MARINE MACROPLASTIC AND MICROPLASTIC LITTER IN THE COASTAL REGION OF NORTHERN STRAITS OF MALACCA

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by

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LIST OF SYMBOLS

°C	Degree Celsius
g/m^2	Gram per Square Meter
g/m^3	Gram per Cubic Meter
p	Statistical Probability
R^2	Coefficient of Determination

LIST OF ABBREVIATIONS

ALDFG	Abandoned, Lost or otherwise Discarded Fishing Gear
ANOVA	Analysis of Variance
BS	Backshore
CIEL	Centre for International Environmental Law
DDT	Dichlorodiphenyltrichloroethane
DOE	Department of Environment
DOSM	Department of Statistic Malaysia
EIA	Environmental Investigation Agency
EPS	Expanded Polystyrene
FTIR	Fourier Transform Infrared Spectroscopy
HDPE	High-Density Polyethylene
JICA	Japan International Cooperation Agency
LDPE	Low-Density Polyethylene
LKIM	Lembaga Kemajuan Ikan Malaysia
MESTECC	Malaysian Ministry of Energy, Technology, Science, Climate Change, and Environment
MHLG	Ministry of Housing and Local Government
MITI	Ministry of International Trade and Industry
ML	Middle Line
MPAs	Marine Protected Areas
MPK	Majlis Perbandaran Kangar
MSFD	Marine Strategy Framework Directive
NSWD	National Solid Waste Management Department
NOAA	National Oceanic and Atmospheric Administration

NW	Northwest
OSPAR	Oslo and Paris Conventions
PC	Polycarbonate
PCBs	Polychlorinated Biphenyls
PE	Polyethylene
PET	Polyethylene Tetraphalate
PMMA	Polymethyl Methacrylate
PP	Polypropylene
PTFE	Teflon
PS	Polystyrene
PVC	Polyvinyl Chloride
SL	Strandline
USFWS	United States Fish and Wildlife Service
PU	Polyurethane
UV	Ultra Violet
WE	Water Edge
WPO	Wet Peroxide Oxidation

SAMPAH MAKROPLASTIK DAN MIKROPLASTIK MARIN DI KAWASAN PANTAI UTARA SELAT MELAKA

ABSTRAK

Pencemaran plastik di sepanjang pantai telah lama menjadi ancaman kepada ekosistem dan merupakan isu penting yang berulang kali menjadi perdebatan. Kajian ini menyiasat taburan dan komposisi makroplastik (>5 mm) dan mikroplastik (<5 mm) di enam lokasi di kawasan pantai utara Selat Melaka untuk meramal taburan microplastik dalam sedimen daripada taburan makroplastik di pantai. Transek 100 m digunakan untuk mengumpul sampah laut dan kuadrat 0.5 m x 0.5 m dengan kedalaman 0.05 m digunakan untuk mengumpul sedimen bagi pengenalpastian mikroplastik. Peratusan tertinggi sampah makro laut yang dikumpul ialah plastik (73.8%), kaca (12%), kain (7.8%), getah (4.4%), kayu (2%) dan logam (0.07%). Jumlah berat sampah makroplastik dan mikroplastik pada tahun 2018 sehingga 2020 adalah 80.371 g/m^2 dan 11.095 g/m^3. Kelimpahan makro- dan mikroplastik didapati lebih tinggi di permukaan sedimen semasa *neap* berbanding keadaan pasang surut *spring,* mencadangkan pemendapan yang tinggi berlaku semasa tempoh air yang lebih tenang. Oleh kerana hampir 95% mikroplastik adalah daripada mikroplastik sekunder (serpihan, filem, foam dan fiber), ia mungkin adalah daripada pecahan plastik besar. Taburan jenis plastik ialah PE (45%), PP (41%), PS (14%), PET (0.3%) dan PU (0.2%). R^2 bernilai 0.744 menunjukkan hubungan yang signifikan antara makroplastik dan mikroplastik pada aras keertian 95%. Persamaan regresi linear ialah $y = 0.1927x + 0.0226$, dengan y mewakili mikroplastik (g/m^3) dan x mewakili makroplastik (g/m^2). Hubungan yang kuat menunjukkan banyaknya mikroplastik dalam sedimen dikaitkan dengan banyaknya makroplastik di pantai dan boleh digunakan untuk meramal.

MARINE MACROPLASTIC AND MICROPLASTIC LITTER IN THE COASTAL REGION OF NORTHERN STRAITS OF MALACCA

ABSTRACT

Plastic pollution along the coastal area has long been a threat to the ecosystem and one of the crucial issues repeatedly in debates. This study investigated the distribution and composition of macroplastic (>5 mm) and microplastic (<5 mm) from six locations in the coastal region of Northern Straits of Malacca providing a prediction of microplastic distribution in sediment from macroplastic distribution on the beach. A 100 m transect was used to collect marine litter and a quadrat of 0.5 m x 0.5 m with a depth of 0.05 m was used to collect sediment for microplastic identification. The highest percentage of macro litter collected was plastic (73.8%), followed by glass (12%) fabric (7.8%), rubber (4.4%), wood (2%) and metal (0.07%). The total weight of macroplastic litter and microplastic abundance in 2018 and 2020 were 80.371 g/m^2 and 11.095 g/m^3. Abundance of macro- and microplastic was found to be higher in surface sediment during neap compared to spring tidal conditions, reflecting enhanced deposition during calmer water periods. Since almost 95% of microplastic was secondary microplastic (fragments, films, foams, and fibers), it was probably from the fragmentation of larger plastics. The distribution of plastic types was PE (45%), PP (41%), PS (14%), PET (0.3%) and PU (0.2%). Calculated R^2 of 0.744 shows a significant relationship between macroplastic and microplastic at a 95% significance level. The linear regression equation is $y = 0.1927x + 0.0226$, with y representing microplastic (g/m^3) and x representing macroplastic (g/m^2). A strong relationship showed the occurrence of microplastic in sediment was associated with the abundance of macroplastic on the beach.

CHAPTER 1

INTRODUCTION

1.1 A General Overview

Nowadays, various techniques are applied to evaluate the current status of the environment, and the techniques have rapidly evolved to provide better results and more accurately capture certain environmental issues. The coast is one of the most important environmental components that must be treated with care to preserve and protect the areas. The surrounding coastal regions represent highly productive ecosystems such as mangroves, coral reefs, seagrasses, and marine ecosystems. The diversity and complexity of coastal regions have resulted in the need for an integrated strategy to address challenging environmental problems and to create an unspoiled and well-preserved area. Development and rapid urbanisation have resulted in pressures on these coastal resources due to anthropogenic activities in the areas. Precipitous growth of urbanisation is also causing more people to use plastic daily, and changes in land use are impacting water quality and coastal plastic pollution (Robertson, 2018).

Many issues in coastal areas have been extensively researched using various methods, such as plastic litter along the coast, but the microplastics distribution in the coastal area has received insignificant attention. Microplastics, described as plastic particles less than <5 mm in length, accumulates in coastal sediments and at the sea surface (Patchaiyappan et al., 2021) and may pose a threat to marine ecosystems due to their reported pervasiveness, persistence, durability, and tendency to be consumed by humans and biota in the coastal environment (Andrady, 2011; Arthur et al., 2009; Galgani et al., 2010; Dowarah et al., 2020). Microplastics generally originated from two sources, primary and secondary microplastics (Lindeque, 2017).

Research in Los Angeles found that the abundance and density of microplastics were 16 times more abundant than debris larger than 5 mm (Moore et al., 2011). It is also confirmed that microplastics most often end up in the river system and eventually in coastal areas because they are carelessly disposed of in the environment or spilt during production and transportation activities. Microplastic has also been detected in the sediment and water column of marine and freshwater ecosystems across the continent. Current estimates suggest that there are currently over 5 trillion pieces of plastic floating in our seas, most of which are surprisingly microscopic in size (Lindeque, 2017). These floating microplastics in the ocean, on the other hand, may pose a similar threat to aquatic life and lead to larger problems in the future.

The detection of microplastics in Pulau Langkawi and Kuala Perlis highlights the pervasive nature of plastic pollution in marine ecosystems. The ingestion of microplastics by marine organisms poses potential health risks to wildlife and humans, particularly through seafood consumption. To combat this issue, it is crucial to implement effective waste management practices, raise public awareness about plastic pollution, and enforce regulations to reduce plastic usage and disposal. Ongoing research and monitoring are essential to understand the full extent of microplastic contamination and to develop strategies for preserving the health of Malaysia's marine environments.

1.2 Problem Statement

Marine plastic pollution is a rapidly expanding threat due to the swiftly increasing amount of plastic produced in combination with intended or unintended littering and an insufficiently mishandled waste disposal and recycling system. According to a recent assessment, 367 million tons of plastic will be produced worldwide in 2020, up from 5 million tons in 1950 (Plastics Europe, 2020). Only 9% have been recycled, and 12% have been incinerated, while the remaining 79% was landfilled or ended up in the environment uncontrolled, much of it in the world's ocean. These plastic pollutions, either large or small, negatively affect more than 1,400 species and cost the tourism sector hundreds of millions of USD each year (Kumar et al., 2021).

According to Lindeque (2017), the way larger plastic litter (macroplastics) affects marine ecosystem is well known. However, microplastic litter has gained more attention recently, which could be just as dangerous to human health and marine life pose a severe environmental threat due to their persistence and potential to enter the food chain. Due to a lack of research or awareness of the possible issue itself, it is not well reported (Jahnke et al., 2017). Most research is focused on macroplastic because of the least visibility of microplastic compared to macroplastic since it is microscopic in size. The primary issue is the continuous fragmentation of larger plastic (macroplastic) items into smaller particles (microplastic), mainly because, over time, exposure to sunlight, microbial oxidation, and hydrolysis, leading to pervasive and persistent microplastic pollution. This process exacerbates the environmental and ecological impacts of plastic pollution (Gewert et al., 2015).

Despite the growing concern over plastic pollution and plastic fragmentation theory, comprehensive data on the relationship between macroplastic pollution on beaches and microplastic distribution in coastal sediments remains poorly understood. This knowledge gap of how larger plastic (macroplastic) on the beach degraded and fragmented over time associated with the distribution of small plastic (microplastic) in sediment will support effective management and mitigation strategies to combat coastal-marine pollution and provide vital insight for developing targeted interventions to reduce plastic pollution.

The distribution of microplastic in beach sediments is influenced by tidal conditions of neap and spring, yet the extent of this influence is not fully understood. Understanding how tidal movements affect the deposition and dispersion of microplastic will enhance understanding. In addition, identifying and categorizing the various types of macroplastic litter and their market sectors provides insight into the primary sources of pollution and informs regulatory actions.

1.3 Research Question

This study establishes based one three research questions which are:

i) What are the predominant categories of macro marine litter and their corresponding market sectors?

ii) Do the tidal conditions (neap and spring tides) affect the concentration and distribution of microplastic in beach sediments?

iii) Is there a significant correlation between the abundance of macroplastic on the beach and the amount of microplastic in sediment?

1.4 Research Objectives

This study aims to profile microplastic distribution in the coastal zone of Northern Straits of Malacca, consisting of the Kuala Perlis Area, Teluk Datai, and Pantai Pasir Tengkorak. It comprises on-site sampling and laboratory work with statistical analysis. The main objectives of this study are:

i) To ascertain the number of different categories of macro marine litter and macroplastics market sectors,

ii) To determine the amount of microplastic present in the sediment based on different tidal conditions,

iii) To establish the possible correlation between macroplastic abundance on the beach and microplastic in the sediment.

1.5 Hypothesis

The hypothesis in this study area:

i) Macroplastic on the beach and microplastic abundance in sediment significantly higher during neap tidal condition than during spring tidal condition,

ii) It is anticipated that is a significant positive correlation between the abundance of macroplastic on the beach and the abundance of microplastic in the sediment,

iii) Higher macroplastic abundance on the beach lead to higher microplastic abundance in the sediment.

1.6 Sampling Locations

Four sampling stations (S1 – S4), are in the vicinity of Kuala Perlis, and two stations in Pulau Langkawi (S5 and S6) are selected shown in Figure 1.1. The six stations are picked based on diverse land use, human activities, population, and natural environments. S1 is located near the busy Kuala Perlis and LKIM jetty. Kuala Perlis jetty is a transportation hub that connects the ferry from the mainland to Pulau Langkawi, while LKIM jetty is for fish landings. On the other hand, S2 is located near the floating mosque, an area for recreational and fishing activities with little natural environment. Located near seafood restaurants and hotels, S3 is also one of the popular recreational areas for visitors to picnic. S4 (Kurung Tengar) is near a fishing village (permanent population). As against S1- S4, S5, and S6 are non-populated but have a periodic population (the population is from tourists and visitors and may vary between seasons). S5 is Pantai Pasir Tengkorak, the famous beach in Pulau Langkawi for recreational activities. Pantai Pasir Tengkorak is located within the Machinchang Cambrian Geoforest Park and is considered an undisturbed environment. Datai Langkawi Resort's 5-star beach (S6), located within the Machinchang Formation, has a pristine natural environment and a well-managed beach with proper waste disposal.

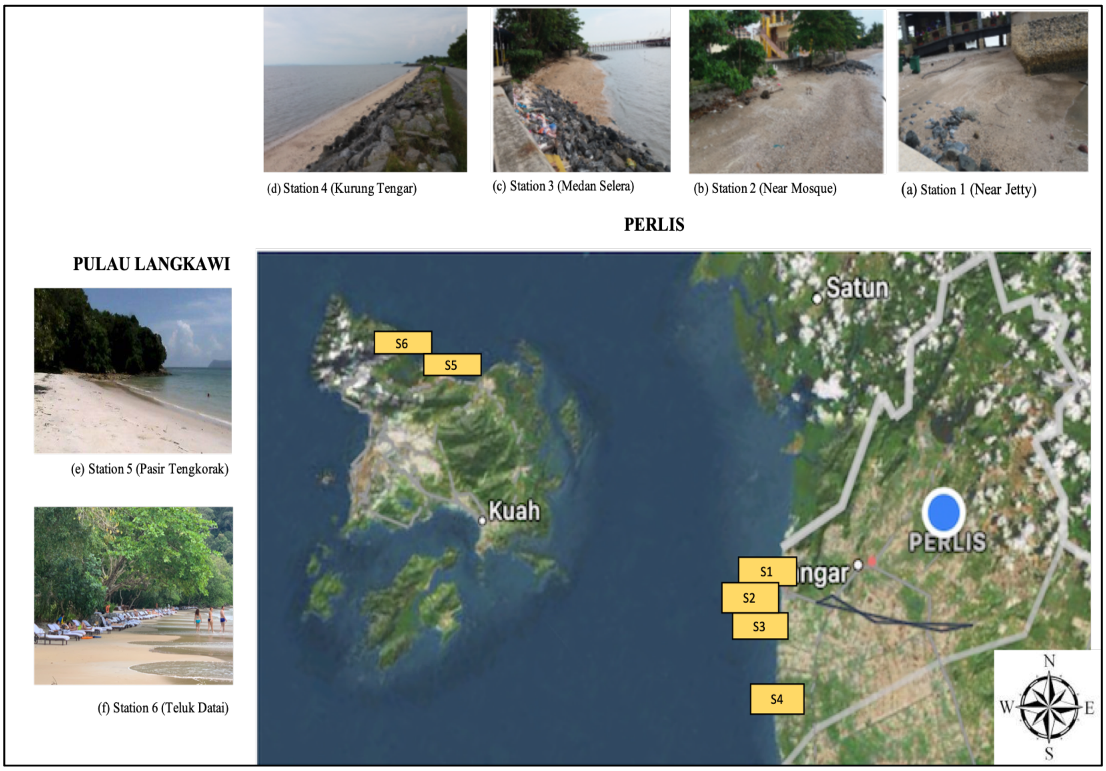

Figure 1.1 Six Sampling Locations in Study Area

1.7 Significance of Study

The significance of establishing the relationship between macroplastic abundance on beaches and microplastic presence in sediments is to understand the connection of large plastics items will fragment and degrade into smaller size of microplastic. This established relationship will offer insight into pathways and transformation processes of plastic debris. Since macroplastic has high visibility compared to microplastic, it is less complicated to collect macroplastic on the coastal sediment. Investigating the presence of microplastic in sediment from macroplastic on beaches contributes to our understanding of the environmental consequences, enabling targeted conservation and clean-up efforts to mitigate the impact of pollution on coastal ecosystems. This spatial understanding is crucial to provide valuable perception into identifying hotspots and patterns for plastic pollution.

The occurrence of microplastic in sediment is crucial for assessing potential risks to human health through the food chain. This understanding is vital for establishing guidelines and safeguards to protect human well-being. It also helps the resilience of coastal ecosystems in the face of plastic pollution, guiding efforts to preserve biodiversity, maintain ecosystem service, and balance the delicate marine habitats. In essence, studying macroplastic and microplastic in coastal marine environments can be utilized to raise public awareness about the severity of plastic pollution and its impact on coastal environments. Educational campaigns based on scientific evidence can foster community engagement and promote sustainable practices to reduce plastic waste.

The coastal zones of the Northern Straits of Malacca, specifically the Kuala Perlis Area, Teluk Datai, and Pantai Pasir Tengkorak are vital ecosystems that support diverse marine life and provide significant economic benefits through tourism and fisheries. However, these areas are increasingly threatened by marine pollution, particularly from plastic waste, through the irresponsible behavior of humans and their activities to add up the pollution, and finally end up on the coastline. This study holds considerable significance for several reasons, including its contribution to the growing body of scientific knowledge on marine pollution, particularly in the context of Southeast Asian coastal regions. It will provide a reference for future studies and inspire further research aimed at understanding and combating marine plastic pollution.

By identifying the types and sources of plastic litter, this study highlights the primary sources of plastic pollution. This information is crucial for designing targeted waste management strategies, engaging relevant stakeholders, informing policies and interventions to prevent further contamination, and developing effective strategies for mitigating pollution at its roots in reducing plastic waste at the source. The findings of this study will provide essential data to local and regional authorities (such as Ministry of Natural Resources and Environmental Sustainability (NRES), Department of Environment (DOE) and SWCorp), enabling them to formulate evidence-based policies and regulations aimed at mitigating plastic pollution. Effective policies can enhance conservation efforts and protect marine biodiversity. By addressing these aspects, this study not only aims to provide a comprehensive understanding of plastic pollution in the Northern Straits of Malacca but also seeks to support efforts in preserving the health and sustainability of its coastal ecosystems for future generations.

1.8 Study Approach

This study conducted on-site sampling in the coastal areas of Kuala Perlis, Teluk Datai, and Pantai Pasir Tengkorak. The study covers four main components; marine litter, macroplastic abundance, microplastic distribution, and correlation between macro- and microplastics. As indicated in Figure 1.2, this study is divided into four phases: planning and surveying, literature review, data collection, and data analysis, which includes laboratory work, statistical analysis, and correlation between large and small plastics.

The approach in this study implemented field sampling work at coastal areas to assess the current condition of the regions in the northern part of Peninsular Malaysia. Marine litter and sediment from the beach are the primary samples collected in this study in order to obtain data on macroplastic abundance and microplastic distribution. Marine litter can be a visible indicator of coastal pollution in study areas.

Sediment is collected within the study area since there is an abundance of microplastics in the coastal area located in sediment (Hidalgo-Ruz & Thiel, 2013; Hanvey et al., 2017). Microplastics in sediment are one of the indicators that shows the level of pollution in coastal areas and the intensity of deleterious plastic in the environment. Commonly, the existence of macroplastics on the beach and microplastics in sediment has become a bad sign for the coastal environment.

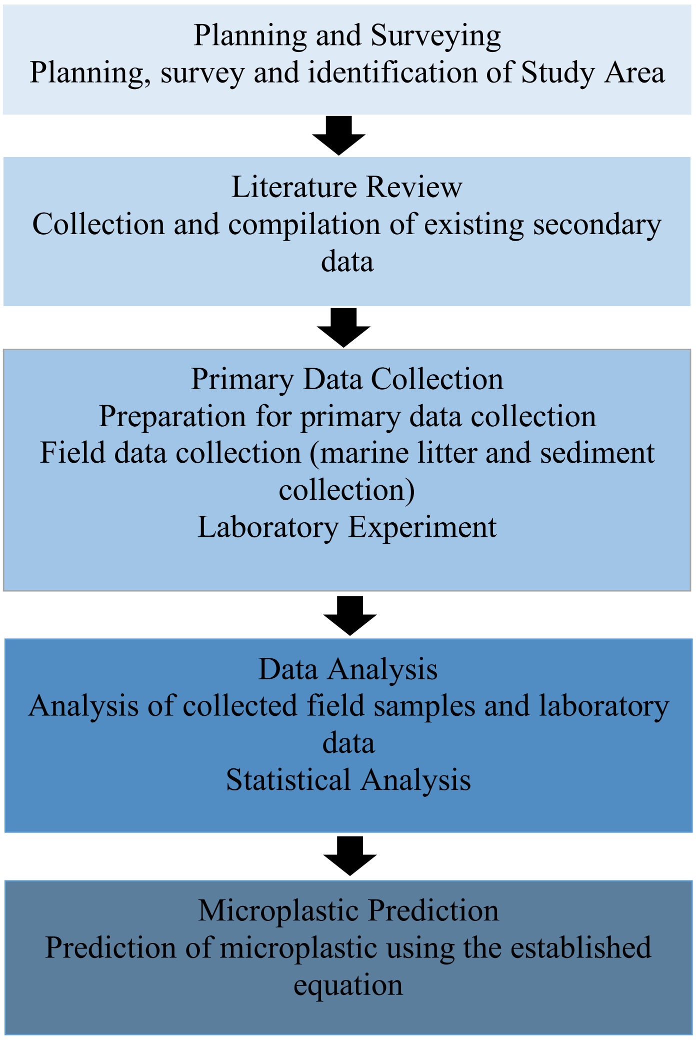

Figure 1.2 The Four Phases of Research

In the past, most researchers only considered marine litter (large plastic) in their studies since the large plastics are noticeable and an eyesore to the eye. Macroplastic litter can also disrupt the ecosystem, wildlife, and coral reefs, damaging vessels and polluting beaches and coastlines, which lead to the loss of the aesthetical value of the area. Since there has been a rising concern about how larger plastic can fragment into smaller and smaller pieces of plastic, researchers have focused their attention on the microplastics on the coastline since microplastic abundance is 16 times more than macroplastic. Furthermore, these microplastics are more deleterious to the environment and humans than the macroplastic.

Since there is an improvement in microplastics study in coastal areas, the sediment depth of 5 cm is adopted for sample collection in this study. A deeper sediment layer is collected instead of surface sediment to make sure that microplastics can present in the deeper sediment layer. The sample are collected during dry and wet season with neap and spring tide took into considerations.

1.9 Conceptual Framework

As indicated in Figure 1.3, the conceptual framework for assessing the relationship between macroplastic on the beach and microplastic in sediments in this study includes three primary components: sources, environments, and threats. The sources of microplastic in coastal marine environments are primary (plastic manufactured in microscopic size) and secondary macroplastic (larger plastic degraded and fragmented into smaller plastic). Larger plastic from different market sectors will break into smaller and smaller plastic items over a long period through chemicals, physical and biological processes. This process, however, contributes to a multiplication of the microplastic abundance in the environment, mainly at beaches and sediment.

Macroplastic and microplastic indicate an unpleasant impact on the beach and sediment, resulting in consequences that pollute the coastal-marine environment, disturb aquatic organisms, and possibly harm humans through exposure to toxic pollutants and ingestion. The polluted coastal marine environment reduces the tourism activities and aesthetic value of the beach, while the aquatic organisms may face significant effects due to ingestion, entanglement, exposure to toxic pollutants, the eruption of the food chain, reduced food intake, and birth rate.

The relationship between macroplastic and microplastic is derived for microplastic pollution prediction and coastal marine management using ANOVA, and Linear Regression. Macroplastics act as indicators of the amount of microplastics in sediment in the coastal areas to express the current state of pollution in coastal regions. From the findings, it is expected that it helps to estimate and control pollution, strategize the waste management and recycling activity, regulate the laws, and relate to coastal area sustainability and conservation.

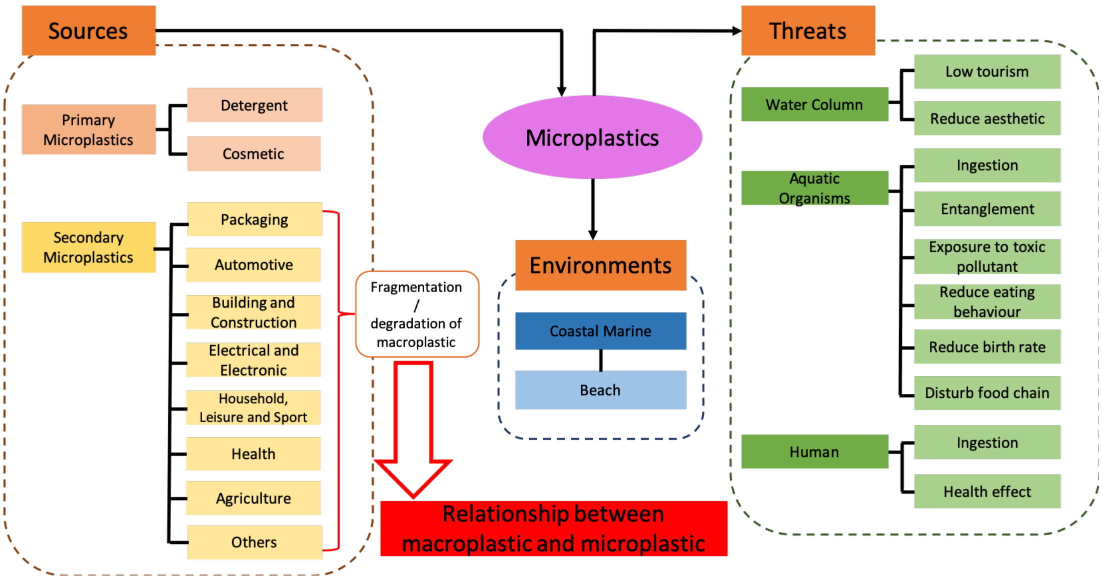

Figure 1.3 Conceptual framework for assessing relationship between macroplastic and microplastic

1.10 Summary

Macroplastic abundance in the coastal areas in general, shows a rapid increase in the numbers, which cause also intensified the numbers of microplastic distribution in the sediment. The increasing numbers of both macro- and microplastics have resulted from human activities, attitudes, and behaviour. The scenario that worsens the condition of the coastline is poor waste management and lack of recycling activities, increasing more macro and microplastics entering the environment and ending up in the oceans and beaches. Therefore, comprehensive action needs to be implemented to tackle the issue from its foundation, even if it is complicated.

The coastal area is a highly rich, very complex ecosystem and important both biologically and economically to organisms. However, with rapid development and urbanisation, the coastal area is under escalating pressure from pollution and human-based activities. To sustain the coastal area, there is a crucial key to recognise first to achieve efficient and cost-effective ways. Since macroplastics and microplastics can be obvious indicators of the pollution level, collecting macroplastics and microplastics is the primary data collection in this study.

With the background information gathered, this study proposed to determine the number of diverse categories of macro marine litter in the study area and macroplastics according to market sectors, to determine the number of microplastics present in the sediment, and to determine the possible correlation between macroplastic abundance and microplastics in the sediment. Macroplastic litter and sediment are the primary data collected to identify the possible correlation between macroplastics and microplastics. The correlation is expected to be positively related, which perhaps can help to control the number of microplastics in the coastal area by controlling the use of plastic daily or even prohibiting the use of plastic in hypermarkets or straws in restaurants.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The coastal zone is one of the most fascinating ecosystems, with a highly productive environment and diverse flora and fauna. The complex and abundant resources in this area have attracted humans to rapidly explore the area, resulting in the challenge of achieving a well-conserved and sustainable environmental area. The coastal region of Malaysia has gained significant attention due to its reputation among local and foreign tourists as a place to come and enjoy beach activities. Other than that, impetuous expansion and rapid urbanization have a seriously impact on disruption this unique region, posing a threat to various species of plant and animal (Mclean et al., 2001).

Urbanization and development also cause more people to use more plastics daily, resulting in escalating plastic pollution and, consequently, in the coastal region since it will end up in this area. This research is raised by the widespread occurence of the coast, particularly the problem of marine litter. Despite the fact that marine litter is a critical concern in Malaysia, research on this subject is limited. Plastic is the highest contributor to solid waste composition, with 24% becoming one of the major factors that add up the amount of microplastic in the environment besides the microbeads from daily routines (Kumar et al., 2021). In the end, both large and small plastics will turn up in the coastal regions. The existence of plastics in coastal environments has urged public awareness. The most critical concern relies on its persistence, ubiquity, and accumulation in the environment and organisms over long periods.

It is complicated to accurately represent the marine litter amount in the coastal region as the region is vast, and the plastic's lasting durability in the environment has become a remarkable environmental risk. Plastic is easily transported over great ranges from its origin, accumulates, and sinks, primarily in the oceans, where it has various environmental and economic impacts (Schwarz et al., 2019). Most large plastics degrade slowly through oxidation, mechanical abrasion, and photodegradation into smaller plastic pieces and fragments, which can be deleterious and harmful to the organisms and environment (Andrady, 2003). Even when exposed to direct sunshine, thick plastic objects last for decades and persist more when protected from UV radiation in sediments or underwater.

There has been a precipitous growth in the abundance of plastic litter in the coastal ecosystem related to the increased plastic use during the 20th century (Horton, 2022). Even the creation of the so-called 'biodegradable' plastics is not a lasting solution to the plastic waste issue since such materials only contain a small percentage of biodegradable materials, leaving behind smaller and smaller plastic fragments in microscopic sizes (Miraj et al., 2021). Plastic has turned into a ubiquitous pollutant found worldwide in all types of marine depositional ecosystems, from beaches (Chubarenko et al., 2018) to epipelagic and mesopelagic (Choy et al., 2020) and to the deep sea (Kane et al., 2020). Small plastic granules used as scrubbers in cosmetics and air-blasting, small plastic fragments are produced from the degradation of macroplastics; hence microplastics have raised environmental concerns in recent years and are expected to affect marine ecosystems globally (Derraik, 2002; Egessa et al., 2020).

2.2 Marine Litter Pollution

Marine debris or marine litter is waste that ends up in a coastal or marine environment, either intentionally or accidentally, generated by humans. These litters consist of any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed or abandoned in the environment. It includes entirely the material discarded on the coast, into the ocean, or indirectly transported into the ocean by rivers, storm water, sewage, winds, or waves. This litter is also often described as one of the major persistent marine pollution issues since it has been found everywhere, from the most popular beaches to the most remote beach locations throughout the world.

Regardless of the scheduled waste management and beach clean-up in coastal areas by municipalities or volunteers, the problem remains preserved as the waste generation and population continue to intensify. The increase in population in certain areas means more stress to the coastline since human activities triggered more marine litter production. Marine litter is not only aesthetically unpleasing as litter on the coastline but may also destroy the environment and human health. A recent study discovered a more serious problem regarding marine litter, where the litter is the transport of toxic chemicals in the coastal environment.

Terrestrial sources generally enter the marine environment through the mismanagement of litter (Rakib et al., 2022). Marine litter accumulates in the ocean: in the water column, at the sea surface, on the seafloor, and on beaches (Goodman,at al., 2019). Most marine debris consist of plastics categorized into macroplastics or smaller plastics (microplastics and nanoplastics). Marine plastic debris can originate from direct or indirect sources such as bottle caps or plastic fragments or maybe originate from ocean or river sources such as food packaging, plastic bags, activities, buoys, fishing equipment, and ropes.

Numerous studies have observed the frequency and geographic distribution of anthropogenic plastic litter on the beach and in the ocean (Hidalgo-Ruz et al., 2018; Kane et al., 2020), while others have explored the factors that influence the deposition and accumulation of plastic litter in specific locations (Moore et al.,, 2001). Several studies have suggested a positive relationship between the rainfall and the abundance of plastic debris on beaches (Bissen & Chawchai, 2020).

2.2.1 The Impact of Marine Litter Pollution

The consequences of marine litter pollution are not just unpleasant and displeasing but also pose a severe threat to coastal-marine environments and, in the worst case, adversely affect human well-being and safety. It can destroy coral reefs, harm ocean floor species, and entangle or drown the bigger species in coastal-marine ecosystems. Based on previous studies, the abundance of marine litter has affected 267-species, including turtles, marine mammals, and marine birds (Cordova et al, 2021). Large pieces of litter and sharp objects can directly threaten the human. The effects of marine trash on the economy are likewise substantial. Ingestion or entanglement is the most broadly known harmful effect of marine litter on wildlife. Tourism can also be affected by marine litter by a drop-off in profit and an increase in the expenditure for coastal clean-up and maintenance when a considerable amount of litter is found on the coastlines.

2.2.1(a) Entanglement or Entrapment

Numerous types of marine litter can endanger marine wildlife through entanglement. Entanglement is an interaction between anthropogenic litter marine and life in which animals become entangled. Countless cases of marine animals' entanglement have been recorded, and the first case identified is in 1944 of the Northern fur seals entangled in a 'rubber collar.' The likelihood that the 'collars' were the remains of Japanese food drop bags from the Aleutian Campaign during World War II was not confirmed by United States Fish and Wildlife Service (USFWS) biologists until 1948 (Scheffer & Kenyon, 1948). Entanglement by marine litter caused the animals to limit their mobility and movement, resulting in malnutrition, infection, suffocation, and mortality. Abandoned, lost, discarded fishing gear such as lines, traps, and nets are frequently guilty of entanglement and entrapment.

Apart from the first Northern fur seal cases, other cases of entanglement for other species are also being documented, for example, threatened Hawaiian monk seal (Donohue & Foley, 2007), New Zealand fur seals, and Australian sea lions (Page et al., 2004), Russian stellar sea lions (Kuzin & Trukhin, 2022), dusky shark (Cliff et al., 2002), marine turtle (Yaghmour, 2020), bottlenose dolphin, (Barco et al., 2010) and seabirds (Costa et al., 2020). Over 350 unique species have now been recorded as entangled in plastic waste (Kühn & van Franeker, 2020).

2.2.1(b) Ingestion

Marine animals also face a huge problem ingesting marine litter, mainly very small or degraded plastic items. It is proved by some of the studies in the Northern fulmar, where 95% of the 1295 dead beached birds gathered from 2003 to 2007 had plastic in the stomach. The average number of plastic items in the birds' stomachs was 35, weighing 0.31 g (Van Franeker et al., 2011). Plastic ingestion may also affect the mobility of seabirds due to additional mass via ingestion, which will reduce wing loading for flying and diving (Senko et al., 2020). It was revealed that the digestive systems of hawksbill and olive ridley sea turtles from the United Arab Emirates contain marine debris. Omnivorous Hawksbill sea turtles most frequently ingest marine debris, with about an average of 30 items and 0.26 g of marine debris (Yaghmour et al., 2021). Most of the ingested marine debris was obtained in the intestines than in the esophagus and stomach.

The indigestible marine litter, usually small pieces, had been recorded to cause to physically obstruct various species' mouths, digestive tract, and stomach lining. Some obstructions, for example, an esophageal blockage, result in nutrient deficiency and eventual starvation because the blockage prevents animals from taking in food (Yaghmour et al., 2021). The worst cases of ingestion, primarily plastic, may cause physiological stress through false satiation, causing some animals to stop eating and slowly starve to death. Accumulating indigestible material reduces nutrition intake and diminishes energy gains (McCauley & Bjorndal, 1999).

The consumption of plastic by marine life is thought to have occurred for various justifications, involving misidentifying the visual characteristic of the debris for foods (Duncan et al., 2019), confusing the smell of bio-fouled plastic as food (Pfaller et al., 2020) and accidentally through non-selective feeding, such as filter feeding (Besseling et al., 2015), the plastic debris is attached to or covered with natural prey (Frick et al., 2009) or through trophic transfer from contaminated prey (Ahmadi et al., 2022).

2.2.1(c) Habitat Destruction

Habitat destruction happens when the conditions required for plants and animals to survive are drastically eliminated. Marine litter can disrupt marine habitats in a variety of ways, including suffocating and reducing light or oxygen. Alteration, degradation, and destruction of organisms' habitat by marine litter, for example, plastic bags or fabrics, can smother and restrict oxygen flow. This interaction with litter can cause severe damage to populations and habitat modification or extermination through physical obstruction, such as interference with sunlight (Watson et al., 2022). Corals and their habitats, as the most delicate organisms, may smother and be damaged by marine litter, especially nets, hence ALDFG (Donohue et al., 2001).

On the other hand, some litter, for example, plastics, have developed in adsorption and concentration of pollutants that are prevalent as environmental contaminants in the aquatic environment. There is evidence of pollutants such as polychlorinated biphenyls (PCBs) and organochlorine pesticides in plastic marine litter (Colabuono et al., 2010). The bigger plastics break down into smaller and smaller pieces; hence microplastics, along with the use of plastic resin pellets as the presence of very persistent organic pollutants such as dichlorodiphenyltrichloroethane (DDT), polycyclic aromatic hydrocarbons and aliphatic hydrocarbons, are a more serious issue that is currently being debated.

2.2.1(d) Chemical Transport and Food Chain

Marine debris, mainly plastic, carries infectious agents, including harmful bacteria (Lu et al., 2019). Threats from chemical contaminants pose an instant result for aquatic and land food webs. Countless of these pollutants in or absorbed by plastics such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) are known as highly toxic compounds (Ris et al., 2018). Its concentration increases at each successive trophic level, leading to biomagnification. Exposure to this chemical can precede alteration and is dangerous for wildlife and humans. Some chemical pollutants also affect the immunological structure of organisms. However, these contaminants in the marine environment come from various non-point sources that are challenging to identify. According to et al,, (2008), chemicals used in the structure of plastics, and those adsorbed onto plastics can be incorporated into living tissues. Plastic fragments can enter the body of certain organisms, persist in the system, and remain for up to 48 days (Browne et al., 2008). The possible transport of chemicals throughout the food chain and the implications for bioaccumulation in humans are acceptable concerns. Floating marine litter, mainly plastics, is also acknowledge as a medium for long-distance dispersion due to its high durability and persistence.

2.2.1(e) Alien Species Spreading and Invasion

Drifting litter can raft entire communities of encrusting and attached organisms and transport them to distant locations where they may hurt or compete with local species. Commonly, these organisms have harboured floating marine life, including plants, animals, and algae; however, human-introduced buoyant materials, for example, fishing nets, lines, and other plastic litter materials, led to increasing the abundance and availability of marine buoyant. Barnes, (2002) evaluates that plastics in the ocean have about doubled the proliferation of subtropical fauna and more than tripled the propagation of high-latitude fauna, which addresses the increased possibilities for the spread of alien species. Introducing non-local species may destroy the environment, such as biodiversity loss, habitat structure alteration, and ecosystem function modification.

2.2.1(f) Socio Economic

The presence of marine litter can cause the social and aesthetic value of coastal areas to be degraded by the displeasure of surrounding property values, with trash everywhere. It became an eyesore and diminished the attractiveness of coastal areas, leading to the visitor's frustration. Some of the litter may stink and disturb human activities near the areas. A descent in coastal areas' activities and tourism can also result a drop in the revenues for a coastal community and plays an important role for local economies that depend greatly on tourism. A study by Ten Brink et al. (2009) Sweden found about 1% to 5% losses in revenue (USD 30.03 million) due to unpleasant coastal areas with litter. The floating litter, usually plastic with high buoyancy characteristics, can disturb the coastal marine routine and increase the cost of cleaning the coastal areas. According to Hall (2008), the cost of removing marine litter can be up to USD 23,000 per year, with physical clearance needed up to four times per week. Marine plastic pollution also adversely affects recreational activities like diving and swimming.

Additionally, marine litter also has numerous economic implications that shrink the economic benefits driven by coastal activities and escalate the costs of cleaning and maintaining it. Fragmentation of litter in the ocean also catches, injures, and kills the aquatic life in the ocean, harming commercial fisheries by reducing the numbers of captured fish, prawns, squids, and other species. Recent statistic demonstrates that in 2016, 59.3 million people engaged in fishing activities, and the high demand for seafood is also rising. The fishing company resulted in an economic downturn due to equipment and vessel damage, removal of marine litter, and time disruption of work. The entanglement of the propellers is the typical problem in the fishing industry regarding marine litter, resulting in a lot of time to repair and is very costly. A more serious problem is when the water intake is blocked by litter, leading to burning hazards. This problem costs a significant amount of money and can be dangerous to the works in the vessel (Aretoulaki et al., 2021). The indirect economic impact of marine plastic pollution on fishing and aquaculture derives from reduced fisheries resources due to illegal fishing.

2.2.1(g) Safety and Health

Human health and safety are affected directly by marine litter in various ways; for example, it can threaten swimmers or divers by entanglement with submerged waste (Cheshire et al., 2009). These safety and health concerns are not only for submerged litter in the coastal areas but also related to the litter on the beach. The litter, such as water bottles, broken glasses, fishing gear, and ropes pose an immediate hazard to human safety when encounters on the shore can cause injury or abrasion.

Plastic litter, for example, can contribute to chemical contamination in the water bodies and pose potential risks to humans. These contaminations also can be preceded by more serious water quality problems, which will then affect human health through direct or indirect contact through consuming contaminated seafood. The route in which marine debris imperils food safety and health is through the consumption of marine organisms. Fishes, shellfish, and crustaceans, which are commercially consumable marine organisms, have all had marine litter found in their stomachs or digestive tracts (Md Amin, Sohaimi, Anuar, & Bachok, 2020). Human health and