene and Ethylene / Propylene 15.0% and (k) Polyethylene-linear low density and Polyethylene-high density 65.3%.these matched percentages of spectra identified by (g) filaments (red and blue) and others in Negambo, (h) filaments (red and blue) and othersin Galle Face, (i) fragments (red and blue) in Sarakkuwa, (j) fragments (red and blue) in Dehiwela and (k) collected all of MPs particles in the in 6 locations respectively. Most identified spectra with a match rate of > 50% to the polymer database were evaluated of samples investigated using FT-IR. Two of the spectra match with < 50% by using the FT-IR machine. In this tested samples were identified at least five main polymers' matched spectra, among the main different polymers.

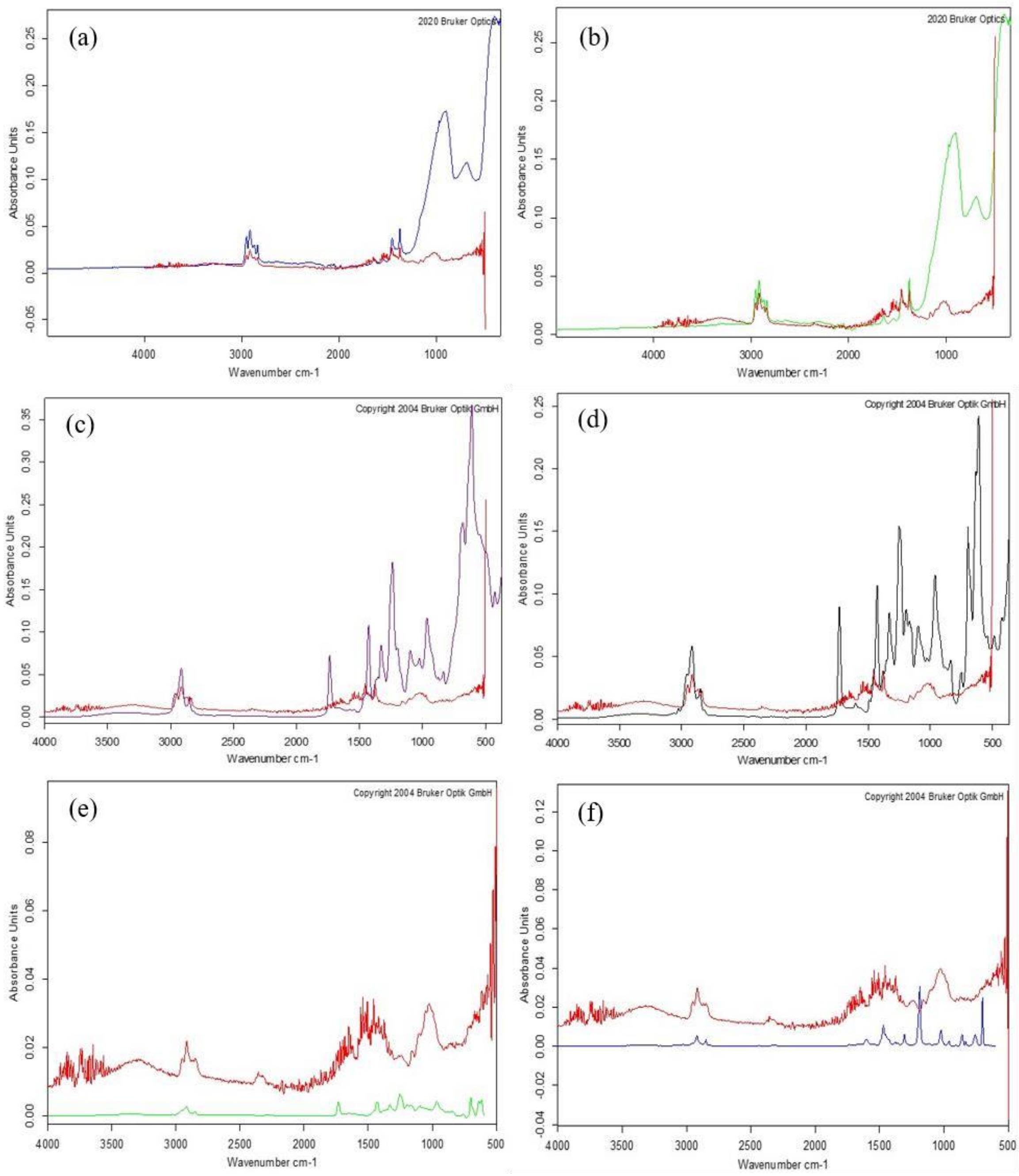

Figure 9: FT IR spectra of analyzed MPs in species

■,■,■,■ Reference spectrum ■ Measured spectrum

(a) Polypropylene (PP) identified by filaments (blue and red), fragments (blue and red) and others in Negambo,Polypropylene (PP) identified by filaments (blue and red) in Sarakkuwa, (c) Polyvinyl Chloride-Hard (PVC- Hard) identified by filaments (blue and red) in Galle Fcaet, (d) Polyvinyl Chloride-Un plasticized (PVC-U) identified by filaments (blue and red) in

Dehiwela, (e) Polyvinyl Chloride-Un plasticized (PVC-U) identified by fragments (blue and red), and others in Panadura, (f) Polyphenylene Ether + High Impact Polystyrene (PPE + HIPS) identified by fragments (blue and red) in Beruwela.

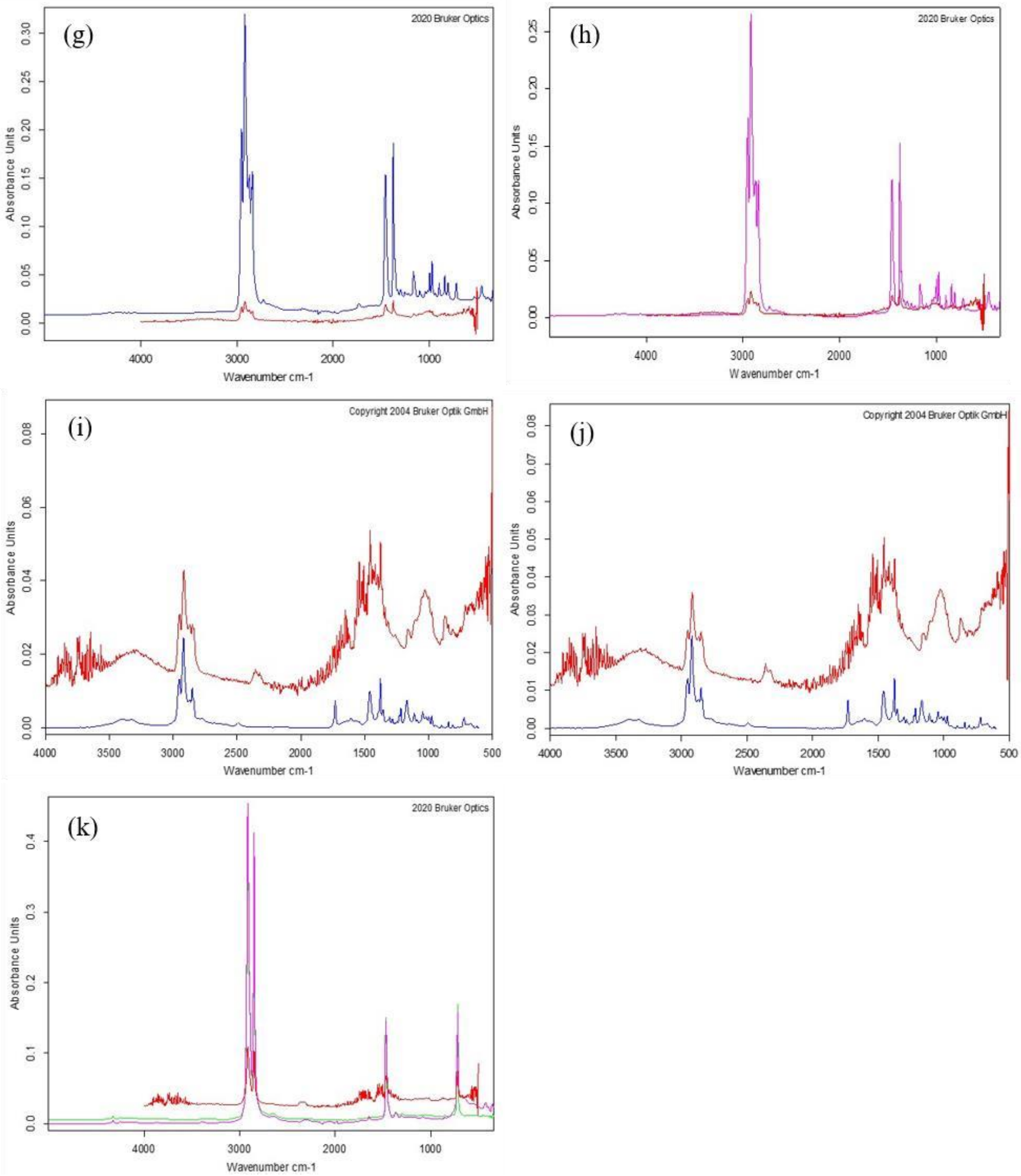

Figure 10: FT IR spectra of analyzed MPs in Selected species

■, ■, ■, ■ Reference spectrum ■ Measured spectrum

(g) Polypropylene (PP) identified by filaments (blue and red) and others in Negambo (h) Polypropylene Copolymer (PP-C) identified by filaments (blue and red) and others in Galle Face, (i) Blend of Polypropylene and Ethylene / Propylene (PP + EPDM) identified by fragments (blue and red) in Sarakkuwa, (j) Blend of Polypropylene and Ethylene / Propylene (PP + EPDM) identified by fragments (blue and red) in Dehiwela, and (k) Polyethylene-linear low density (PE-LLD) - pink color and Polyethylene-high density (PE-HD) – green coloridentified by collected all of MPs particles in six selected locations.

Recommendations and Implications for Seafood Safety

The findings from this study emphasize the urgent need for comprehensive waste management strategies and pollution control measures to address microplastic contamination in Sri Lanka. Understanding the temporal and spatial patterns of microplastic accumulation is critical for developing targeted strategies, particularly in areas with high seafood consumption. Improved waste management, stricter pollution controls, and public awareness campaigns are essential for reducing plastic waste in coastal regions. The presence of microplastics (MPs) in *Saccostrea cucullata*, a commonly consumed oyster species, raises serious concerns about seafood safety. As filter feeders, oysters can accumulate MPs from their environment, potentially exposing humans to harmful particles and associated contaminants. MPs can adsorb toxic chemicals, such as polychlorinated biphenyls (PCBs) and heavy metals, posing significant health risks, especially for populations in Sri Lanka that rely on seafood as a primary protein source.

High levels of MP contamination at sites like Galleface and Dehiwala, both densely populated and industrialized, underscore the need for increased monitoring and regulation of plastic pollution. Given the reliance on coastal fisheries, it is crucial to implement public awareness campaigns regarding the risks of microplastic contamination. Stricter waste management policies are necessary to mitigate health risks from contaminated seafood. Future research should focus on the long-term effects of microplastic ingestion on marine species and the implications for human health. Developing localized interventions that consider the specific environmental and socio-economic contexts of coastal regions is essential to protect both aquatic ecosystems and the health of seafood consumers.

Ecological and Health Implications of Specific Polymer Types

The polymer types identified in the oysters were dominated by filamentous blue particles, with sizes smaller than 1 mm accounting for nearly 25% of the total MPs. The identification of these polymer types, including polyethylene (PE), polypropylene (PP), and polystyrene (PS), raises several important ecological and health concerns.

MPs like PE, PP, and PS are among the most commonly found plastics in marine environments and are resistant to degradation. These plastics can persist in the marine environment for hundreds of years, posing a long-term threat to marine ecosystems. These polymers can entangle marine organisms, block feeding mechanisms, or be ingested by a variety of species, including filter-feeding organisms such as oysters, leading to physical harm and reduced survival. Additionally, these plastics can act as carriers for harmful contaminants, such as heavy metals and persistent organic pollutants (POPs), which can further harm marine life.

From a human health perspective, the ingestion of MPs through seafood consumption is a growing concern. Polyethylene and polypropylene, in particular, are known to leach toxic chemicals into marine organisms over time. These chemicals can enter the human food chain, posing risks of chemical toxicity and endocrine disruption. The study underscores the need for further research into the chemical toxicity of specific polymers and their potential to bioaccumulate in higher trophic levels, ultimately affecting human health.

Future Research Directions

The study offers several future research directions, although these could be expanded to include more specific and actionable suggestions

Bioaccumulation in Higher Trophic Levels: One of the critical areas for future research is the study of MP bioaccumulation in higher trophic levels, particularly in fish and marine mammals. Since filter feeders like oysters are known to accumulate MPs, it is essential to assess how MPs may move up the food chain and whether they pose risks to apex predators and humans who consume seafood.

Chemical Toxicity of Microplastics: Another key area for future studies is assessing the chemical toxicity of different types of MPs. Specific attention should be given to the leaching of hazardous chemicals, including additives and monomers that could have adverse effects on marine organisms and human health. Laboratory-based experiments examining the impact of these MPs on marine life could help us understand their potential to disrupt ecosystems and cause long-term environmental damage.

Continuous monitoring of microplastic contamination in coastal ecosystems is necessary to identify long-term trends and the effectiveness of mitigation strategies. Future research should include the establishment of long-term monitoring programs to track MP pollution over time and assess the success of waste management initiatives.

Conclusion

This study successfully met its objectives by analyzing microplastic (MP) accumulation in *Saccostrea cucullata* along Sri Lanka’s West coastal belt and revealing significant spatial and temporal variations. The results showed that MP concentrations were highest in urbanized areas such as Galleface (5.11 ± 2.2 MPs/g w.w.) and Dehiwala (4.87 ± 0.71 MPs/g w.w.), where human activities like urban runoff, industrial waste, and tourism were prevalent. Negombo Beach had the lowest MP concentration (2.60 ± 0.77 MPs/g w.w.), indicating less exposure to pollution compared to more urbanized regions. In terms of temporal variation, the highest MP concentrations were recorded during the South-west monsoon, suggesting that increased rainfall and runoff significantly contributed to plastic debris entering the coastal waters. The study also observed a decline in MP levels during the inter-monsoonal and North-east monsoon periods, reinforcing the influence of seasonal changes on MP distribution.

The presence of MPs in *Saccostrea cucullata* raises critical concerns for seafood safety. As filter feeders, oysters are particularly vulnerable to MP contamination, and these particles can adsorb toxic chemicals such as polychlorinated biphenyls (PCBs) and heavy metals, which pose risks to human health when contaminated seafood is consumed. These findings emphasize the need for improved waste management practices, stricter regulation of plastic pollution, and targeted interventions in areas with high contamination. Public awareness campaigns and policies to reduce plastic waste are essential to mitigate the risks associated with MP contamination in seafood and protect both marine ecosystems and human health. Further research should explore the long-term effects of MP ingestion on marine organisms and human health, as well as strategies to reduce the sources of plastic pollution in Sri Lanka's coastal environments.

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