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CHARACTERISTICS AND DISTRIBUTION OF MICROPLASTICS IN SURFACE SEDIMENT OF SELAT PULAU TUBA, LANGKAWI, KEDAH

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ABSTRACT

This study aims to assess the characteristics and occurrence of the microplastics contamination in surface sediment of Selat Pulau Tuba, Langkawi, Kedah. Van Veen Grab Sampler was used to collect the samples of sediment. The samples were immediately preserved and analyzed using a Fourier-transform infrared spectrophotometer and a microscope to determine the presence and characteristics of microplastics. The result indicates the presents of polypropylene and polyethylene with a size of 500 µm -1000 µm and 1000 µm - 1500 µm respectively. Overall, Selat Pulau Tuba, Langkawi, Kedah has minimal pollution of microplastics in sediment.

Keywords: *Sediment, Selat Pulau Tuba, Microplastics, Polypropylene, Polyethylene*

INTRODUCTION

Sustainability of the coastal water areas is important to be maintained due to the benefits they have towards economic and ecological roles. Ecological systems and socioeconomic importance of this area are vital because residents depend so much on it (Kandel et al., 2018). Sustainability development and management such as protection, conservation, and prevention of marine pollution allow future generations to appreciate marine resources and utilized them for better use (Kamaruddin et al, 2018). In Malaysia, where tourism activity is an important sector, it could initiate anthropogenic effects that potentially harm the marine environment.

Pulau Langkawi (Langkawi Island) is one of the tourists' hotspots in the northern region of Malaysia that generates much income to Malaysia's growth (Mohd Zahir et al., 2011). The archipelago was declared a UNESCO Global Geopark in 2007 and has become a challenge to constantly maintain nutrients in sediment and the survival of marine aquatic life because of the anthropogenic activities (Mokhtar et al., 2017). Uncontrolled anthropogenic activities and the rapidly increasing population have caused pollution to coastal water areas (Jalal et al., 2009). In addition, chemicals from industrial wastes, agricultural activities, wastewater discharges, domestic sewage releases, and atmospheric depositions could pollute the coastal environment (Gallo et al., 2018). All of these activities can cause accumulations of microplastics in the coastal water areas especially on the surface sediment (Maes et al., 2017). To date, contamination of microplastics in marine ecosystems has become an issue faced by many countries (Campanale et al., 2020; Chapron et al., 2018; De Souza Machado et al, 2018; Galloway et al., 2016; Kramm & Völker; 2017; Westphalen & Abdelrasoul, 2018). Thus, effective management plans and monitoring programs should be formulated to control and reduce the impacts of microplastics in local and global scales.

Sustainability in managing the development in Pulau Tuba especially along the strait region (Selat Pulau Tuba) is important because there has been considerable number of growing human activities recently. Besides, by monitoring and preserving this area it will encourage the conservation of mangrove ecosystems and promote sustainable eco-tourism activities. Thus, there is a need to monitor the contamination of microplastics in the surface sediment in Selat Pulau Tuba, Pulau Langkawi as sediment is important nutrients to seawater and marine organisms to survive. Without proper awareness, the presence of microplastics will give a huge negative impact to marine ecosystems in the short-term and even worse in the long-term perspectives (Kamaruddin et al., 2019). Mokhtar et al., (2017) stated that potential sources of the contamination of microplastics in sediment at Pulau Langkawi could be expected from the anthropogenic activities that include agricultural activities, industrial conducts, and domestic sewage.

Sediment is important to the ocean because it often enriches the soil with nutrients and also as a habitat for marine biodiversity (Chough et al., 2018). Plastic is a term used in many fields to describe the physical properties and behaviour of materials. The term ‘plastic’ is used here to define a sub-category of the larger class from materials called synthetic organic polymers (Lucia et al., 2018). Polymers are very large molecules that have characteristically long chain-like molecular architecture and therefore they exhibit very high average molecular weights (Rochman, 2015). They may consist of repeated identical units (homopolymers) or different sub-units in various possible sequences (copolymers).

Those polymers that soften on heating, and can be moulded, are generally referred to as ‘plastic’ materials (Kershaw & Rochman, 2015). Microplastics are widely used to describe plastic particles with a size ranging from 1 nanometer to 5 millimeters (Cont et al., 2016). Microplastics present in sediments relative to other key sediment components that govern metal behaviour that could also influence metal bioavailability (Kazmiruk et al., 2018). This sediment will be entering stormwaters and will degrade the quality of water. If not treated effectively, health problems could occur and thus, affects the social-economic activities of local residents and natural ecosystems nearby.

Consequently, this study used the Geographic Information System (GIS) applications to map and visualize the spatial distribution of microplastics. GIS is a computer-based tool that analyses, stores, manipulates, and visualize geographic information usually on the map (Sato & Iwasa, 2012). It can also provide an electronic representation of information which is called spatial data, about the Earth's natural and man-made features of a particular location into a coordinate system (Alam, 2012). The strength of a GIS is its ability to relate different information into a spatial context and to reach a conclusion about this spatial relationship that cannot be seen if the information is looked at independently (Jebara, 2007). GIS also identifies what is happening inside the specific area in terms of the relationship between environmental geography and physical geography (Rickles et al., 2017). Therefore, GIS can help to formulate the management plans to improve the quality of impaired waters (Zaidi, 2012) and monitor the human activities that can be a factor in reducing water quality. Therefore, through the analysis of contamination of microplastics by Fourier-transform infrared spectroscopy (FTIR) and mapping by using GIS applications, this study will contribute valuable information about microplastics pollution in surface sediment in the coastal regions of Pulau Langkawi, Kedah.

This study aims to investigate the distribution and characteristics of microplastics in the surface sediment of coastal water of Pulau Tuba, Langkawi, Kedah, Malaysia. The research used GIS to visualize the location of the presence of microplastics accumulations. The results and outcomes of this research could be utilised by concerned parties such as government and non-government bodies as well as environmentalists to monitor, sustain, protect, and conserve these areas effectively.

LITERATURE REVIEW

Pulau Langkawi is located in the Straits of Malacca and has a total covered area of about 478.5 square kilometres (Nasher et al., 2013) and has been earmarked as one of the country leading destinations for tourism hotspot and development. The island is well known because of the beautiful scenery of its beaches, rich in marine aquatic life and coral reef, tropical weather, verdant rainforests, freshwater lakes, and the karst landscape, which makes it as an asset to be protected and support the economics of this country especially in the tourism sector (Omar et al., 2014).

Agriculture, aquaculture, fishing, and transportation are the activities contributing to the problem of ocean pollution (Salleh et al., 2014). Besides, the non-point sources such as manufacturing activities, sewage treatment plants, animal farms, and agro-based industries have degrading effects on the environment (Mokhtar et al., 2017). Becoming a popular destination for tourists, its marine and coastal environment is being exposed to the anthropogenic effects (Azmir & Samat, 2010). This has caused an alarming concern about marine water and sediment pollution. As a result, the issue pertaining to anthropogenic should be highlighted effectively.

Sediment is important because it transports inorganic and organic nutrients to the ocean bottom (Forsberg, 1989). It is important to the ocean because it often enriches the soil with nutrients and it is also rich in biodiversity (Chough et al., 2018). When plastic is exposed to the environment, it will cause slow degradation (Zobkov & Esiukova, 2017). This sediment will be entering the stormwater and would degrade the quality of water used for drinking, wildlife, and the land surrounding the streams; this is particularly true when it is contaminated with microplastics.

Microplastics can be classified into two types which are primary and secondary (Hamid et al., 2018). Primary microplastics are small plastic particles released directly into the environment by domestic and industrial effluents, spills, and sewage discharge or indirectly (Rochman, 2015). On the other hand, the secondary microplastics are formed as a result of the gradual degradation of larger plastic particles already present in the environment, due to the ultra-violet (UV) radiation mechanical transformation and biological degradation of microorganisms like polyethylene (PE), polystyrene (PS), polypropylene (PP) and polyvinylchloride (PVC) (de Sá et al., 2018).

Ingestion of microplastics by aquatic organisms can give negative health impacts, such as mechanical injury, false satiation, low growth rate, increased immune response, energy depletion, blocked enzyme production, decreased fecundity, oxidative stress, and even morbidity (Wang & Wang, 2018). Microplastics particles have a large surface area to volume ratio which provides a high association potential for environmental contaminants including polycyclic aromatic hydrocarbons (PAHs) (de Sá et al., 2018). Besides that, microplastics that are contaminated into marine aquatic will give possible adverse human health effects (Lavorante et al., 2018). It is thought that only the smallest particles (1.5 μm or less) will penetrate the capillaries of the organs and the remaining will be excreted. Mapping the pattern and distribution of microplastics in the sea area would help concern parties to formulate strategic preservation and conservation plans.

The Geographic Information System (GIS) is a system that was designed to compile, capture, store, manipulate, analyse, manage, and present all types of geographical data (Childs, 2004). Xiong et al., (2018) for instance, used GIS applications to map the distribution patterns and the characteristics of microplastics. They indicate that tourism activities are important sources of microplastics found in the study area.

METHODOLOGY

Study Area

Pulau Tuba is a remote island located next to the Pulau Dayang Bunting, Langkawi, Kedah. This research is conducted at the Selat Pulau Tuba (The Strait of Pulau Tuba) due to its importance for future development and significant natural resources. In addition, complex mangrove species and other marine vegetations can be observed along the coastal water of Pulau Dayang Bunting and Pulau Tuba. The strait is also home to the islanders where the daily activities vary from fishing to working in the mainland island, Perlis and Kedah. When compared to Pulau Langkawi, Pulau Tuba is quite remote and less developed. Thus, the research and knowledge on the impact of anthropogenic activities in this area are limited.

Raw Materials and Chemicals

Samples of surface sediments were randomly collected at the Selat Pulau Tuba, Langkawi, Kedah. The chemical involved in this research were Sodium Chloride (NaCl), Ferrous sulphate heptahydrate (FeSO4.7H2O), Sulphuric acid (H2SO4), and 30% Hydrogen Peroxide (H2O2).

Apparatus

The experiment required 800 mL beakers, 500 mL beakers, weighing balance, stir bars, watch glasses, hot plates, microscope, metal forceps, and sieving apparatus with a mesh size of 0.5 mm, 1.5 mm, and 1.0 mm. The research also used aluminium cups, glass slides, funnel, vacuum filters, and measuring cylinders.

Instruments

This research used Fourier-transform infrared spectroscopy (FTIR) for the identification and determination of functional group and types of microplastics, an oven for the drying processes, and a dissecting microscope for the determination of the colour and size of microplastics in the samples.

Software

Beside, this research used a geo-processing program - ArcMap Version 10.0 software to create, store, and modify spatial maps. This research also used Microsoft Excel for data entry, manipulation, and record.

Assessment

Sampling Method and Design

The samples of surface sediment were collected during two sampling activities (31 March 2019 and 21 April 2019). The samples were collected using Van Veen Grab Sampler and shovels. Van Veen Grab Samplers are instruments used to collect the bottom sediment underwater. Consequently, a total of 20 sampling points has been set up along the Selat Pulau Tuba, Langkawi, Kedah. The locations of the sampling sites were randomly chosen and the latitude and longitude of the sampling points were recorded by using Geographic Positioning Systems (GPS). A boat was used to navigate through mangrove ecosystems and low water areas. Observations along the sampling areas and points were made to record and determine the potential sources of point and non-point pollution of the microplastics contaminations. The sampling activity was carried out during high tide and the weather was reported to be sunny and dry. The sampling activities commenced at 11.00 am and finished at 4.00 pm for both dates.

The sediment samples were collected and weighed in at 400±0.2g using the weighing apparatus. Seashells, dead vegetative parts (leaves, stems, roots, etc.), garbage, etc. were removed to leave only the raw sediment. The samples were inspected repeatedly before they were being stored in a container that was cleaned and sanitized using distilled water and less concentrated sulphuric acids. A cleaned container was required to avoid sample contaminations of any microorganisms. After the sampling activities were carried out, the samples were immediately transferred to the marine technology laboratory and chemistry laboratory located at the Universiti Teknologi MARA Perlis Branch, Arau campus for laboratory analyses.

Sample Preparation for Detection of Microplastics

The method of sample preparation for the detection of microplastics in the sediment was referred to the work of Prata et al., (2019). The samples were primarily prepared by undergoing the drying process. Then, the process of density separation was carried out to collect the potential microplastics elements. This research used Wet Peroxide Oxidation digestion in the presence of a Fe (II) catalyst to digest the labile organic matter. The characterization of microplastics was carried out to identify the type, functional group, size, and colour. The procedures are explained thoroughly in section 3.6.3, section 3.6.4, section 3.6.5, and section 3.6.6. Figure 1 shows the overall flowchart for the characterization of microplastics in sediment:

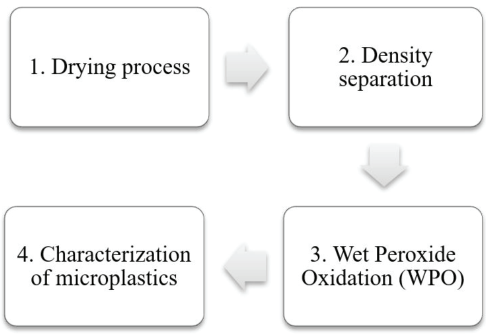

Figure 1: Overall Flowchart for Characterization of Microplastics in Sediment
Source: Author

Drying Process

The samples weighed about 100g±0.02 and poured into aluminium cups. Next, the samples were transferred into the drying oven at 900C overnight. Lastly, the samples were left dried in room temperature for 24 hours.

Density Separation

73 g of NaCl was added into 1L of distilled water. A metal spatula was used to stir the sediment vigorously to make the microplastics float on the

surface. The upper layer particles were discarded into another beaker and left in the oven at the temperature at 90 ºC. 0.5 mm, 1.0 mm, and 1.5 mm mesh sizes were used to sieve the solids. Then they were transferred to another beaker to determine the size of microplastics particles. Micro-particles that were below than 0.5 mm and larger than 1.5 mm were removed.

Wet Peroxide Oxidation (WPO)

0.05 mole (M) of Fe (II) was prepared by mixing 7.3 g of FeSO4.7H2O into 500 mL distilled water and 3 mL of concentrated sulphuric acid (H2SO4). Then 20 mL of 0.05 M Fe (II) solutions were added into the beaker which contained samples. 20 mL of hydrogen peroxide (H2O2) was added in the same beaker and the mixture at room temperature for 5 minutes. A stir bar was added in the beaker and the beaker was covered with a watch glass. The mixture in the beaker was boiled on the hotplate with a temperature of 75 ºC. The temperature was kept below 750C to avoid the overflow of the solution. The process was conducted inside the fume hood. The man aim of WPO is to reduce organic matter presents in the samples. Bubbles were observed after the temperature reached 75 ºC.

Characterization of Microplastics

The characteristics of the shape and colour of microplastics were observed under the dissecting microscope (optical microscope). The types of microplastics were identified by using the FTIR spectrophotometer located at the chemistry laboratory of Universiti Teknologi MARA, Perlis Branch, Arau Campus. Besides, the colour, size, type, material, and the shape of the microplastics were determined based on the "Guidance on monitoring of marine litter in European seas" (Galgani et al., 2013).

Mapping of Microplastics Pollution

Geospatial data containing the latitude, longitude, stations, and microplastics data were transformed into a spatial model for visualization purposes. Spatial visualization allowed the researcher to relate between the geo-location and the attribute data (microplastics). The elements of maps such as map's titles, north arrow, scales, and legends were added to provide information to the reader (Kamaruddin et al., 2020). Presence and not presence are the two criteria used to assist in explaining the potential source of microplastics and as a guide for future scientific research at these locations.

RESULTS AND DISCUSSIONS

Spatial Variation of Microplastics

Microplastics elements were found in two sampling points: station 1 (Lat: 99.84133 E, Long: 6.266250 N) and station 5 (Lat: 99.83175, Long: 6.259717 N). These locations are situated near to the mouth of Selat Pulau Tuba opposite to ferry dock at Kuah, Langkawi. Based on the observation during sampling activities, these locations are nearby to Selat Bagan Pauh and Selat Bagan Nyior, which are the main possible site for human activities or anthropogenic contributors. Anthropogenic activities have caused many problems due to the increasing marine litter into the water environment (Williams & Rangel-Buitrago, 2019). Marine litter that came from the beach or coastal waters may contribute to microplastics pollution in the sediment (Renzi et al., 2020). Furthermore, these sampling points are located at the main entrance of the sea where microplastics could be transported from long distances following the ocean current (Iwasaki et al., 2017).

Both sampling points are also covered with thick mangrove and shallow marine ecosystems. Having complex root systems, mangrove served the location to trap microplastics (Yona et al., 2019).

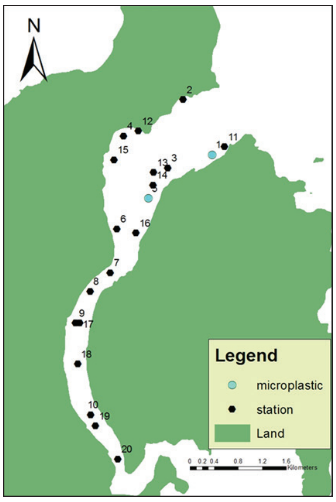

Figure 2: Sampling Stations Where Microplastics have been Identified Along The Coastal Water of Selat Pulau Tuba, Langkawi, Kedah

However, based on the findings of this research, these locations contained fewer microplastics abundance. The monitoring of microplastics in these areas should be seriously handled to preserve and sustain marine biodiversity. Figure 2 shows the location of microplastics found in the sediment of Selat Pulau Tuba, Langkawi and is visualized using GIS applications.

Type of Microplastics

The types of microplastics are known by the density separation. The density separation is used to isolate the particles which have low-density from higher density particles like sediments (Wang & Wang, 2018). In this research, two types of microplastics were identified which are polyethylene (PE) and polypropylene (PP). Various plastic polymers have a lower density than seawater but some are denser and depend on their physical shape that could lead those to sink on the ocean floor (Woodall et al, 2014). Polyethylene (PE) and Polypropylene (PP) have a lower density in comparison to seawater (1.10 g/ cm3) (Fazey, & Ryan, 2016). Saturated NaCl was mostly used during this process because of its non-hazardous characteristics. Besides that, it is cheaper and quite easily available in the market. Although it is non-hazardous, it cannot separate microplastics that have higher density such as Polyvinylchloride (PVC) which may not be completely extracted during the process. Table 1 shows the list of locations where the microplastics have been identified.

Table 1: List of Locations where Microplastics have been Identified

Sampling Points	Registration	Latitude	Longitude	Microplastics	Range Size (μm)
1	SPT001	99.84133	6.266250	Found	500–1000
2	SPT002	99.83697	6.274483	-	N/A
3	SPT003	99.83472	6.264233	-	N/A
4	SPT004	99.82803	6.269017	-	N/A
5	SPT005	99.83175	6.259717	Found	1000–1500
6	SPT006	99.82708	6.255117	-	N/A
7	SPT007	99.82605	6.248550	-	N/A
8	SPT008	99.82303	6.245767	-	N/A

9	SPT009	99.82083	6.241033	-	N/A
10	SPT010	99.82312	6.227283	-	N/A
11	SPT011	99.84320	6.267417	-	N/A
12	SPT012	99.83025	6.269767	-	N/A
13	SPT013	99.83258	6.263550	-	N/A
14	SPT014	99.83252	6.261667	-	N/A
15	SPT015	99.82665	6.265467	-	N/A
16	SPT016	99.82992	6.254500	-	N/A
17	SPT017	99.82147	6.241050	-	N/A
18	SPT018	99.82118	6.234883	-	N/A
19	SPT019	99.82385	6.225617	-	N/A
20	SPT020	99.82720	6.220633	-	N/A

Source: Author

Size of Microplastics

The particles that were floating on the surface during the density separation method were collected and dried again for about one day. Then, the particles were sieved with 500 µm, 1000 µm and 1500 µm in order to identify the range size of microplastics. The research found that the microplastics analysed at station 1 has a range size of about 500 µm–1000 µm, while microplastics from station 5 has a range size of 1000 µm–1500 µm. A research conducted in Sungai Skudai and Sungai Tebrau (Sungai= river) has reported that microplastics with size ranging from 500 to 5000 µm could lead to high chance of ingestion incidence by aquatic animals (Said et al., 2018). The smaller in size will make the microplastics easy to be carried away by the current (Iwasaki et al. 2017). Table 2 shows the sizes of microplastics recorded.

Table 2: The size of Microplastics Recorded

Sam-pling Points	Registration	Latitude	Longitude	Microplastics	Range of Size (µm)
1	SPT001	99.84133	6.266250	Found	500–1000
5	SPT005	99.83175	6.259717	Found	1000–1500

Source: Author

Colour of Microplastics

The colour of microplastics was observed under the optical microscope. From the observation, plate 1 shows that microplastics from station 1 has a white colour and plate 2 microplastics from station 5 shows the reflection of green colour. Plate 1 and Plate 2 shows the colour of microplastics under optical magnification 4.0x0.10. The colour of microplastics can help researchers to identify the source of microplastics pollutants (Nor & Obbard, 2014; Zhao et al., 2014). Due to a lack of data, this research found that the identification of the sources of microplastics is challenging and very limited.

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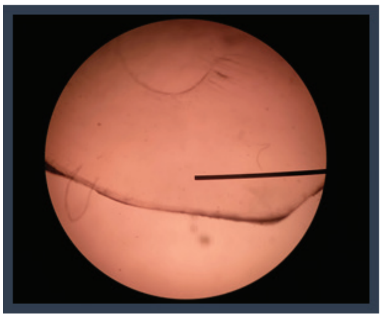

Plate 1: White microplastics

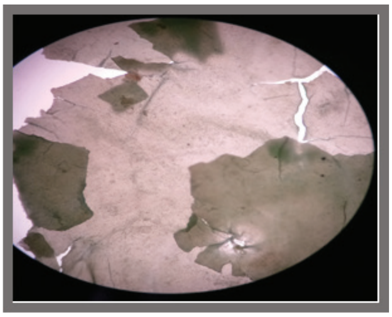

Plate 2: Green microplastics

Source: Author

Functional Group and the Molecular Formula

The microplastics that were obtained from the WPO process were analysed with the FTIR to identify the functional group. The functional group of microplastics from station 1 shows polypropylene with peak 1654 cm-1 of C=C of alkene and 2916.96 cm-1 of C-H (Stretching) of alkane. Polypropylene is bad for the endocrine system. It can cause genetic mutations and tumours, while the microplastics from the station 5 were polyethylene with the presence of a functional group of 2913.87 cm-1of alkane C-H2 stretching and a peak of 1654 cm-1 of alkene (Khalik et al., 2018). However, in the IF-spectrum of polyethylene, there was a presence of the peak of ketone at 1711.66 cm-1.due to the interference during sample preparation.

Wet peroxide oxidation digestion used digestive agents such as hydrogen peroxide and strong mineral acids at a high temperature and it can cause damage or complete dissolution of certain kinds of exposed polymers (Wang & Wang, 2018). Polyethylene would give bad effects on marine aquatic life which can cause ingestion towards fish (Carlos et al., 2018). Table 3 and Table 4 show the wave number, functional group, and molecular formula of each type of the microplastics.

Table 3: Wave Number, Functional Group, and Molecular Formula for Polypropylene

Wave number (cm-1)	Functional group	Molecular Formula
2916.96	Alkane	C-H (Stretching)
1654	Alkene	C=C
1455.95	Alkane	-CH2-
1375.13	Alkane	-CH3 (bend)

Source: Author

Table 4: Wavenumber, Functional Group, and Molecular Formula for Polyethylene

Wave number (cm-1)	Functional group	Molecular Formula
2913.87	Alkane	CH3
2848.38	Alkane	CH3
1711.66	Ketone	C=O
1467.86	Alkane	C-H (bend)
1039.62	Alkene	C=C (bend)

Source: Author

However, the findings of this study have to be seen in light of some limitations. The research only covered the detection of microplastics in surface sediment of about 30 cm depth. Due to the activity of wave and current, microplastics may be buried deep down under the sediment. Besides, the research also has an insufficient number of sampling points. The research also acknowledged the limited technology used such as the scanning electron microscope to determine the texture of microplastics found. Furthermore, the sampling activities were only carried out during March and April 2019 due to limited time and budget. The researchers were also aware of the limitation in reporting the quantity and concentration of microplastics found in sampling areas. In addition, comparative assessments with other researchers were also found to be challenging and limited due to the lack of available data and prior research studies especially in Selat Pulau Tuba, Langkawi, Kedah.

CONCLUSION AND RECOMMENDATION

Overall, the sediment from the coastal water of Selat Pulau Tuba, Langkawi, Kedah is free from microplastics pollutions. There are two sampling points where microplastics have been detected using Wet Peroxide Oxidation Process. The microplastics found were identified as polypropylene and polyethylene which are found to be white and green colour respectively.

Consequently, the research recommends adding the number of sampling points and increases the frequency of sampling activities. Comparative analyses of the effects of monsoon and tidal activity towards the spatiotemporal variation on microplastics pollution could be beneficial especially in explaining the pattern of pollution in this area. The researchers wish to inspire other researchers to conduct more environmental-based research for the sustainability and conservation of Pulau Tuba, Langkawi, Kedah as a major tourism site and provide high impacts to socioeconomic regions.

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