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RESEARCH ARTICLE

Abundance of microplastics in coastal area surface water at Tok Bali, Kelantan.

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ABSTRACT

Plastic is a man-made material made up of polymers, which are long molecules structured around carbon chains. Microplastic pollution affects the environment by altering habitats and natural processes. Human activities produce plastic waste, which causes pollution to the environment. Tourism areas are one of the highly exposed areas for microplastic pollutants since a lot of activity is held. Tok Bali Beach is a tourist attraction and a resort area for residents around Tok Bali Beach. Therefore, this study is needed to assess the abundance, distribution, and characteristics of microplastics in the surface waters of Tok Bali beach, Pasir Puteh, Kelantan. In this study, 10 sampling points were selected in the beach area to determine the presence of microplastics in the surface water. Photomicroscopic examination, Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) were used to identify the presence of microplastics in surface seawater samples. Five types of microplastics in the surface seawater such as pellets, fibers, fragments, filaments, and films were identified in this study. Photographic microscopy revealed that flakes were the most dominant form, followed by pellets and fibers. These findings highlight the significant presence of microplastics in the surface waters of Tok Bali Beach, emphasizing the need for pollution mitigation and sustainable coastal management.

1. INTRODUCTION

Plastics derived from petroleum—including polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polyethylene terephthalate (PET) are produced at massive scales worldwide. PE and PP dominate global output, while PET accounts for nearly 18% of the market share (Leng et al., 2018). Global plastic production now exceeds 400 million metric tons annually and is projected to double by 2040 if trends continue. Due to their durability, plastics persist in natural environments, fragmenting into smaller particles and accumulating in soils, rivers, and marine ecosystems (Kavitha & Kandasubramanian, 2020).

A growing environmental concern is microplastic (MP) pollution. MP is defined as plastic fragments under 5 mm in size derived from degradation or primary sources like microbeads. These particles can remain in the environment for decades and have been detected in oceans, rivers, estuaries, lakes, polar ice, and alpine snow (Bergmann et al., 2019; Bellasi et al., 2020). They bioaccumulate in aquatic organisms, move through trophic levels, and pose ecological and human health risks (Ivar do Sul & Costa, 2014; Jiang et al., 2022). Recent research has also raised health concerns: microplastics in drinking water are often smaller than 20 µm, increasing the likelihood of passage into blood and organs (Chadwick, 2025), while bottled water may contain about 250,000 nanoplastic particles per liter (AP News, 2025).

In Malaysia, mismanaged plastic waste totals approximately 0.94 million metric tons annually, positioning the country among the world's top contributors to marine plastic pollution (Jambeck et al., 2015). In response, Malaysia has implemented the Malaysia Roadmap Towards Zero Single-Use Plastics 2018–2030 and aligned its policies with the Sustainable Development Goals (SDGs), particularly SDG 14 (Life Below Water). Despite these initiatives, systematic microplastic monitoring remains limited compared to other Southeast Asian countries, constraining ecological risk assessment and management strategies (Anuar et al., 2023).

Malaysia's extensive coastline of over 4,800 km supports mangroves, seagrass beds, and coral reefs vital for fisheries, tourism, and food security. Coastal waters are especially vulnerable to plastic leakage from urban runoffs, ports, and tourism hotspots. Recent studies have detected microplastics and macroplastics in Malaysian contexts such as Kuala Langat beaches, where contamination was recorded even in remote areas (Nor et al., 2025); in river basins including Kelantan and Langat, where MPs reached up to 1,465 items/L (Anuar et al., 2023); and in the intertidal sediments of Kota Kinabalu, Sabah (Lau et al., 2022). These findings indicate widespread contamination yet highlight geographic gaps, especially along the east coast of Peninsular Malaysia.

Kelantan is one such under-researched area, despite its coastal ecosystems' importance for local livelihoods and fisheries. A recent investigation found an average of 5.36 particles per gram of sediment along Kelantan beaches, with intertidal zones heavily impacted (Abd Wahid et al., 2025). Although previous research has reported the spatial distribution of microplastics in beach sediments, information on their occurrence in coastal surface waters remains scarce.

To address this gap, the present study investigates the occurrence and characteristics of MPs in the surface waters of the coastal area in Tok Bali, Kelantan. Tok Bali, being a rapidly developing port and fishing hub, experiences unique anthropogenic and hydrodynamic influences that may alter microplastic transport and accumulation patterns distinct from the environments. Therefore, investigating microplastics in the surface seawater of Tok Bali provides new baseline data essential for understanding their mobility, ecological risk, and management implications. By situating local evidence within national waste management and global marine plastic contexts, this research aims to inform coastal environmental management and policy strategies that Malaysia is pursuing to curb plastic leakage into aquatic ecosystems.

2. MATERIALS AND METHODS

This study includes sampling activities on the site and lab analysis to determine the microplastic pollution in the water in the coastal area.

2.1. Sample collection

Water samples were taken at 10 sampling points as shown in Figure 1 by using 1 L glass jars (1 L x 10 jars). The distance between the sampling points is about 200 to 300 m. The coordinate for the sampling points is shown in Table 1. Samples were collected by venturing beyond the point where the waves crashed to avoid sediment contamination, wading to a depth of about 2 feet beyond the surf line, and then opening the glass jar. Surface water samples were obtained by submerging a container into a body of water. The jar is lifted carefully to ensure it is filled with water and to remove any air bubbles. The jar number was recorded, and the relevant data sheet was completed with details such as sample related information, GPS coordinates and date and time of sample collection. This sample is taken back to the laboratory for the filtration process. Water samples were stored at room temperature indefinitely. If there is a large amount of sediment in the water sample, allowing it to settle facilitates the filtration process (Sartain et al., 2018).

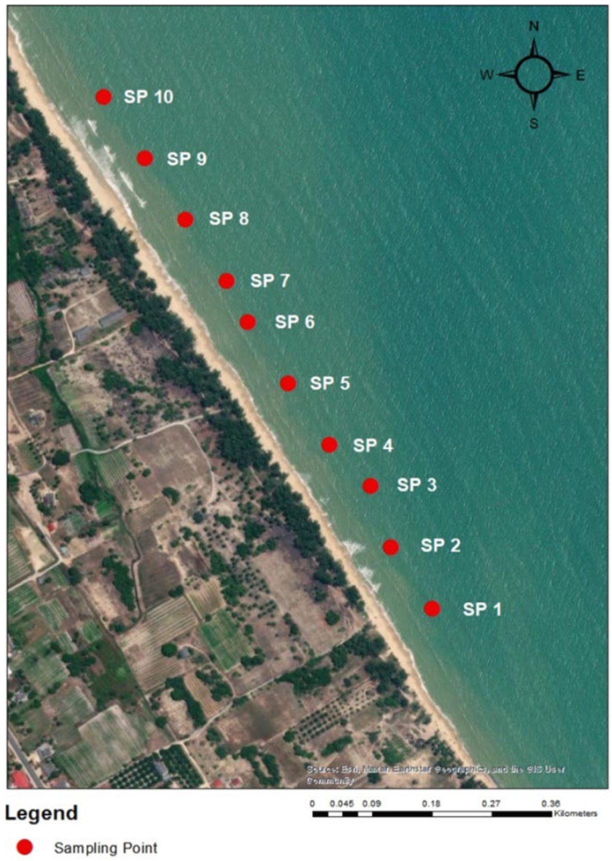


Figure 1: Sampling points at Tok Bali, Pasir, Puteh, Kelantan

Table 1: Coordinates of the sampling points

Sampling Point	Latitude (N)	Longitude (E)
1	5°54'07"N	102°28'50"E
2	5°54'10"N	102°28'48"E
3	5°54'13"N	102°28'47"E
4	5°54'15"N	102°28'45"E
5	5°54'18"N	102°28'43"E
6	5°54'21"N	102°28'41"E
7	5°54'23"N	102°28'40"E
8	5°54'26"N	102°28'38"E
9	5°54'29"N	102°28'36"E
10	5°54'32"N	102°28'34"E

2.2. Density Separation

About 20 ml of water samples were poured into nine different 250 ml beakers. Then, 40 ml of 0.05 M Fe (II) solution was added. Next, about 40 ml of 30% hydrogen peroxide (H_2O_2) was added. The mixtures were stand on for five minutes in the room temperature. After that, the mixtures were stirred and heated at a temperature of 75˚C on the hotplate. Then, the beaker on the hotplate was removed and placed inside the fume cupboard until the boiling subsides. After that, the mixtures were heated for another 30 minutes at 75˚C. About 40 ml of 30% H_2O_2 was added to the mixture when the presence of visible natural organic material in the mixture occurred. Thus, these steps were repeated until there was no visible natural organic material. After that, about 6 g of sodium chloride (NaCl) was added to the mixture. This was to increase the density of the aqueous solution. After NaCl was completely dissolved, the beakers were sealed with aluminium foil loosely and kept for three days at room temperature in the fume cupboard before the filtration process.

2.3 Water Filtration

The water samples were filtered by placing the filter funnel on the filter flask and connecting the vacuum pump to the flask. The water sample was poured into the funnel under a vacuum. The cap on the sample bottle was replaced immediately, and the tab on the funnel cap was opened to prevent the vacuum funnel from closing once the filtration process began. A vacuum filter set was used to separate foreign matter from the water sample. The filter paper was carefully lifted by its edges using forceps and transferred to the petri dish. The microplastics were assessed under the microscope to determine the count, shape, and colour (Microplastics Sampling and Processing Guidebook, 2018).

2.4. Photography Microscope Exam

Each filter paper was examined under a photographic microscope with 40x and 10x magnification to detect the presence of microplastics in each sample. This process will be important to count the amount of each microplastic, distinguishing the shape and colour of the microplastic deposited on the filter paper. The computer screen will display a clear image depicting the size and shape of the microplastic identified on the filter paper due to its connection with the microscope. After the identification of microplastics, the findings were recorded in a computer database before undergoing analysis by Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscope (SEM) for further characterization.

2.5. Hot Needle Test

The utilization of the hot needle test presents an alternative approach for the direct detection of microplastics within bulk samples or during remnants from prior treatments (Devriese et al., 2015). A hot needle, which is cautiously managed with tweezers, is brought into contact with suspected microplastics. The Hot Needle Test was utilized on the sample in situations of uncertainty. This method involves the application of a hot needle technique for the categorization of microplastics and non-microplastics. A pin or needle is straightened and heated at the tip with a candle or lighter, ensuring no combustion occurs.

Subsequently, the heated needle was inserted at the location where the identification of microplastics is challenging. The microplastic present will adhere to the hot needle. The needles induce sticky behavior in plastic materials and create distinctive marks on their surfaces, unlike non-plastic particles that remain unaltered upon interaction with the hot needle (Vandermeersch et al., 2015).

2.5. FTIR Analysis

Fourier Transforms Infrared Spectroscopy (FTIR) analysis is used in the mapping of cellular constituents (proteins, lipids, and carbohydrates) to detect atypical cells (Petibois & Déléris, 2006). Therefore, the use of this tool is very suitable for knowing the type of microplastic polymer in water. A few samples, as representatives of all samples, will be analysed to ascertain the presence of microplastics using Fourier Transform Infrared Spectroscopy (FTIR).

Micro-Fourier Transform Infrared Spectroscopy equipped with Attenuated Total Reflection (μ-ATR-FTIR) will be utilized to create a highly accurate microplastic detection system. This step will be important to characterize the morphology and composition of the particles taken from the sample. The bands used in FTIR will span from 400 to 1200 cm^{-1}. Subsequently, the characterization of the microplastics found in the sample will be compared with the spectrum of standard plastics based on their type.

2.6. SEM Analysis

Scanning Electron Microscope (SEM) is being employed by most studies that are characterizing microplastic debris (Wagner et al., 2017). The use of SEM is to measure the morphology of microplastics in terms of size and shape, and to determine the fragments of microplastics digitally. SEM in the subsequent attributes and traits Lenses use light bending to enlarge pictures. SEM, which depends on the release of electrons. SEM with a 300,000x magnification. On the other hand, grayscale images from SEM reveal a more detailed field.

A few samples, as representatives of all samples, will be transferred onto conductive carbon tape and adhered to an aluminium SEM sample holder for analysis. The particles underwent chemical and morphological characterization using a scanning electron microscope (SEM) (Quanta 200FEG, FEI) equipped with an energy dispersive X-ray microanalyzer

(EDAX Genesis). Operating in "low vacuum" mode at 1.2 mbar prevented any electrical charging effects on the sample, eliminating the need for additional sample preparation such as coating. EDX analysis in "low vacuum" mode was conducted at a working distance of 10 mm, utilizing a high voltage of 15-25 kV and a spot size of 5 (Fries et al., 2013).

2.7. Data Analysis

The data acquired through sampling and subsequent laboratory analysis were incorporated into ArcGIS PRO 3.4 software for visualization as a distribution map and were analysed using IBM SPSS version 27 based on the sampling point for significant differences. The map generated using ArcGIS PRO 3.4 software is designed to illustrate the spatial dispersion of microplastics in the coastal surface waters of Tok Bali, Pasir Puteh, Kelantan. A significant ANOVA test ($p<0.05$) was conducted to compare the MPs occurrence in the sampling points.

3. RESULT AND DISCUSSION

3.1. Abundance of Microplastics

The abundance of microplastics in water samples is an indicator for assessing the level and impact of plastic pollution around the coast. 275 microplastic particles were found in water samples taken from 10 sampling locations along ±1 km of coastline during this study, which was carried out at Pantai Tok Bali, Pasir Puteh, Kelantan. The total abundance and type distribution varied considerably among sampling points, indicating the influence of both anthropogenic and environmental factors such as sediment properties and hydrodynamic processes (Li et al., 2022).

The sampling point exhibiting the highest concentration of microplastic content was identified at point 10, which recorded 91 examples of fiber type microplastics. While sampling point 3 had the lowest concentration of microplastics, which was 7 particles/L. According to Imhof et al. (2017), the global distribution and abundance of microplastics are influenced by environmental factors such as wind, tides, currents, river flow, and tributary input, as well as human activities, including the discharge of effluent containing microplastics from water treatment plants. This shows that the distribution of microplastics is influenced by wave flow, tides that occur on the beach, changes in wind flow, and human activities that occur along the Tok Bali beach.

During the quantitative analysis of microplastics, it was observed that the prevalence of fiber types was notably significant across all examined surface water samples under microscopic scrutiny. The findings of the investigation revealed the presence of various hues, including red, blue, white, black, and colourless entities within the aquatic samples. The coastal waters located in Tok Bali, Pasir Puteh, Kelantan exhibited a diverse array of fiber types. Analysis of microplastics across 10 sampling sites reveals that fiber type microplastics were the most prevalent, significantly outnumbering flakes, filaments, pellets, and films. This finding underscores the high abundance of fiber type microplastics within the samples. The predominance of fibre-type microplastics observed in this study aligns with findings from other Malaysian coastal surveys, such as those in the Terengganu estuary and offshore waters, where fibres represented over 70% of total particles (Taha et al., 2021). Similar dominance of fibres has also been recorded in tropical estuaries and coral reef regions in Peninsular Malaysia, reflecting the widespread release of textile fibres from fishing gear, tourism-related litter, and domestic wastewater discharge (Lim et al., 2024; Yusof et al., 2023).

In this study, the type of microplastic that was very rarely found in all samples was the film type. Only 2 particles/L were found in the form of films in all samples. The results of the abundance of microplastics are shown in Table 2.

Table 2: Abundance of Microplastics in Coastal Surface Waters of Tok Bali

Sampling Point	Types of Microplastics (particle/L)				
	Fiber	Fragment	Filament	Pallet	Film
S1	17	-	-	-	-
S2	8	1	-	-	1
S3	5	1	-	1	-
S4	16	-	2	1	-
S5	18	3	-	5	-
S6	24	1	-	2	-
S7	39	-	-	2	-
S8	21	-	-	-	-
S9	16	-	-	-	-
S10	91	-	-	-	-

The amount of microplastics found from the study results was used to calculate the percentage of microplastics throughout the investigation. When compared to other types of microplastics, the investigation revealed that the fiber type was the most common. According to Zhu et al. (2018), the use of fishing gear such as nets and lines as the main source of replacement microplastics is the type of microplastics that is abundant in coastal areas. In seawater samples, the replacement type was present in 92% of cases. A total of 4% pellets came next, then 2% filament pieces (0.7%) and, lastly, films (0.3%). The graph of the percentage of abundance of microplastic types is shown in Figure 2.

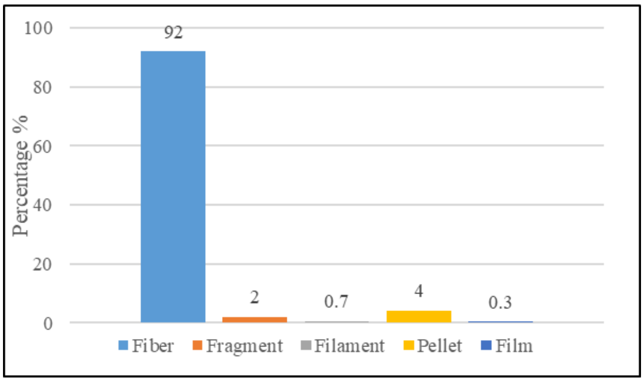


Figure 2: Percentage of abundance of microplastic types

Some sampling points exhibit higher levels than others, indicating the diversity and breadth of sources of microplastic contamination. This variation is likely due to local activities, such as inappropriate waste disposal and fishing operations that harm the environment. Meanwhile, the MPs abundance in coastal surface waters was analysed using one-way ANOVA, showing no significant difference between each sampling site with $F(8, 1) = 0.7$, $p=0.734$ (> 0.05).

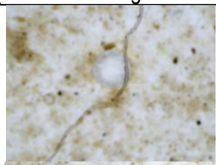
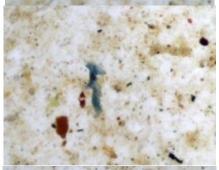
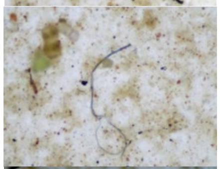
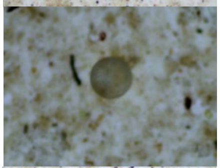
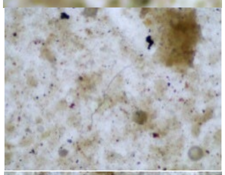
3.2. Physical Characterization of Microplastics

Upon applying the filtration technique utilizing filter paper, the subsequent Photographic Microscopic Examination (Biological Microscope-Rax Vision Y-100) was employed to ascertain the existence of microplastics by employing 4x and 10x magnification. The Photographic Microscopic Examination revealed that each specimen exhibited a diverse array of types and various colours, including fibers, pellets, and flakes. A spectrum of colors was identified, notably blue, black, and red. These were the various types observed in each sample procured from the respective sampling locations. A comprehensive inventory of the shapes, colors, and forms of microplastics detected during the initial sampling is presented in Table 3.

Microscopic examination identified fibres, fragments, and pellets as the dominant morphotypes, with colours such as blue, red, black, and transparent observed across sampling sites, as shown in Table 3. The high proportion of coloured fibres suggests extensive inputs from synthetic textiles, ropes, and fishing nets, consistent with reports from both Malaysian and regional waters (Anuar et al., 2023; Sulaiman et al., 2023). Transparent and clear particles likely originate from packaging materials and degraded fishing lines, while coloured fragments reflect the breakdown of consumer plastics.

Microplastics can be easily identified and categorized by kind utilizing photographic microscopic examination. When examined under a microscope, fibers of different shapes are discovered. Sometimes they resemble threads, as seen in the sample point 3 image, and other times they are wrapped up, as seen in the sample point 9 image. The pellet kind has a distinctive shape that is clear, round, and pearl-like. Sample point 6 displays translucent, triangular-shaped particles that

Table 3: Physical characteristics of microplastic presence in each sampling point

Sample Point	Microplastic (4x and 10x magnification)	Physical Characteristics
1		Shape: Fiber and Pellet Colour: Transparent
2		Shape: Fragment Colour: Blue
3		Shape: Fiber Colour: Blue
4		Shape: Pellet Colour: Transparent
5		Shape: Fiber Colour: Blue
6		Shape: Fragment Colour: Transparent
7		Shape: Fiber Colour: Red
8		Shape: Fiber Colour: Red
9		Shape: Fiber Colour: Black
10		Shape: Fiber Colour: Black

resemble crystals. Fragments were detected at several sampling points, with larger amounts at sampling points 2 and 6. These irregularly shaped particles, characterized by sharp edges at sample point 6. According to Chubarenko et al. (2016), fragments are formed through mechanical breakage of larger rigid plastic items such as bottles, containers, and caps.

The Scanning Electron Microscope (SEM) revealed that each specimen exhibited a diverse array of morphological types. Figures 3 (A – D) show the range of 200 µm to 500 µm, the type of microplastic fibers detected in selected areas of the sample. The clearest image obtained at 100x magnification shows long, thin fibers and the shape of the microplastic can be seen by its somewhat scattered surface at the ends. The majority of microplastics found were fibers only. The shape found is like thread and hair. As shown in Figure 3(A), these fibers appear slightly curled and overlap with one another.

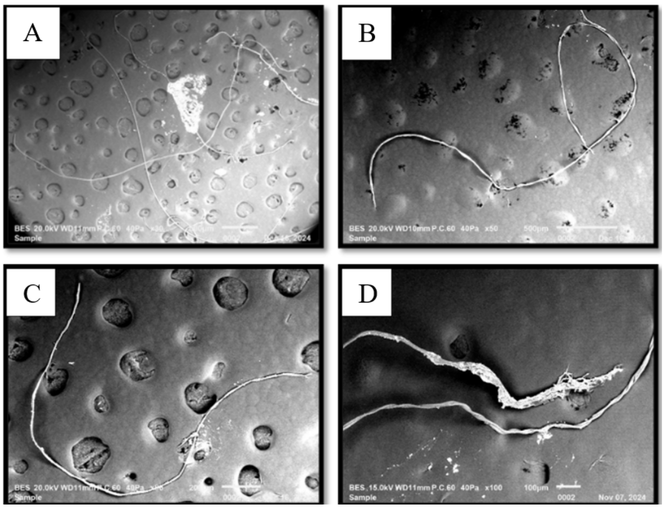


Figure 3: Fiber types of microplastics under magnification of (A)30x, (B)50x, (C)80x, and (D)100x

SEM imaging provided detailed visualization of microplastic fibres, showing frayed ends and surface pitting consistent with mechanical abrasion and photooxidation. Such degradation patterns are indicative of prolonged exposure to seawater and UV radiation (Goh et al., 2025). These microstructural features suggest that some particles have undergone secondary fragmentation rather than being introduced as pristine primary microplastics.

The prevalence of fibre-like morphologies at all sampling stations underscores the persistence and mobility of these particles in surface water. Fibre buoyancy and flexibility enable longer residence times compared with denser fragments that tend to settle. Similar findings were observed in microplastic assessments in coral reef waters off Peninsular Malaysia and other tropical coastal environments (Wei et al., 2022; Yusof et al., 2023). The diversity of shapes and colours recorded in this study therefore provides critical clues to mixed-source contamination pathways and environmental degradation processes in the Tok Bali region.

3.3. Chemical Characterization of Microplastics

Chemical characterization of the microplastic found in the samples was analysed by using FTIR. The results of FTIR analysis for two water samples are shown in Figure 4 and Figure 5.

Figure 4 shows that aliphatic primary amides are the chemical elements found in the water sample. The highest peak is at 3274 cm^{-1}, and the lowest peak is at 1636 cm^{-1}. Amides have relatively high boiling points because they are capable of strong intermolecular interactions. Based on Figure 4, the FTIR spectrum results for sample 1 were found to contain the type of polymer, namely polyether, which was found at a percentage of 59.83%. The range of wave numbers that can be identified is almost equivalent to and matched with the reference FTIR spectrum of cellulose provided in the FTIR Sains Termos library.

The presence of polyether polymers is particularly noteworthy, as these are commonly associated with industrial coatings, fishing materials, and household synthetic products (Lim et al., 2024). The similarity of FTIR spectra to known polymers found in regional studies indicates both primary and secondary origins, supporting the conclusion that microplastics at Tok Bali are derived from diverse terrestrial and marine-based sources (Anuar et al., 2023; Andersen et al., 2024).

For Figure 5, the analysis shows that in sample 2, the chemical content, namely primary aliphatic alcohol, has the highest peak at 3281 cm^{-1} and the lowest peak at 1636 cm^{-1}. Based on Figure 5, the FTIR spectrum results of most of the samples were found to contain the type of polymer, namely polyether, which was found at 59.83%. Based on the FTIR results, the type of polymer found to be polyether was 62.29% matched. This match is very high compared to other samples.

3.4. Map interpretation using ArcGIS PRO

The quantity of microplastics found in seawater samples from Tok Bali Beach, Pasir Puteh, Kelantan, is illustrated on a distribution map based on the types of microplastics identified. The data is categorized into fibers, fragments, filaments, pellets, and films. The distribution map for microplastics in Figure 6 illustrates the types of microplastics identified at each sample point.

Five categories are represented on the map: fiber, fragment, filament, pellet, and film. The total counts across all sample points range from 8 to 91, encompassing all microplastic types. Among these, fibers are the most prevalent and consistently present at every sample point. The map revealed that microplastic abundance increased progressively from sampling point 1 to 10, with the highest concentration corresponding to areas of intense human activity, such as fishing, small port operations, and tourism facilities. This pattern parallels recent estuarine-front studies showing that hydrodynamic convergence zones and anthropogenic proximity jointly shape spatial variability in microplastic dispersion (Paramasivan et al., 2024; Wei et al., 2022). Similar spatial heterogeneity was also reported in the Perhentian and Redang marine park islands, where accumulation hotspots corresponded to tourism and recreational areas (Yusof et al., 2023).

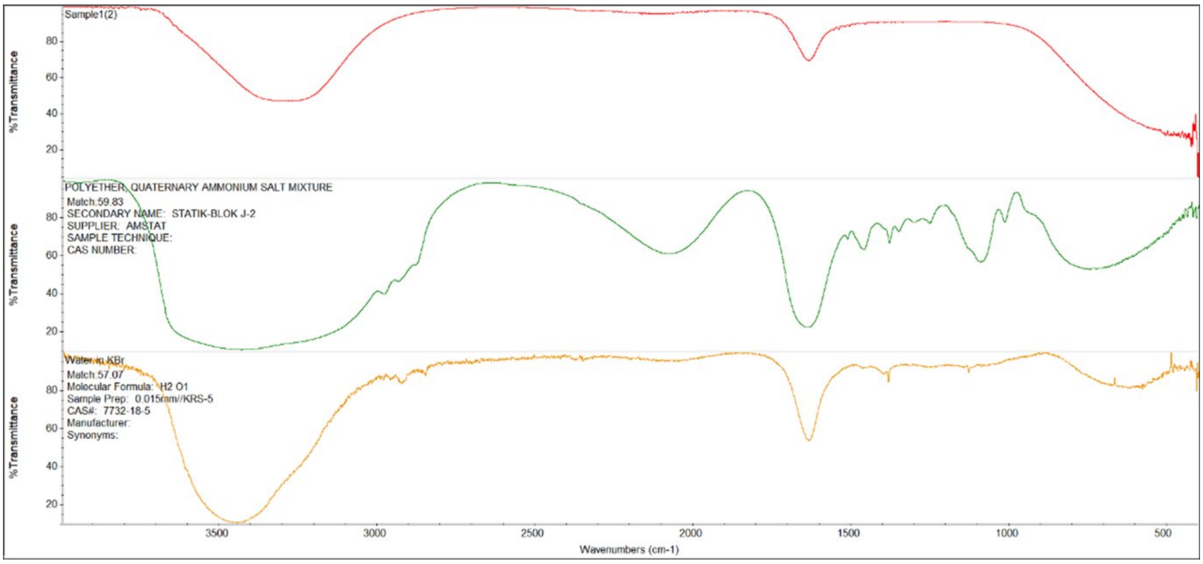


Figure 4: FTIR spectra of water sample 1 (red line) and reference polyether (green line)

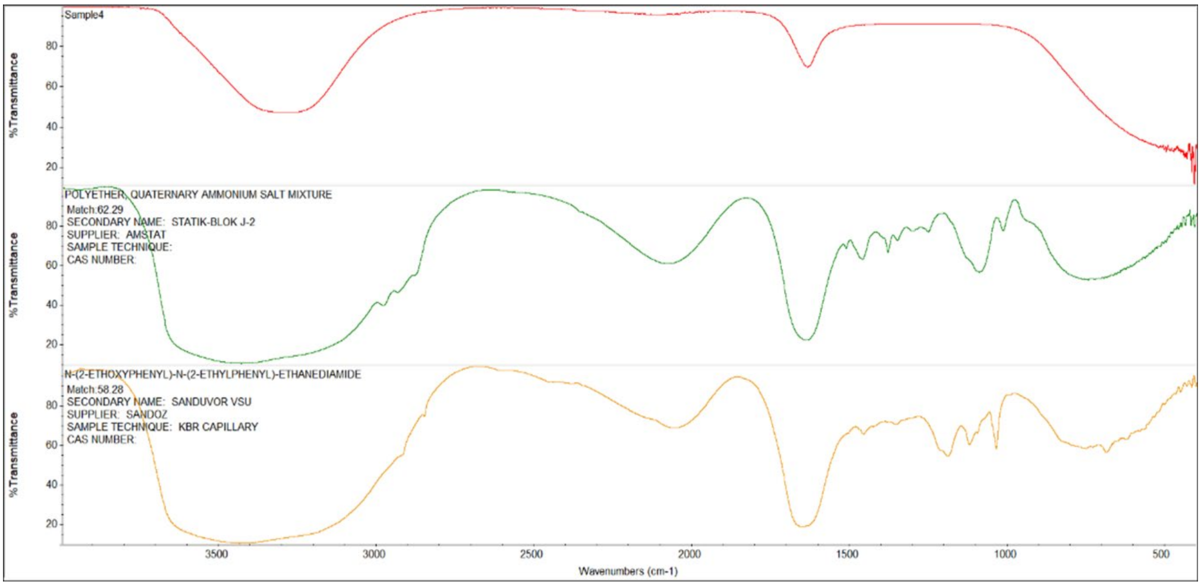


Figure 5: FTIR spectra of water sample 2 (red line) and reference polyether (green line)

The distribution map of microplastic types shows that the highest concentrations were found at sampling point 10, which is associated with intense and frequent human activities. Human behavior and activities significantly contribute to microplastic pollution at Pantai Tok Bali, Pasir Puteh, Kelantan. This issue is further compounded by the lack of general awareness of the environmental and health impacts of microplastics and insufficient motivation to engage in actions to reduce microplastic emissions (Deng et al., 2020). Raising awareness about the causes and consequences of plastic pollution is important and requires collaboration between all responsible parties. As suggested by Dowarah et al. (2022), implementing structured education programs, leveraging mass media, enforcing strict policies, and promoting the use of environmentally friendly polymers can effectively reduce microplastic pollution.

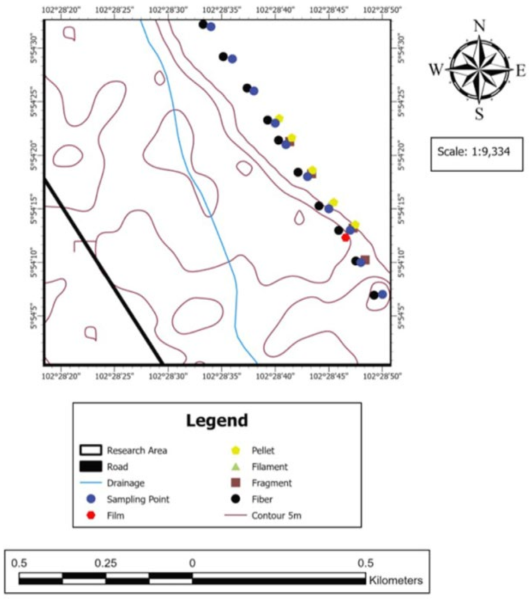


Figure 6: Distribution map of microplastics at coastal surface waters

According to Barboza & Gimenez (2015), plastic decomposes into smaller pieces rather than rotting, and microplastics emerge as uncontrolled pollutants that persist in the environment. They are also considered to be ubiquitous because they are found in all compartments of the marine environment (water, sediment, and organisms) at locations that have been studied worldwide. This indicates that the plastic debris will continue to be in the coastal area, along with the movement of waves from the sea and the wind blowing, which allows the microplastics to be present in any environment.

4. CONCLUSION

This study highlights the identification and occurrence of microplastics at Tok Bali Beach, Pasir Puteh, Kelantan. Environmental factors likely contributing to MP occurrence at Tok Bali include fishing activities, port operations, and tourism-related plastic leakage. However, causal relationships should be interpreted cautiously, as this study did not directly quantify source contributions. Instead, our findings demonstrate that Tok Bali shares contamination profiles similar to other Malaysian coastal zones, suggesting a broader issue of insufficient plastic waste management.

The findings also reveal diverse types of microplastics at specific sampling points, influenced by activities like fishing, recreation, and others. The study also notes that Tok Bali Beach is not as clean as expected, with visible garbage pollution, including plastic waste and other debris. This contributes to microplastic contamination, driven by the lack of environmental awareness and care among residents.

The detection of diverse morphotypes and polymers in Tok Bali highlights potential risks to marine organisms through ingestion and trophic transfer. Given the site's importance as a fisheries hub, MP contamination poses both ecological and socio-economic concerns. Establishing standardized monitoring protocols and integrating MP data into Malaysia's coastal management strategies will be critical to addressing this issue.

At a broader scale, recent reviews on Malaysia's microplastic pollution indicate significant gaps in standardized surface-water monitoring and cross-matrix comparison (Goh et al., 2025; Noor et al., 2024). This study, therefore, contributes essential baseline data for an understudied site, complementing sediment-based surveys such as Abd Wahid et al. (2025). By employing integrated FTIR–SEM characterization and GIS spatial mapping, this research provides a model for systematic coastal microplastic monitoring in line with the nation's Zero Single-Use Plastics 2030 Roadmap and Sustainable Development Goal 14 (Life Below Water). Continuous long-term monitoring across monsoon cycles, coupled with biological uptake studies, is recommended to assess the persistence and ecological risk of microplastics in Malaysia's eastern coastal waters.

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