INFLUENCE OF TIDAL CURRENT ON MICROPLASTIC DYNAMICS IN CHAO PHRAYA RIVER ESTUARINE ECOSYSTEM

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A Thesis Submitted in Partial Fulfillment of the Requirements
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อิทธิพลของกระแสน้ำขึ้นน้ำลงต่อพลวัตไมโครพลาสติกในระบบนิเวศปากแม่น้ำเจ้าพระยา

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ไมโครพลาสติกสามารถพบได้เกือบทุกที่ในระบบนิเวศทางทะเล และเป็นหนึ่งในประเด็นที่น่าเป็นห่วงในระดับโลกรวมถึงประเทศไทยด้วย ระบบนิเวศปากแม่น้ำก็จัดอยู่ในกลุ่มที่ถูกรบกวนมากที่สุดเช่นกัน โดยระบบนิเวศปากแม่น้ำ ได้รับผลกระทบจากทั้งแม่น้ำและมหาสมุทร เช่น ปากแม่น้ำเจ้าพระยาของประเทศไทย เนื่องจากการเปลี่ยนแปลงของกระแสน้ำ ดังนั้นจึงจำเป็นต้องศึกษาพลวัตของกระแสน้ำขึ้นน้ำลงตามระดับความลึกของไมโครพลาสติก โดยเก็บตัวอย่างน้ำตามระดับความลึก 60 ตัวอย่าง เป็นเวลา 24 ชั่วโมง ซึ่งจะเก็บตัวอย่างและตัวชี้วัดคุณภาพน้ำ สามรายการที่ปากน้ำเจ้าพระยา จากนั้นจึงตรวจวัด รูปร่าง และสีของไมโครพลาสติกด้วยกล้องจุลทรรศน์ จากนั้นทำการนับจำนวนและวิเคราะห์ชนิดของโพลิเมอร์ด้วย μ-FTIR จะพบไมโครพลาสติกเฉลี่ย 4.0±3.8 ชิ้น/ลิตร ในตัวอย่างการทดลอง และจากตัวอย่างทั้งหมดพบว่าพลาสติกรูปร่าง Fragment มากที่สุด และเป็นพลาสติกสีฟ้า โดยที่มีขนาดพลาสติกที่ 16-100 ไมโครเมตร ที่พบมากที่สุด และเทฟล่อนเป็นชนิดไมโครพลาสติกที่พบมากที่สุด สำหรับไมโครพลาสติกที่ตรวจพบในช่วงน้ำขึ้นและน้ำลง ไมโครพลาสติกเฉลี่ยอยู่ที่ 0.1-7.7 และ 0.2-8.2 ชิ้น/ลิตร ตามลำดับ นอกจากนี้ พลาสติกรูปแบบชิ้น และขนาด 16-100 ไมโครเมตรเป็นพลาสติกที่พบได้บ่อยที่สุดในช่วงน้ำขึ้นและลง โดยที่ เทปลอน ยังเป็นโพลิเมอร์ชนิดที่พบได้บ่อยที่สุดในช่วงน้ำขึ้นและน้ำลง ซึ่งประการสุดท้าย พบว่าการเปลี่ยนแปลงของน้ำขึ้นน้ำลงส่งผลโดยตรงต่อความเค็มและพลวัตของไมโครพลาสติก และเรายังพบว่าไมโครพลาสติกบริเวณปากแม่น้ำเจ้าพระยามีความเสี่ยงสูงมากต่อระบบนิเวศ

ปัจจุบันพบไมโครพลาสติกอยู่ทั่วไปในสิ่งแวดล้อม อย่างไรก็ตาม งานวิจัยทั่วโลกยังไม่มีความรู้เกี่ยวกับอัตราการตกตะกอนของไมโครพลาสติกสิ่งแวดล้อมทางทะเลและชายฝั่ง ในการศึกษานี้เลือกปากแม่น้ำเจ้าพระยาเป็นพื้นที่วิจัยเพื่อศึกษาอัตราการสะสมและลักษณะสมบัติของไมโครพลาสติกบนตะกอนผิวดิน และวิเคราะห์กระแสน้ำที่อาจส่งผลต่อปริมาณการสะสม จากผลการศึกษาแสดงให้เห็นว่า อัตราการสะสมสูงสุดของไมโครพลาสติก 1,401 ชิ้น/ตารางเมตร/ชั่วโมง เกิดขึ้นระหว่างเวลา 06:00-13:00 น. เมื่อกระแสน้ำเปลี่ยนจากระดับสูงสุดเป็นระดับน้ำต่ำสุด ในขณะที่อัตราการตกสะสมของไมโครพลาสติกต่ำสุดคือ 533 ชิ้น/ตารางเมตร/ชั่วโมง ซึ่งเกิดขึ้นในช่วงน้ำกำลังขึ้นจากระดับต่ำสุดระหว่างเวลา 14:00-17:00 น. พบไมโครพลาสติกขนาด 16-100 ไมโครเมตร เป็นลักษณะสมบัติเด่นที่เกิดขึ้นตลอดวัฏจักรน้ำขึ้นน้ำลง รูปร่างชิ้นส่วนและเส้นใยเป็นรูปร่างของไมโครพลาสติกที่มีอยู่มากที่สุดในทุกตัวอย่าง นอกจากนี้ โพลิเอไมด์ เป็นพอลิเมอร์ ชนิดหลักของไมโครพลาสติกที่เกิดการตกตะกอนลงบนตะกอนดินชั้นผิว และ ในช่วงเวลา 24 ชม. พบการตกตะกอนของไมโครพลาสติก 446±108 ชิ้น/ตารางเมตร/ชั่วโมง พบว่ามากที่สุดเป็น ไมโครพลาสติกขนาด 16-100 ไมโครเมตร ลักษณะเป็นชิ้นส่วน มีสีดำ และเป็นพอโพลิเอไมด์ เป็นพอลิเมอร์ชนิดหลัก

สาขาวิชา	พิษวิทยาอุตสาหกรรมและการประเมินความเสี่ยง	ลายมือชื่อนิสิต ....
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Jiradet Tang-siri : INFLUENCE OF TIDAL CURRENT ON MICROPLASTIC DYNAMICS IN CHAO PHRAYA RIVER ESTUARINE ECOSYSTEM. Advisor: Asst. Prof. SARAWUT SRITHONGOUTHAI, Ph.D.

Microplastics (MPs) can be found almost everywhere in marine ecosystems. That is one of the issues of concern around the world, including in Thailand. Estuary ecosystems are also among the most disturbed. By the estuary ecosystem affected by both rivers and oceans, such as the mouth of the Chao Phraya River in Thailand. Due to the change in tide, it is necessary to study the effects of tidal currents on the depth of MPs. Water samples were collected at approximately 60 water levels in 24 hours. Samples and three water quality indicators were collected at Pak Nam Chao Phraya. The number, shape and color of the MPs are then counted and analyzed under a microscope. When polymers were counted and analyzed with µ-FTIR for size and type. An average of 4.0±3.8 pieces/L was found in the experimental samples. And from all the samples, it was found that the most shape of MPs was fragment (shape), blue (color), at 16-100 µm (size) from the sample and Polytetrafluoroethylene (type) is the most polymer of MPs. For MPs detected during high and low tide. The average MPs were 3.4±3.3 and 4.0±4.2 pieces/L, respectively. In addition, fragment shape, blue color, 16-100 µm and PTFE polymer were the dominant plastic during high and low tide. It was found that tidal changes directly affect salinity and the effects of microplastic also found that MPs in the Chao Phraya Estuary are very high ecological risk.

Currently, microplastics are found everywhere in the environment. However, research around the world is not known about the deposition rates of MPs in marine and coastal environments. In this study, the Chao Phraya River Estuary was selected as the research area to study the deposition rate and characteristics of microplastics on surface sediments and analyze the tidal current that might affect the accumulation. The results show that the highest deposition rate of microplastics (1,401 pieces/m^2/hour) during 6:00-13:00 when the tide changes from the highest to the lowest. While the lowest deposition rate of microplastics was 533 pieces/m^2/hour. Which occurs during the rising tide from the lowest-high tide 14:00-17:00. Microplastics, 16-100 µm was dominated throughout the tidal cycle. Fragment and fiber shapes were the most abundant microplastic shapes in all samples. In addition, polyamide (PA) was the main polymer type of microplastics that precipitated in surface sediments. And for 24 hours found 446±108 pieces/m^2/hour of MPs at surface sediment. It was found that the most The MPs were 16-100 µm in size, fragment shape, black color, and polyamide (PA) as the main polymer. Monitoring the accumulation rate of microplastics in the aquatic environment and to better understand the factors of tidal currents in controlling the accumulation rate of microplastics.

Field of Study:	Industrial Toxicology and Risk Assessment	Student's Signature ....
Academic Year:	2022	Advisor's Signature ....

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CHAPTER 1
INTRODUCTION

1.1 Significance of the Research

Plastic is a dynamic material that has widespread applications; however, it poses a significant threat to marine ecosystems. It is estimated that between 4.8 and 12.7 million tons of plastic debris entered the oceans in 2010 and that this number may increase to 100-250 million tons by 2025 (Jambeck et al., 2015) . Consequently, marine plastic debris is considered an alien solid interacting with natural environmental components. The term microplastics (MPs) debris refers to plastic particles smaller than 5 mm that is manufactured (primary MPs) and small pieces that emerge from the fragmentation of large plastic debris (secondary MPs) (Cole et al., 2011). The behavior of MPs has been continuously studied to determine where and how they affect the environment. After being released into a dynamic aquatic environment, Microplastics are transported and transformed by physical, chemical, and biological processes. River discharge, wind, waves, and surface currents are the main factors inducing the horizontal transport of MPs, which mostly float on surface water (Zhang, 2017). Plastics are activated by ultraviolet radiation, temperature, and weathering processes in the environment and become yellow and fragmented as a result of photooxidative reactions, thermal reactions, and mechanical forces (e.g., wave action, abrasion with sand, or contact with animals), (Andrady, 2011); (Andrady, 2017). microplastics not only float on surface water but also sink into the water column and accumulate in sediments. Plastics generally settle when they are denser than seawater, e.g., polyvinylchloride (PVC) (1.16-1.58 g/cm^3). On the other hand, lighter plastics are subject to biofouling; natural compounds accumulating on the plastic surface can increase their density and sedimentation on the seabed (Chubarenko et al., 2016); (Hidalgo-Ruz et al., 2012); (Wang et al., 2016); (Zhang, 2017). With environmental movement and aggregation processes, Microplastics can be transported to all components of the ecosystem while being degraded simultaneously.

The Chao Phraya River is one of the most important estuaries in Thailand and we bring water to make tap water for supply and use in the province and we used for transportation, commuting, sightseeing, and tourism to see the beauty of the river. We use tap water to bath and wash clothes including the utensils for the household, as a source of recreation and lifestyle for farming, animal husbandry and fishing, industrial use, electricity generation, and drainage. Branch streams also become a habitat for many important aquatic species, including some spices that are endangered.

According to the rapid economic development of the Chao Phraya River basin, a lot of MPs produced by industrial, agricultural, and house waste, including the daily waste activities are contaminated into the river, and subsequently transported downstream. While the Chao Phraya River Estuary is an importantly complex to transition zone at the land to the sea interactions, where both significant transformations of the river and tidal current suspended MPs and the biogeochemical cycling of plastics occurs. Therefore, the Chao Phraya River and an estuary can serve as important sources of plastic contaminants in the inner Gulf of Thailand. As a result, the Chao Phraya is contaminated by various sources of pollution such as heavy metals, factory chemicals, garbage, household effluents, leachate, as well as various plastics such as plastic bags, water bottles, clothing, etc., all causing contamination in the environment, aquatic ecosystems and eventually into the sea.

Although the tidal currents were the one of important factors in the estuarine system, there are still less research to evaluate the tidal effects on microplastic dynamic especially in Thailand. Therefore, the present study focused on the changes in microplastic concentration in the water column and the deposition rate of particulate MPs onto the surface sediment during 24 hours of a tidal cycle at the Chao Phraya River estuarine ecosystem. Additionally, the accumulation of MPs in the suspended deposition water profile was also investigated to evaluate the contamination status and assess ecotoxicological risk. The finding data of this study will contribute to the understanding of the significance between tidal factors and MPs in the Chao Phraya River estuarine ecosystem.

1.2 Research Question

How do the tidal changes affect the MPs dynamics in the Chao Phraya River estuarine ecosystem?

1.3 Research Hypothesis

Microplastic concentrations in the water column and the deposition rates onto the surface sediment are significant differences during the changes of the tidal current at the Chao Phraya River estuarine ecosystem.

1.4 Research Objectives

1.4.1 To investigate the abundance and characterization of MPs in the water column during the change in tidal current.

1.4.2 To experiment the deposition rate of MPs in total and the different effects of tidal current onto the surface sediment.

1.4.3 To assess the risk of MPs contamination in the Chao Phraya River estuarine ecosystem during the change of the tidal current.

1.5 Scope of the Research

1.5.1 **Study area:** the Chao Phraya River estuarine ecosystem was chosen to study MPs during the changing of tidal current.

1.5.2 **Sampling points:** a sampling point (13°26'26.1"N 100°34'05.0"E) was established at the mouth of the Chao Phraya River in order to collect the samples during the tidal cycle.

1.5.3 **Samples:** water along the vertical profiles and depositing particulate were sampled using the standard sampling equipment and methodology.

1.5.4 **Sampling period:** the sampling was carried out during the highest tide to the lowest tide on April 29-30, 2021.

1.5.5 **Parameters:** water properties including depth, temperate, conductivity, salinity, DO and pH and microplastic abundance and characteristics including sizes, shapes, colors, and polymer types.

1.5.6 **Laboratory analysis:** all microplastic sample analysis was carried out during January to May 2022 at the Department of Environmental Science, Faculty of Science, Chulalongkorn University.

1.5.7 **Data analysis:** low-high tide variations of MPs in the water column, suspended of MPs in the water column, vertical distribution of MPs in the Chao Phraya River estuary. In addition, contamination status of plastics was analyzed using one-way ANOVA. Finally, the risk from the contamination of plastics in the water was assessed using potential ecological risk.

1.6 Research Outcomes

1.6.1 Demonstrating the abundance and physical characteristics of MPs, including shapes, sizes, colors, and chemical polymeric types in the Chao Phraya River estuary.

1.6.2 Prevention and providing accumulation of data in estuary areas for management that can lead to more effective use of microplastics.

1.6.3 Find the risk of MPs contamination in the Chao Phraya River estuarine ecosystem during the change of tidal current.

CHAPTER 2

LITERATURE REVIEW

Plastic is almost everywhere. And plastic pollution affects ecosystems everywhere as well. From the ocean, water sources, forests, distant islands or even in the ice of the Arctic continent. Most plastics take a long time to decompose. We can't know for sure how long it will take, but it is certain that if the plastic enters the environment, it can be contaminated. It's not easy for us to clean it all up. plastic we use after becoming trash there will be a destination at the landfill. Or contaminate the environments such as rivers, seas, over time, it will break down into small plastics. Or microplastics that we cannot see with the naked eye. Plastic production is correlated with economic growth. Multinational corporations often choose underdeveloped countries with inefficient waste management and weak law enforcement as the destination for their discharge of plastic products. While toxic chemicals in the plastics manufacturing process can escape and remain in the environment for a long time. This results in a hazard to human and animal health.

2.1 Plastics

A vast variety of materials that may be extruded, molded, cast, spun, or used as coatings are referred to as plastics. Oil or gas-derived monomers are often used to create synthetic polymers, and a variety of chemical additives are frequently used to create plastics (Thompson et al., 2009).

The synthetic materials used to make plastics are called polymers. Polymers are lengthy molecules with a backbone made up of carbon atom chains and multiple side chains that dangle from the backbone. Polyethylene (PE), polyvinyl chloride (PVC), and polypropylene (PP) are only a few examples of the range of plastics made possible by varied chemical structures that change the qualities of plastics. For instance, ethylene (C_2H_4) is the primary component of polyethylene (PE), one of the most popular polymers in use today. Due to its symmetrical structure, PE offers great chemical resistance, high ductility, and toughness. However, many plastics are created by polymerizing hazardous monomers, for example in the case, polyvinyl chloride (PVC), which contains chloride in the core, is robust and resistant to rust and the elements. PVC is utilized in gutters, electrical equipment, and plumbing because of its favorable features, but as it deteriorates, it releases hydrogen chloride into the atmosphere and eventually produces hazardous products. Various chemical additives that have been added to plastic since its inception to improve specific features can have negative impacts on the environment and human health in addition to its poisonous composition (Hong et al., 2018).

2.1.1 Plastics waste

Currently, the increased use of plastics poses a major plastic waste management problem, as plastic waste can accumulate in the environment, causing problems related to the aquarium hobby. Crawford and Quinn (2017b) reported that an estimated 10% of plastic ever produced ended up in the ocean. Additionally, approximately 33% of plastic produced annually cannot be reused and is typically discarded within 12 months of production (Crawford & Quinn, 2017). One way to dispose of plastic waste is by incineration. However, burning plastic materials releases highly toxic chemicals such as furans and dioxins, which can seriously affect human health and are extremely harmful to the environment.

Additionally, many countries have not enacted laws mandating the recycling of plastic waste. As a result, it is often cheaper and easier to choose landfill instead. 16% of all municipal waste generated worldwide is plastic (Crawford & Quinn, 2017).Inevitably, much of this plastic waste ends up in the aquatic environment on land, and current estimates suggest that 15-40% of all plastic waste ends up in the ocean (Crawford & Quinn, 2017).This usually occurs when landfilled or discarded plastic material is carried by the wind or discharged into rivers and urban waterways and carried to the sea. Many underdeveloped and developing countries use open landfills due to the low costs associated with this practice. A preventive measure to reduce the amount of plastic entering the ocean is to close landfills in flood-prone areas.

2.1.2 Microplastics

A wide variety of tiny plastic fibers and particles are referred to as microplastics together. The United States' National Oceanographic and Atmospheric Agency (NOAA) organized the inaugural International Microplastics Symposium in 2008. Workshop and created a working definition for all plastic particles less than 5 mm in diameter as part of this conference (Napper & Thompson, 2019). The categories of primary and secondary microplastics may then be created based on the origin of the MPs.

1) Primary microplastics are defined as particles with a diameter of less than 5 mm that are directly released into the environment (Li, 2018).

2) Secondary microplastics are small plastic debris fragments that are created in the environment when bigger plastic debris objects are broken up. This deterioration is brought on by oxidation and ultraviolet (UV) light, which over time may weaken the plastic's structural integrity and cause fragmentation. Physical forces from abrasion, wave action, and turbulence may help with this (Li, 2018).

Plastics can be classified based on many factors, such as chemical structure, color and size. Plastics can be divided into four main groups based on their size: macro-, meso-, micro-, and nano-plastics. Microplastics are plastic particles that are smaller than macro- and mesoplastics but larger than nanoplastics. Microplastics are small plastic particles less than 5 millimeters in length and greater than 1000 nanometers in length, as shown in Figure 1 (Barboza et al., 2019); (Hamzah et al., 2021); (Shim et al., 2018); (Xiang et al., 2022).

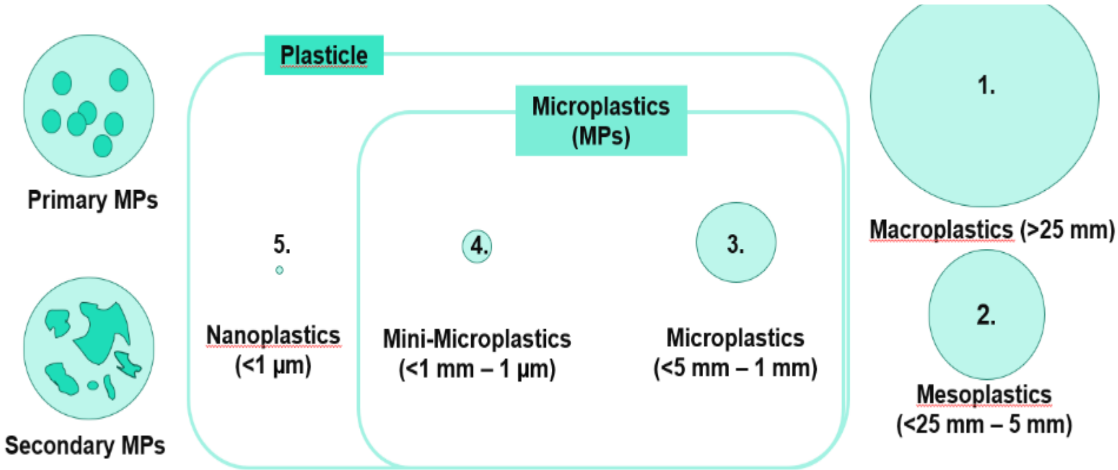


Figure 1 Diagram of microplastics

2.1.3 Sources of microplastics

Researchers were concerned long time ago about the appearance of microscopic particles of plastic, known as MPs, that were not apparent to the human eye. As a result, microplastics can be made from primary sources such as plastic resins and microbeads in cosmetic items and plastic resins. Secondary sources of MPs include UV degradation associated with wind and wave impact on bigger plastics, as well as road abrasion of larger plastic goods due to vehicle and transit damage, as well as concrete walkways (Barnes et al., 2009); (Gregory & Andrady, 2003). Microplastics can also be found in textile washing facilities and sandblasting (Browne et al., 2011); (Napper & Thompson, 2016). These contaminants, which are generally sub-millimeter in size, are flushed down the drain because they are too tiny to be screened by sewage treatment facilities, and hence wind up in river systems and, eventually, the seas.

In the early 1970s, the first reports of plastic trash in the oceans (Fowler, 1987); (Carpenter et al., 1972); (Carpenter & Smith Jr, 1972); (Colton Jr et al., 1974) garnered little attention from the scientific community. With the accumulation of data on the ecological repercussions of such debris in the following decades, the issue drew a growing amount of persistent study attention. Most of the research has focused on marine mammals (Laist, 1997) cetaceans

(Clapham et al., 1999), and other species (Eriksson & Burton, 2003) being entangled in net fragment litter, as well as 'ghost fishing' by derelict gear in the benthos (Bullimore et al., 2001); (Tschernij & Larsson, 2003). Plastic ingestion by birds (Cadée, 2002) At least 44 percent of maritime bird species are known to swallow plastics (Rios et al., 2007), including verifiable examples of species like the black-footed albatross giving plastic granules to its young (Mascarenhas et al., 2004); (Bugoni et al., 2001); (Tomás et al., 2002). Following recent findings on the unusually high prevalence of plastic debris in the North Pacific gyre (Moore et al., 2002); (Moore et al., 2002),the issue has been designated as a high-priority study area in Marine Biology (Derraik, 2002); (Page et al., 2004). Smaller particles of plastic trash, particularly those that aren't visible to the naked eye, are a particular source of worry. Microplastics, which are tiny particles of plastic garbage that are not visible to the human eye, are a major source of worry in the world's seas. The destiny of plastics in the marine environment, the methods by which MPs are formed from marine trash, and the possible ecological implications of MPs are all addressed in this study.

Because of its widespread prevalence in marine and freshwater species, Microplastics attracts worldwide attention. Despite this, few studies on estuarine creatures have been conducted. The number and distribution of MPs in the gastropods of a tropical estuary in Selangor, Malaysia, are investigated in this baseline investigation. Microplastics were found in concentrations ranging from 0.50-1.75 particles per gram or 0.25-0.88 particles per person. The difference in MPs dispersion between the higher and lower estuaries suggests that the MPs came from the Klang River estuary's urbanized region. Microplastics ranged in size from 30-1850 micrometers, with the majority falling between 300 and 1000 micrometers (57%). Microplastics were most prevalent in fibres with a black hue (91%). The major polymer components were polyethylene-propylene-diene (PE-PDM) and polyester. The feasibility of using gastropods as bioindicators for monitoring and baseline investigations is revealed by assessing the contamination of gastropods by MPs (Zaki et al., 2021).

2.1.4 Fate and transportation of microplastics in the marine environments

In the context of MPs movement, tidal force is commonly overlooked. Tidal-induced barotropic currents are generally one or two orders of magnitude weaker than wind and buoyancy driven surface currents in the open ocean and are thus predicted to have a little impact on MPs movement. Nonetheless, in coastal locations, barotropic tidal currents are in general leading order, which is important for plastic transport and accumulation (Zhang, 2017), as the majority of plastic enters the ocean in coastal habitats (Cole et al., 2011). Furthermore, many plastics put into the ocean linger near the coast for a long time (Lebreton et al., 2012), and large relative quantities of MPs have been found in near shore locations (Auta et al., 2017); (Desforges et al., 2014). It's uncertain if the tides influence MPs movement in the open ocean. The effect of barotropic tidal currents on the transport of MPs can help us better understand how MPs are transported and distributed throughout oceans. Furthermore, it can assist us in determining the importance of incorporating barotropic tidal currents in simulations used to examine global microplastic transport in Figure 2.

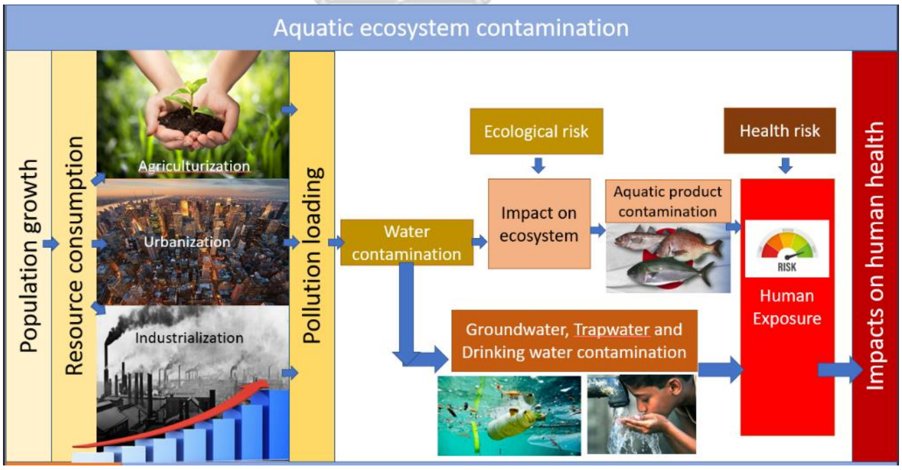


Figure 2 Causes, sources, uses, transports, fate, and cycle of MPs in the marine environment.

2.1.5 Toxicity effect of microplastics

The inherent toxicity of plastics and the contaminants that are absorbed or released from MPs have been used to examine the ecological implications of MP environmental change. Microplastics are exposed to the environment, which causes oxidative stress and inhibits several metabolic processes. In addition, because of their bioinert nature, ingested pseudo food. Microplastics can build up in the gastrointestinal system, resulting in decreased food consumption (Anbumani & Kakkar, 2018). For example, following exposure to polystyrene in the culture media, the phytoplankton *Chlorella pyrenoidosa's* photosynthesis, electron transport rate, reaction center activity, and efficiency of the oxygen–evolving complex all decreased (Mao et al., 2018). Electrons accumulated in the cell as a result, and oxygen species increased. As a result, the alga was under oxidative stress. This caused lipid peroxidation and cell membrane injury. Furthermore, Microplastics toxicity may be seen as a vector for the accumulation and transport of hazardous compounds into the ecosystem. Microplastics have a high partition coefficient, indicating that they have a lot of potential for long-term adsorption of organic contaminants (Hüffer et al., 2018); (Hüffer et al., 2018). Microplastics can also amass a large amount of heavy metal (Ashton et al., 2010); (Munier & Bendell, 2018); (Rochman et al., 2014). However, additional chemicals utilized in plastic goods may include both harmful organic and heavy metal compounds (Hahladakis et al., 2018). Dangerous chemical adsorption and desorption on polymers may be discussed on a case-by-case basis in terms of how they affect the release of toxic chemicals. Poisonous biota should be avoided or toxic components should be removed (Koelmans et al., 2016).It's critical to examine MPs' destiny and mobility in order to learn more about their environmental consequences and behavior.

2.1.6 Risk of microplastics

Plastic particles can injure the lungs and intestines, and extremely tiny particles can pass through cell membranes, the blood-brain barrier, and the human placenta. Cell damage, inflammation, and impairment of energy allocation processes have all been seen. Plastics harboring pathogens may enter bathing or drinking water after being ejected into surface water, exposing humans and increasing their risk of illness. While the dangers of some plastic compounds are better understood, the dangers of plastic particles to people are only beginning to emerge from a few research. While the dangers of some plastic compounds are better understood, the dangers of plastic particles to people are only beginning to emerge from a few research. To give a thorough evaluation of the dangers to people, the degree of human exposure, chronic toxic impact concentrations, and underlying toxicological processes by which micro- and nanosized plastic particles elicit effects are currently too little known (Vethaak & Leslie, 2016).

Microplastics derived from bigger polymers have produced a slew of environmental issues due to the plastic industry's fast growth. The danger of MPs contamination in the Changjiang Estuary's surface waters was investigated using risk assessment models. Microplastics concentrations averaged 23.1±18.2 pieces/100 L. Microplastics were studied for their shape, size, color, and composition. Data on the concentration and chemical hazard of MPs polymers was used to create the risk assessment models. According to the findings, polyvinyl chloride poses a significant danger of microplastic contamination. Because of the buildup of MPs and the presence of harmful microplastic, areas near aquaculture farms were deemed "hotspots" of microplastic contamination. This Microplastics risk assessment filled in the gaps between field research and surface water policy-making. In this developing field of research, this study offers baseline data for estimating the environmental danger of MPs (Xu et al., 2018).

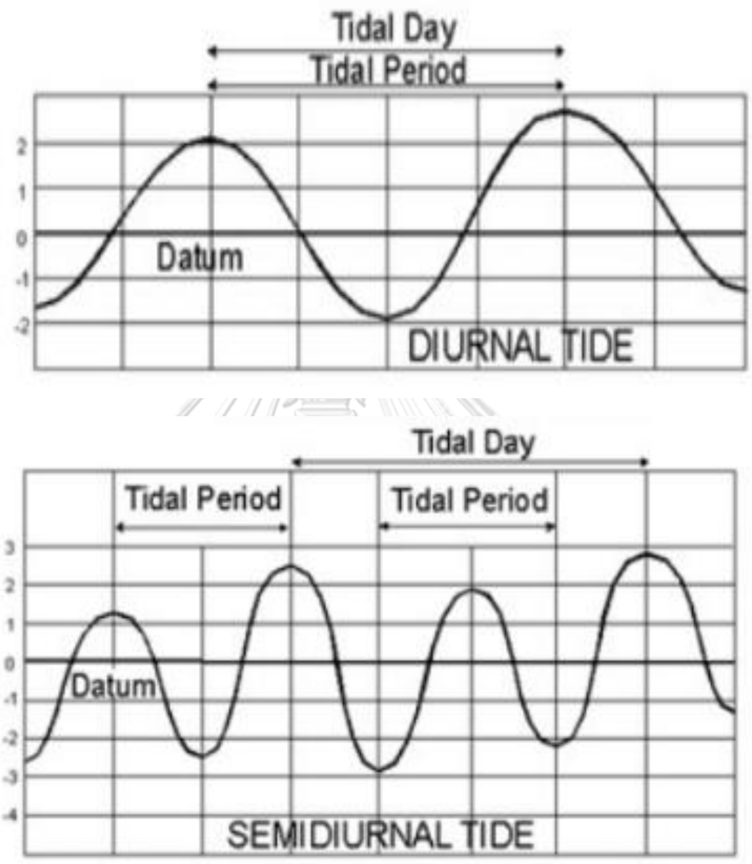
As plastic manufacturing rises, so do the risks of pollution from it. Microplastics (defined as plastics with a diameter of less than 5 mm) are a kind of marine debris about which we know less than we do about bigger debris items, even though they are potentially ubiquitous in the ocean. We took sediment cores from an estuary in Tasmania, Australia, to determine the distribution and change in MPs levels over time. We expected that increased plastic manufacturing, coastal population expansion, and proximity to urban water outflows and local hydrodynamics would be linked to the kind, location, and quantity of MPs found. Each core was sub-sampled with sediments dating from 1744 to 2004. MPs were identified in every sample, with higher plastic frequencies in the top (newer) strata. Microplastics build up followed the same temporal pattern as global plastic manufacturing and coastal population expansion. Fibers were found to be the most common kind of MPs in our samples. These fibers were found in sediments deposited before the introduction of plastics into the environment. To evaluate the amount of contamination in our samples, the researcher presents a simple statistical model. That the current literature trend of very high fiber loads, especially in distant sites such as the deep bottom, is mostly attributable to contamination (Willis et al., 2017).

2.2 Tidal Current

Tidal currents are described as the periodic flow of water caused mostly, but not completely, by a head difference induced at each end of a constriction by out-of-phase ocean tides. Tidal currents are subjected to a variety of external and often nonperiodic factors, which are influenced by local weather patterns (radiational tides), ocean properties (internal tides), and geology. The Coriolis forces, which are influenced by the Earth's rotation, change the flow away from the equator. The flow parameters are also influenced by the local terrain and bathymetry at any given place, since these factors influence bottom friction energy losses and turbulent mixing intensity (Sterl et al., 2020). Three tidal patterns occur along the Earth's major coastlines. In general, most areas have two high tides and two low tides each day. A pattern in which two highs and two lows are approximately the same is called a half-diurnal or semi-diurnal tide. When the tides are of different heights, the pattern is called a mixed semi-diurnal tide (Yusoff et al., 2015).

1. Diurnal tide cycle (top). An area has a diurnal tidal cycle if it experiences one high and one low tide every lunar day. Many areas in the Gulf of Mexico experience these types of tides.
2. Semidiurnal tide cycle (middle). An area has a semidiurnal tidal cycle if it experiences two high and two low tides of approximately equal size every lunar day. Many areas on the eastern coast of North America experience these tidal cycles.

3. Mixed Semidiurnal tide cycle (bottom). An area has a mixed semidiurnal tidal cycle if it experiences two high and two low tides of different size every lunar day. Many areas on the western coast of North America experience these tidal cycles also in the Gulf of Thailand as show in Figure 3.



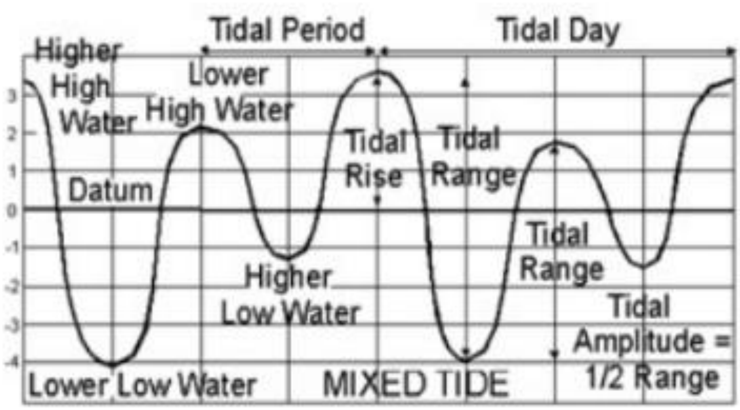


Figure 3 Tidal patterns, diurnal tide cycle (top), semidiurnal tide cycle (middle) and mixed semidiurnal tide cycle (bottom).

Due to changes in the moon's gravitational pull, there are four main phases in the tidal cycle. High tide is when the sea level is at its highest. Low tide is when the sea level is lowest. High tide is the phase of sea level rise between high and low tides, and low tide is the phase of sea level decline between high and low tides. As different tide levels occur each day, huge amounts of seawater move towards or away from the coast, creating tidal currents. These movements play an important role in ocean circulation, and undergo even more complex changes, especially in estuaries where freshwater streams meet the ocean in Figure 4 (Darwin, 1895).

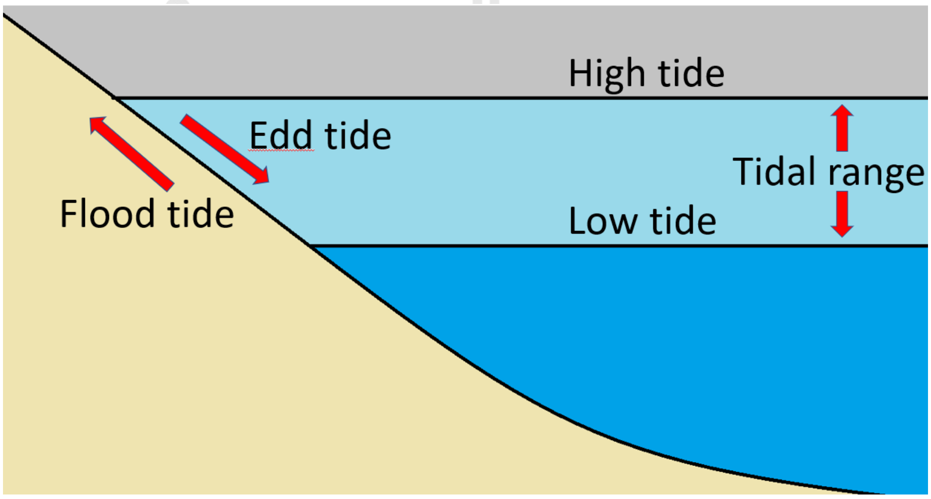


Figure **4** Tidal phenomena during high and low tide through the tidal current.

Basically, tides are very long period waves that move through the ocean in response to the forces exerted by the moon and the sun. Tides originate in the ocean and progress toward the coast, manifesting as a periodic rise and fall in sea level. A high tide occurs when the crest or crest of a wave reaches a certain point. The ebb tide corresponds to the lowest part of the wave or its valley. The height difference between high tide and low tide is called tidal level difference. That means water moves toward the shore. This is called a flood current (flood tide) that made high tide. On the other hand, the waters move away from the shore. This is called an ebb current (ebb tide) that made low tide. So, the movement of water toward and away from the shore.

2.3 Estuaries

The river estuary is a very important area between land and sea, which receives large amounts of pollutants from point sources, including household waste, wastewater treatment plants etc. and non-point sources such as plastic bottles, cloths, plastic bag, and fishing net. Estuaries receive more pollution inputs per unit surface area than any other type of ecosystem. Therefore, the fundamental knowledge of estuaries and their regulating factors, which make the extreme of pollution in plastics area are needed to review.

An estuary is a brackish water feature that is partially contained along the coast, with one or more rivers or streams flowing into it and free access to the open sea. Estuaries are an example of an ecotone, which is a transition zone between river and marine habitats. Tides, waves, and the entry of saline water all have an impact on estuaries, as can fluvial factors like freshwater flows and silt. Estuaries are among the most productive natural environments on the planet because the mixing of seawater and freshwater generates high amounts of nutrients both in the water column and in the sediment.

2.3.1 Importance of estuaries

The estuaries are significant since it is a major supplier of biological products. Particularly the plankton. Many types of marine life are found in abundance in the estuaries. The estuaries are home to a diverse range of marine life. It isn't found anyplace else on the planet. These animals are vital to the seas. It also relies on the estuary, which serves as the biological engine that propels the product into the sea.

In addition, the estuary is the location of the coast in a part of the ocean. But it turned out to be a place that people wanted to leave behind. Both the mud and the seagrass or plankton. in order to have more space to build a residence, port or business district The estuary became a dumping ground. All the pollutants that people don't want. The mouth of the river is the confluence of the most precarious conflict between man and nature. Researchers forget that the estuary is the most precious natural resource. But the most fragile and it is a resource that was poached and destroyed by human action more than any other resource.

2.4 The Chao Pharya River

The Chao Phraya Continental Divide is the largest watershed in Thailand, covering about 35% of the country and draining an area of 157,924 km^2. The Chao Phraya River is an important river in Thailand that has long been used by Thai people for agriculture, recreation, transportation, main food and water source, or settlement. There are four rivers: Ping River, Wang River, Yom River and Nan River. The Yom River which formed by the merger by converging in Nakhonsawan province and depart for the Gulf of Thailand in Samut Prakan province. It's Chao Phraya known for pollution, including microplastics (Figure 5).

Figure 5 Chao Phraya River in Bangkok, Thailand

Many societal advantages have resulted from the use of plastic materials, as well as technical and medical advancements. However, excessive plastic manufacturing combined with poor waste management has resulted in major environmental issues. Plastic garbage already pollutes a variety of natural terrestrial, river, and marine environments (UNEP-WCMC, 2018).Over 600 species have been observed to swallow or become entangled in plastic trash, including invertebrates, turtles, fish, seabirds, and mammals (Dias & Lovejoy, 2012). Concerns about the presence and consequences of tiny plastics, notably MPs, have recently grown in the public and environment.

The consequences of MPs pollution are alarming; it is predicted that 0.2-0.4 million metric tons of plastics entered the sea from Thailand in 2010, accounting for 3.8-3.9 percent of global intake (Jambeck et al., 2015). Thailand's inner Gulf is a shallow, semi–enclosed bay that lies beneath the country's most populous landmass. It is an important economic and ecological resource. The Mae Klong, the Tha Chin, the

Chao Phraya, and the Bangpakong Rivers, which flow above the inner Gulf of Thailand, convey freshwater from the mainland as well as pollution. The surface current in Thailand's inner Gulf is mostly controlled by monsoon winds, and it is thought to be linked to northward river water flow. During the southwest, the current moves in a clockwise direction. During the southwest monsoon season (May–August), the current circulates clockwise, with minor counterclockwise circulation during the northeast monsoon season (November–January) (Buranapratheprat et al., 2008). On the western and eastern shores of Thailand's inner Gulf, prominent tourist beaches and industrial sites may be found. In the inner Gulf of Thailand, there are also maritime recreation activities, fisheries, mariculture, marine transportation, and marine transshipment.

Given that plastics are derived from anthropogenic activity, it is reasonable to assume that plastic garbage from diverse sources around the land enters the inner Gulf of Thailand. Importantly, the physicochemical dynamic interactions of river and coastal habitats might fragment the plastics into MPs. These MPs might either build up in the Gulf or be exported out to sea. The inner Gulf of Thailand is currently under constant pressure from anthropogenic activities that have resulted in marine garbage, notably microplastic contamination. As a result, scientific data is required for coastal environment management, particularly in Thailand's inner Gulf.

2.5 Literature Reviews

He et al. (2021) that collected samples used two different methods by trawling water with a 300 μm mesh Manta trawl net and filtering the water though 48 μm stainless-steel from the Yangtze River to the estuary and found that the microplastics average. The abundance was reported between $1.62\pm0.61\times10^5$-$4.25\pm3.87\times10^6$ items/km^2 for the trawling samples and 800.0±300.0–3088.9±330.6 items/m^3 for filters samples. In addition, Fragment and fibers were dominated in the Trawling samples and filtering samples, respectively. However, small microplastics (< 1 mm) and transparency were the dominant characteristics in both method samples (He et al., 2021).

Li et al. (2021), that collected the sample from 10 cm below the surface and filtered the water with 75 µm screen, the amount of microplastics in the Renhuai basin Chishui River between 1.77-14.33 items/L. In this investigation, Microplastics majority is fibrous and white microplastic features predominated (including transparent). Additionally, the predominant size of microplastic that polluted the area was 500-1000 µm (Li et al., 2021).

Napper et al. (2021) collected samples 50 cm below the surface by filtering water with 330 µm nylon cloths from pre- and post-monsoon seasons, and in 120 samples (60 of his pre- and post-monsoon) It reported finding 140 microplastic items. sample). rainy season). The mean microplastics found in pre- and post-monsoon seasons were 0.051±0.007 and 0.026±0.004 MP/L. The average size of microplastics was 2529±263 µm in the pre-monsoon season and 2317±341 µm in the post-monsoon season. Additionally, in this study, fiber, blue, and rayon were key features in terms of color, shape and polymer type, respectively (Napper et al., 2021).

Oo et al. (2021) collected water samples at a depth of 10 cm using a 335 µm manta net at the mouth of the Chao Phraya River at low tide during the dry season and found that the average amount of microplastics at high tide was 5.16×10^5 at low tide. 105 particles/km^2, but at low tide it was 3.11×10^5 particles/km^2. In contrast to abundance, the dominant properties of microplastics were similar in the two currents. Fragments, Whites and Polypropylene dominated both streams. In addition, microplastics ranging in size from 335 to 515 µm were also the largest (Oo et al., 2021).

Vibhatabandhu and Srithongouthai (2022) collected water samples at a depth of 50 cm using a phytoplankton net with a 100 µm mesh during the dry season and the flood season in the interior of the Gulf of Thailand demonstrated that the average microplastics during the dry season and rainy season is 8.70±15.34 pieces/L and 34.59±46.02 pieces/L respectively. Film is the predominant form found in the dry season, while fiber is the predominant form during the rainy season. By the way, microplastics of size 100-300 µm and transparent accounted for the main proportion in both seasons. Similar in size and color, PP is the micropolymer that dominates both seasons. This study shows that research on microplastics has no standard. The abundance of microplastics and microplastics varies depending on many factors such as sampling time, sampling method, sample preparation, including the criteria for classifying the characteristics of microplastics (Vibhatabandhu & Srithongouthai, 2022).

CHAPTER 3
METHODOLOGY

To meet the objectives of the present study, the methodologies including appropriate materials and standard methods were used to evaluate the influence of seasonal variations on contamination level and ecological risk of heavy metals in the surface sediments as follow:

3.1 Study Area

3.1.1 The Chao Phraya River estuarine ecosystem

The Chao Phraya River is a significant important river of Thailand. The river formed by the merger of two main rivers from the north, namely the Ping River and the Nan River by converging in front of the dam in the city at Tambon Pak Nam Pho, Mueang Nakhon Sawan district, Nakhon Sawan province. Then flows to the south through Uthai Thani, Chainat, Sing Buri, Ang Thong, Phra Nakhon Si Ayutthaya, Pathum Thani, Nonthaburi and Bangkok, before leaving into the Gulf of Thailand at Pak Nam in Mueang Samut Prakan district and Phra Samut Chedi district, Samut Prakan Province. Due to 372 km long river, the Chao Phraya River is receiving diverse pollutants from various activities throughout the riverbanks, particularly macro-MPs. Therefore, the Chao Phraya River could influent the contamination of MPs in the inner Gulf of Thailand. On the other hand, accumulated MPs in the inner Gulf of Thailand could influent the Chao Phraya River due to the tidal current, which was affected on the changes of concentration in the water column and deposition rate onto the surface sediment of an estuarine ecosystem. These processes can be impact on the Chao Phraya River estuary through the precipitation of microplastic into the water profiles that can causes the bioaccumulation of plastics and bio–expansion in food chains, and it may affect to humans. Therefore, the Chao Phraya River estuarine ecosystem was chosen to investigate the influence of tidal current on microplastic contaminations and their risks on the ecosystem.

3.1.2 Sampling point

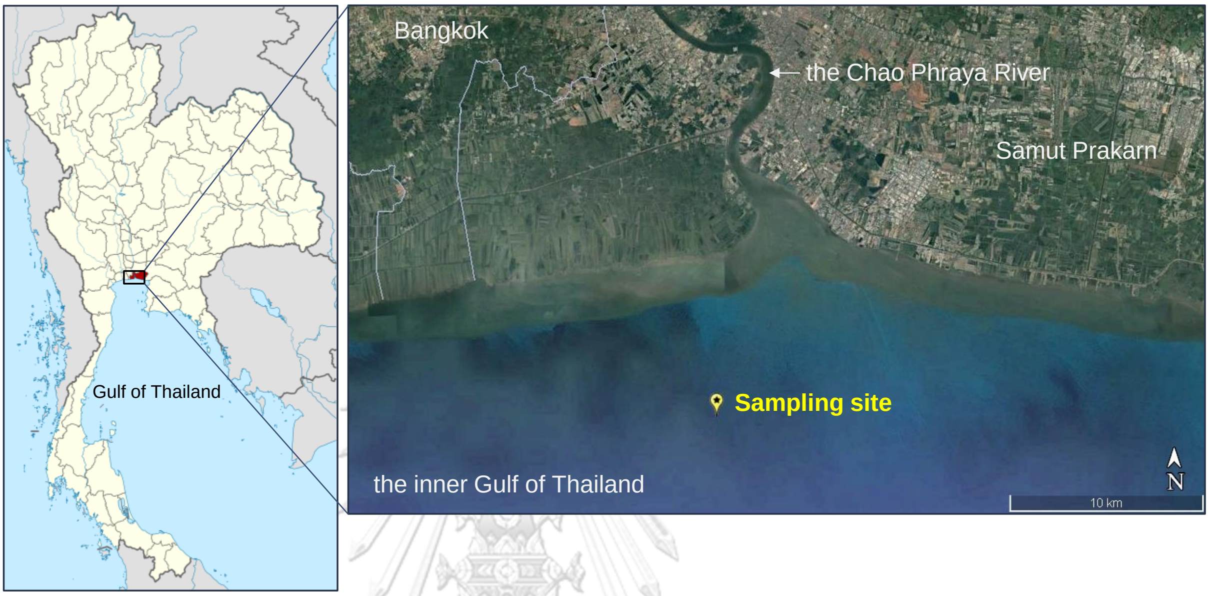


Figure 6 Map showing the sampling site at the mouth of the Chao Phraya River, where located in inner Gulf of Thailand.

3.2 Research Materials

3.2.1 Sampling cruise

1) Research vessel (Kasetsart Research Ship I)
2) Global positioning system (GPS)
3) Depth meter (Sonar sensor)

3.2.2 Water sampling

1) 3 L horizontal Van Dorn water sampler
2) 10 L cleaned stainless-steel bucket
3) Conductivity meter (HACH sension156, USA)
4) Rubber band

5) Plastics bag
6) 500 mL polyethylene measuring cylinder
7) 1000 mL polyethylene measuring cylinder
8) 600 mL wash aluminum can
9) Aluminum foil
10) Waterproof labeling pen
11) Dip net (pore size 16 µm)

3.2.3 Sedimentation experiment

1) Sediment trap
2) Rubber band
3) Plastics bag
4) 600 mL wash aluminum can
5) Aluminum foil

3.2.4 Laboratory instruments

1) Digital balance 2 digits (Mettler Toledo, ML1602/01, Switzerland)
2) Digital balance 5 digits (Mettler Toledo, MS204S, Switzerland)
3) Hot air oven (Memmert, 600, Germany)
4) Stereo microscope 30X magnification (Shodensha, Trinocular Stereomicroscope NSZ405J3, Japan)
5) Laboratory mixer (Humboldt, H-4260.5F, United State)
6) FTIR microscope (µFTIR, Bruker Lumos II, Germany)

3.2.5 Laboratory equipment

1) Polycarbonate membrane (Whatman, USA)
2) Glass beakers
3) Standard metal forceps
4) Distilled water bottle
5) Metal spatula
6) Watch glass
7) Laboratory hot plate

8) Separation unit
9) Retort stand
10) Spring clamp
11) Aluminum foil
12) 4-mL glass vial

3.2.6 Chemical substances

1) Iron (II) sulfate (Fe_2SO_4 15 g [*KemAus* AR grade, Australia] + H_2SO_4 6 ml [Sulfuric acid 98% Qrec AR grade, Newzealand] + H_2O 1 L)
2) 30% Hydrogen peroxide (Merck KGaA AR grade, Germany)
3) Sodium chloride (Carlo Erba AR grade, France)

3.3 Measurement Parameters

3.3.1 Water analysis

1) **Properties of water**
   - Salinity (ppt)
   - Temperature (°C)
2) **Microplastics**
   - Size
   - Shape
   - Color
   - Polymer type

3.3.2 Deposition rate of microplastics

1) Size
2) Shape
3) Color
4) Polymer type

3.4 Sampling Methods

All samplings were carried out on board of Kasetsart Research Vessel 1 from April 27 to May 01, 2021. The present study was designed to study the influence of tidal current on changing concentration of MPs in the water column of the Chao Phraya River Estuary. Water was sampled 8 times on April 29-30, 2021 during the tidal cycle (Figure 7). Sampling was carried out at the high tide times and low tide times, which is twice a day, and at the middle time between tide occurring at the different water sampling layers depending on water depth on the sampling time.

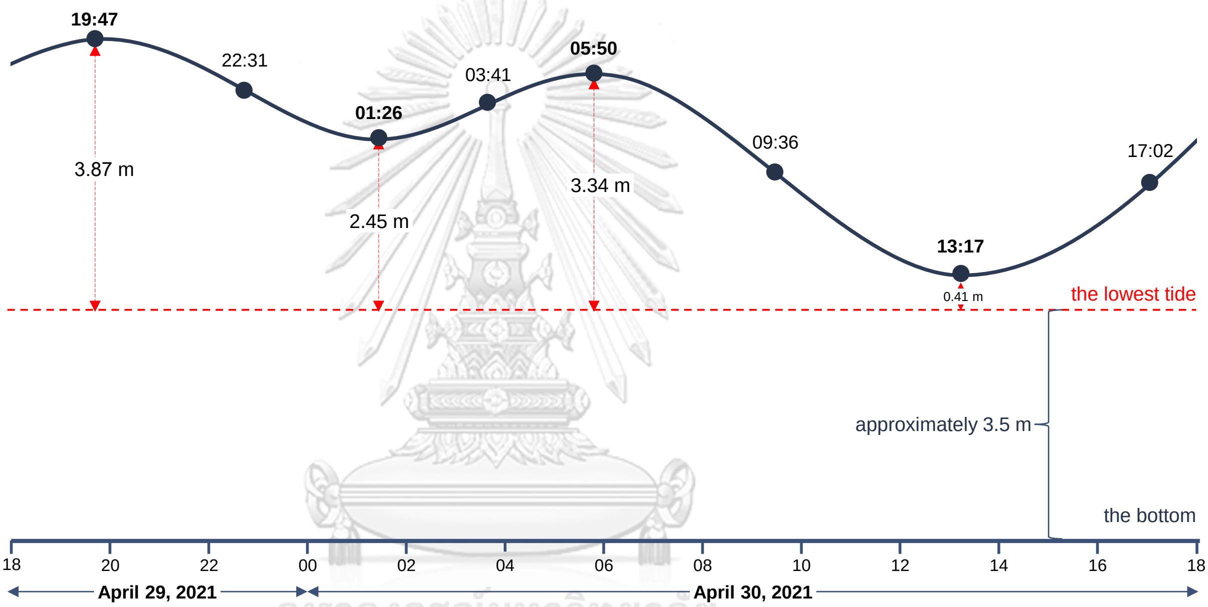


Figure 7 Schematic drawing of tidal current during April 29-30, 2021, and 8 sampling times.

3.4.1 Sampling and sample preparations

Water sampling was carried out 8 times including at 19:47 (highest tide), 22:37 (intermediate highest-low tide), 01:26 (low tide), 03:41 (intermediate low-high tide), 05:55 (high tide), 09:36 (intermediate high-lowest tide), 13:17 (lowest tide), and 17:02 (intermediate lowest-highest tide) (Figure 7).

Surface water was sampled using a cleaned stainless-steel bucket, while vertical water at various depths was collected using horizontal Van Dorn water sampler. Water sample was divided into 2 sub-samples. First sub-sample (ca. 0.3-

0.5 L) was carefully transferred into 1 L of cleaned polypropylene breaker to measure temperature and salinity using the conductivity meter. Remaining sub-sample (1.0-6.0 L) was filtered through the dip net before transferred into the 600 ml cleaned aluminum cans, subsequently covered with aluminum foil in order to avoid the microplastic contamination.

3.4.2 Deposition sampling

Total deposition rate of microplastics onto the surface sediment was measured using a set of sediment trap (including 4 tubes of 40 cm in height and 8.4 cm in diameter) at the sampling site. The sediment trap was deployed approximately 24 hours during April 29-30, 2021 at 1 m above bottom (Figure 8). Additionally, the influence of tidal current on the deposition rate of MPs was also experimented in this study. The microplastic deposition during high to low tide was conducted 2 times during 19:47-01:26 and 05:50-13:17. While, deposition from low to high was conducted 2 times during 01:26-05:50 and 13:17-17:02 (Figure 8). Particulate samples of each experiment were allowed to settle for 1 hour. Supernatant was subsequently removed using syphon technique. Particulate samples were sieved through dipnet (16 µm mesh size), then transferred into aluminum can, which sealed with aluminum foil in order to minimize the contamination.

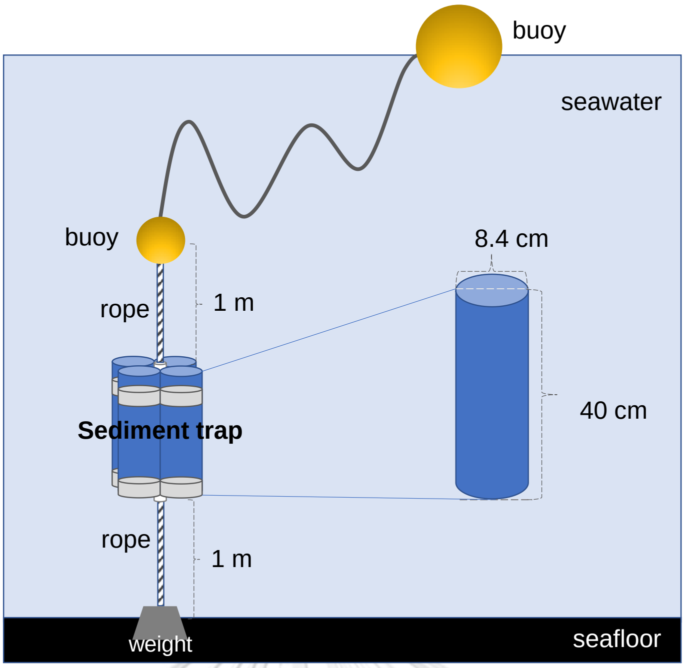


Figure 8 Schematic drawing of sediment trap deployment for deposition rate experiment.

3.5 Laboratory Analysis

3.5.1 Size fractionation

1) Particulate samples of the water were directly used in the second step. While particulate depositing sample was put into a 500 mL glass beaker and then dried in an oven at 60 °C overnight.
2) Both particulate in water and depositing samples were sieved in different sizes (16-100, 101-200, 201-300, 301-400, 401-500 and >500 µm) using 16 µm Dip net. Samples were dried at 60 ºC using the hot-air oven (Memmert, 600, Germany).

3.5.2 Wet peroxide oxidation

Wet peroxide oxidation (WPO) is the process, which can remove organic matters from the surface of MPs. All dried samples are added with 20 ml of $FeSO_4$ and 20 ml of H_2O_2 into the breaker, then stirred at 150 rpm at room temperature for 10 minutes, subsequently sample are heated at 75 °C for 30 minutes. Then, 12 grams of NaCl were added to increase the density of aqueous solution to 5 M NaCl and stop heating.

3.5.3 Microplastic separation

Sample solutions are transferred into the separation unit and allowed the solution to stand overnight. In this process, MPs were floated on the surface, the settle particle Transfer the sample to the separation unit and allow the solution stand overnight.

3.5.4 Filtration

After that, Add HCl to remove contaminated $CaCO_3$ before filtered. MPs are filtered from the solution by using the 12 µm polycarbonate membrane Nuclepore Track-Etched membrane (Whatman, 110616, USA).

3.5.5 Microplastic characterization

1) Stereo microscopic analysis

Total number of MPs was counted under the stereomicroscope (Shodensha, Trinocular Stereomicroscope NSZ405J3, Japan), subsequently was calculated as “pieces/L”. MPs were classified according to shape of fiber, fragment, film, foam, and pellet, with fiber referring to a filament, strand line; fragment referring to an irregular shape with a roughly broken shape; film referring to a thin sheet, film that we can see though it, or membrane; foam referring to a piece of sponge, or porous and pellet referring to a group of spherical or an ellipse bead shape. Additionally, identified color of MPs also.

2) FTIR microscope analysis

Weigh filtered MPs and randomized the MPs on the surface of filtered for optimize the polymer type and size. randomly by using paintbrush then put it out by tong and placed on a KBr window and analyzed on light transmission using a Fourier-transform infrared microscope (µ-FTIR, Bruker Lumos II, Germany). Use a program for analysis and take a photo with OPUS (8.5 SP1).to analyze and identify type of plastics at the wavelength and then compare with the database in the command library program. Such as PE: Polyethylene, PP: Polypropylene, EPDM: Ethylene-propylene diene monomer, rubber, SEBS: styrene-ethylene-butylene-styrene, PA: polyacrylate derivatives, and polyamide etc.

3.6 Data Analysis

3.6.1 Microplastic abundance and characterization

MPs Samples were calculated from MPs column from depth level in the unit pieces/L (the level of depth can change by the tidal such as in high tide has a high sea level). then calculated the rate of total MPs compared to other MPs depth column in unit of pieces/L during highest-lowest tide, highest-low tide, highest-high, high-lowest tide, high-low tide, low-lowest. Then MP characterization of the water column from depth level are classified as sizes, shapes, and color both 24 hours cycle and tidal changes.

3.6.2 Microplastic deposition

Mass flux was calculated from total MPs deposit onto the surface sediment in the unit of pieces/m^2/day. Subsequently, deposition rates are calculated as a rate of total MPs deposited onto the surface sediment (pieces/m^2/hr) during highest-low tide, low-high tide, high-lowest tide, and lowest-highest tide. Additionally, the MP characteristics of deposition are classified as sizes, shapes, and color both 24 hours cycle and tidal changes.

3.6.3 Risk assessment

The present study was selected the Håkanson mathematical approach to evaluate the potential ecological risks caused by MPs pollution (Hakanson, 1980). This method has been wildly applied in previous studies of the heavy metal pollution in the surface sediment (Effendi, 2016); (Rezaee Ebrahim Saraee et al., 2011) and researchers have developed recently for evaluating the microplastics risk (Lithner et al., 2011); (Xu et al., 2018). Therefore, the potential ecological risk factor (E_{r}) and potential ecological risk index (RI) were examined for risk assessment of MPs in the Chao Phraya River estuarine ecosystem.

According to the Håkanson approach, the MPs concentration factor (C_f^i), toxicity response factor ($T_{\mathrm{r}}^{\mathrm{i}}$), E_r^i, and RI of the environment were calculated by Eq 3.1-3.4.

$$\boldsymbol{C_f^i} = \frac{C_s^i}{C_b^i} \tag{3.1}$$

$$\boldsymbol{T_{\mathrm{r}}^{\mathrm{i}}} = P_n \times S_n \tag{3.2}$$

$$\boldsymbol{E_{\mathrm{r}}} = T_{\mathrm{r}}^{\mathrm{i}} \times C_{\mathrm{f}}^{\mathrm{i}} \tag{3.3}$$

$$\boldsymbol{RI} = \sum_{i=1}^{n} E_r^i \tag{3.4}$$

where

C_s^i is the observed concentration of MPs at each sampling location.

C_b^i is the background concentration, which is the lowest concentration reported in Thailand.

$\boldsymbol{T_{\mathrm{r}}^{\mathrm{i}}}$ is toxicity response factor for the polymer. It is the percent of each MPs polymer type in total sample at each site (P_n) multiplied with hazard score on each of polymers (S_n) (Lithner et al., 2011) as shown in Table 1.

$\boldsymbol{E_{\mathrm{r}}}$ is the potential ecological risk factor for the given plastic polymer types (i).

$\boldsymbol{RI}$ the requested potential ecological risk index for spatiotemporal study.

The categories for *RI* were as follows: *RI*≤150 (low ecological risk), 150<*RI*≤300 (moderate ecological risk), 300<*RI*≤600 (considerable ecological risk), and *RI*>600 (very high ecological risk).

Table 1 Detailed information for microplastic polymers detected in this study, including monomer, density, usage, and score (Europe, 2016).

Polymer	Abbre-viation	Monomer	Density (g/cm^3)	Main applications	Score[b]
Polyethylene	PE	Ethylene	0.91-0.96	Toys, bottles, pipes, house ware, etc.	11
Polypropylene	PP	Propylene	0.85-0.94	Food packaging, microwave-proof containers, etc.	1
Polyvinyl chloride	PVC	Vinyl chloride	1.41	Pipes, cable insulation, garden hoses, etc.	10,551
Polyamide (nylon)	PA	Adipic acid	1.14-1.15	Bearings, automotive applications, etc.	47
Acrylonitrile-butadiene-styrene	ABS	Styrene	1.02-1.08	Automotive applications, pipes, etc.	6,552
Polyurethane	PUR	Propylene oxide	0.40-0.60	Upholstery, sports mats, packaging bags, etc.	13,844
Polystyrene	PS	Styrene	1.05	Spectacle frames, plastic cups, packaging, etc.	30
Polycarbonate	PC	Bisphenol A	1.19	Information storage discs, security windows, etc.	1,177
Styrene acrylonitrile	SAN	Styrene	1.06-1.10	Cosmetic containers, ballpoint pens, lighters, etc.	6,788
Acrylate-styrene-acrylonitrile[a]	ASA	styrene	1.05	Sporting goods, antennae, sanitary products, etc.	-

a Acrylate -styrene - acrylonitrile lacks ecological toxicity data, therefore its hazard score cannot be determined.

b The value for the score of each polymer is taken from Lithner et al. (2011).

3.6.4 Statistical analysis

The collected data compared the mean of MPs that contamination between the differences in tidal levels with significant differences of microplastics contaminations in water and by 95% confidence intervals (significance level, 0.05) were using one–way ANOVA and Post-Hoc test using the Duncan multiple range test (DMRT).

3.7 Quality Control

To avoid any background contamination, a series of measurements were made in the lab. During the test, gloves and cotton lab coats were used. After each stage, all tools, glassware, and containers were thoroughly cleaned with deionized water and wrapped in aluminum foil. While undertaking microscopic examination to reduce additional contaminants, all synthetic clothing was denied.

CHAPTER 4
RESULTS AND DISCUSSION

In the result, Fourier Transform Infrared Spectroscopy (μ-FTIR) was used to characterize the polymer composition as the chemical image within the wavenumbers between 600-3800 cm^{-1}. The chemical image to prevent the analysis interference were used H_2O and CO_2 bands to exclude samples. The chemical image was compared with the standard database and found that MPs, which had matching degree of more than 60%, were identified in about 95% of all particles. The Non-microplastics were identified as protein, wool, cotton, natural fiber, glass fiber and glass wool. That mean non-plastic particles might contaminate the water samples during the sampling time. The presence of these non-plastic particles can be caused by many reasons. For example, the digested process might incompletely digest these non-plastic particles due to the insufficient process time as well as the dried particles become lumps that probably caused more difficulty to be completely digested.

Microplastics analysis in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem demonstrated that MPs were contaminated in various concentrations, diverse sizes, different shapes, and colors. Moreover, the variations of MP polymer types were also found in the present study. Finally, the deposition rates of MPs onto the surface sediment were first reported in various rates at the Chao Phraya River estuarine ecosystem (Figure 9 and Table 2).

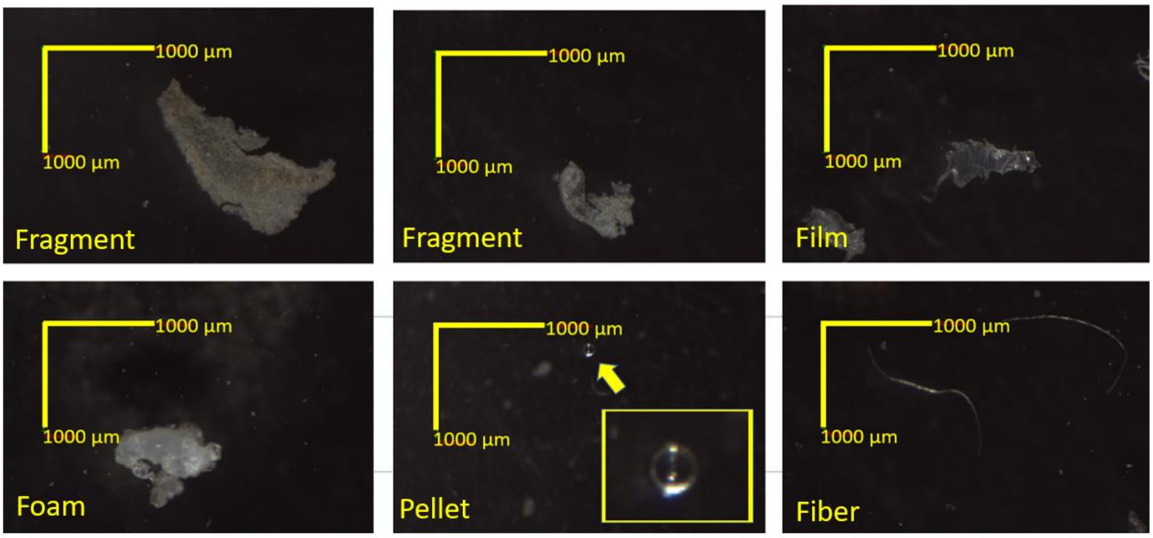


Figure 9 Microplastic characterizations in the water column during the changes of tidal current of the Chao Phraya River Estuary.

Table 2 Overall detection of microplastic occurrences in the water column during the changes of tidal current.

Abundance/characteristics	Categories	Tidal phenomena			
		High Tide	Ebb Tide	Low Tide	Flood Tide
Total concentration	pieces/L	✓	✓	✓	✓
Size composition	16-100 µm	✓	✓	✓	✓
	101-200 µm	✓	✓	✓	✓
	201-300 µm	✓	✓	✓	✓
	301-400 µm	✓	✓	✓	✓
	401-500 µm	✓	✓	✓	✓
	>500 µm	✓	✓	✓	✓
Shape composition	Fragment	✓	✓	✓	✓
	Fiber	✓	✓	✓	✓
	Film	✓	✓	✓	✓
	Foam	✓	✓	✓	✓
	Pellet	✓	✓	✓	✓
Color composition	Brown	✓	✓	✓	✓
	Black	✓	✓	✓	✓
	White	✓	✓	✓	✓
	Transparent	✓	✓	✓	✓
	Blue	✓	✓	✓	✓
	Green	✓	✓	✓	✓
	Red	✓	✓	✓	✓
	Others	✓	✓	✓	✓
Polymer types of MPs	Variations	✓	✓	✓	✓
Deposition rate of MPs	Variations	✓	✓	✓	✓

According to the tidal current, the present study used the variations of tidal changes to investigate and compare microplastic contaminations in the water column, deposition onto the surface sediment and ecological risk assessment at the Chao Phraya River estuarine ecosystem. The variations were analyzed according to high tide (HT: 19.47 and 05.40), ebb tide (ET: 22.37 and 09.34), low tide (LT: 01.26 and 13.17), and flood tide (FT: 03.41 and 17.02). All results and discussion described as follow:

4.1 Occurrence of MPs in the Chao Phraya River Estuarine Ecosystem

The average concentration of MPs which was found in this study 4.03±3.85 pieces/L. That result is nearly 4.137 pieces/L at Changjiang Estuary, China (Zhao et al., 2014)and nearly 4.1±0.4 pieces/L at The Pearl River estuary, China (Chau et al., 2023) From the study, which is similar to the estuary, causing MPs to be found in small amounts equivalent to similar research such as 9.97 pieces/L at the inner Gulf of Thailand (Vibhatabandhu & Srithongouthai, 2022) that was two times from normally MPs that we found nearby area. On the other hand, the total abundance of MPs of the Chao Phraya River mouth, Thailand was ten times higher than the Goulburn River, Australia about 0.4 pieces/L (Nan et al., 2020) and the Nile Delta estuaries, Egypt about 0.3-4.1 pieces/L (Shabaka et al., 2022). Anyway, the abundance of MPs in this study was nearly in the middle range of the contamination in the river and estuaries compared to others study. This could be discussed that the high contamination was strongly influenced by the rivers above the gulf compared with the other enclosed sea. Whatever the MPs concentration also shown that sampling, methods, analytical procedures, and sizes of detected MPs, even though the environment of the study area, were different. In the present study, MPs can be change concentration by the mouth of the Chao Phraya River was affected by both seawater and freshwater. Thus, the variation of salinity occurs over the time depend on the dominant water at that time. However, this study has a different study method than the other study. By focusing on the differential of depth to the MPs comparison that found every size, shape, color and type in every sample but in minimize scale. And also, the tidal current of MPs at the seawater and fresh water were new research in Thailand that the researcher wants to know the Tidal current may affect to the MPs that can change the direction of MPs that sources from land waste or ocean waste.

Table 3 A comparison of average MP concentration in the Chao Phraya River estuarine ecosystem and different water worldwide.

Study area	Sampling method	Sizes (mm)	Average MPs (pieces/L)	Reference
The Vellar Estuary, India	Towing a plankton net	0.33-5	0.1-5.1	(Nithin et al., 2022)
The Nile Delta Estuaries, Egypt	Grab sampling	0.055-5	0.3-4.1	(Shabaka et al., 2022)
The Goulburn River, Australia	Grab sampling	0.02-5	0.4	(Nan et al., 2020)
The Chao Phraya River mouth, Thailand	Grab sampling	0.016-5	4.03±3.85	Present study
Changjiang Estuary, China	Pump	0.51-6.29	4.137	(Zhao et al., 2014)
The Pearl River Estuary, China	Grab sampling	0.02-5	4.1±0.4	(Chau et al., 2023)
The Weser Estuary, German	Grab sampling	0.011-5	5.4	(Roscher et al., 2021)
The Chubut River Estuary, Argentina	Grab sampling	0.029-5	5.5	(Giarratano et al., 2022)
Ciwalengke River, Indonesia	Grab sampling	0.05-2	5.8	(Alam et al., 2019)
The Baram River Estuary, Malaysia	Grab sampling	0.02-5	9.3-18.0	(Choong et al., 2021)
The inner Gulf of Thailand	Grab sampling	0.125-5	9.97	(Vibhatabandhu & Srithongouthai, 2022)
Small-Scale Estuaries, China	Grab sampling	0.02-2.54	27.84	(Zhang et al., 2019)
The Tecolutla Estuary, Mexico	Grab sampling	0.012-5	151	(Sánchez-Hernández et al., 2021)

4.2 Evident of Tidal Effects at the Chao Phraya River Estuarine Ecosystem

Freshwater discharge from the Chao Phraya River and seawater inflow from the inner Gulf of Thailand, associated with mixing and transport processes in the mouth of the river, which were caused an estuarine mixing zone, and provide ideal conditions for the microplastic occurrence in term of spatio-temporal variations in the water and fluctuate sedimentation, increasing the accumulation in the sediment. Freshwater discharge and seawater inflow have the potential to cause changes in the salinity gradient, due to the tidal current in estuarine environments, factors that influence the contamination and distribution of MPs at the river mouth. Therefore, salinity gradient in estuaries is an indicator of mixing processes between freshwater from the Chao Phraya River and saline waters from the inner Gulf of Thailand.

The present study used the changes of salinity in the water column to investigate the evident of tidal current during April 29 (from 19.47) to 30 April 2021 (to 17.02), which was the main factor that control the variations of MPs in the Chao Phraya River Estuarine Ecosystem. Results showed that salinity at the surface water fluctuated over the study period (27.9-32.5 psu). The first evident occurred during ebb tide, which slightly decreased from 31.8 to 31.3 psu, subsequently increased again to 31.7 psu at 05.40 with high tide (Figure 10). The second evident occurred during flood tide with a strong decreasing of salinity in the surface water, which was from 31.7 psu at high tide to 28.8 psu at low tide (Figure 10). While vertical distributions of salinity in the water column decreased slightly from the surface to the bottom water, particularly at the low tide (Figure 10). As a result, the changes of salinity over the study period indicated that the freshwater runoff affected salinity during ebb tide, on the other hand, seawater from the inner Gulf of Thailand affected salinity during flood tide. Therefore, due to MP sources from both the Chao Phraya River and the inner Gulf of Thailand could affect the heterogeneity contaminations of MPs in the present study. As the previous research mentioned that the tidal movements are the key factor which controls the changes of MPs in that area (Wu et al., 2022). Tidal had a significant impact on pollution properties and MP distributions, so the sampling could not reflect the abundance of MPs in tidal channels. Compared with tide level, the amount of MPs was more closely related to the direction of tidal currents also the responsive relationship between microplastic abundance and amount in a typical tidal current, can be obtained by considering local hydrometeorological factors and making long-term continuous observations, could be a potentially effective real-time monitoring method for the indirect assessment of MPs pollution (Li et al., 2023).

For temperature, certainly, the light of day and night has an impact on the temperature more than the vacillation of tidal. The temperature from 19.47 slightly changed from 30 °C to 29 °C. Until 05.40 on 30 April. Then the temperature is 28 °C, then gradually changes to 29 °C at 09.34 and continually change to 30 and 31 °C at 13.17. Finally, the temperature changed to 32 °C at 17.02 at the surface water. That means the temperature from surface water has a higher temperature more than the lower depth. Otherwise, the lower depth in the water column of water mean that the temperature has lower temperature than the surface water, shown in (Figure 11) where the temperature is higher affect the degradation of plastics to breakdown and change to the MPs according to the process mentioned in the theory. By oxidation and ultraviolet (UV) light, that causes fragmentation plastics into MPs.

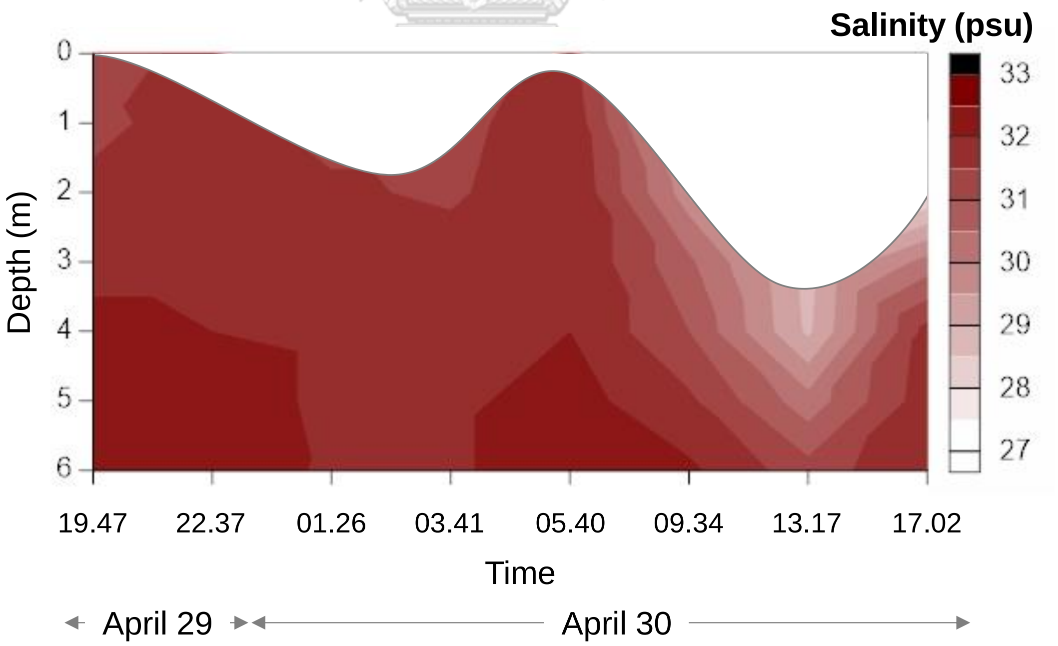


Figure 10 Variations of salinity (psu) in the water column during April 29 to 30, 2021 at the Chao Phraya River estuarine ecosystem.

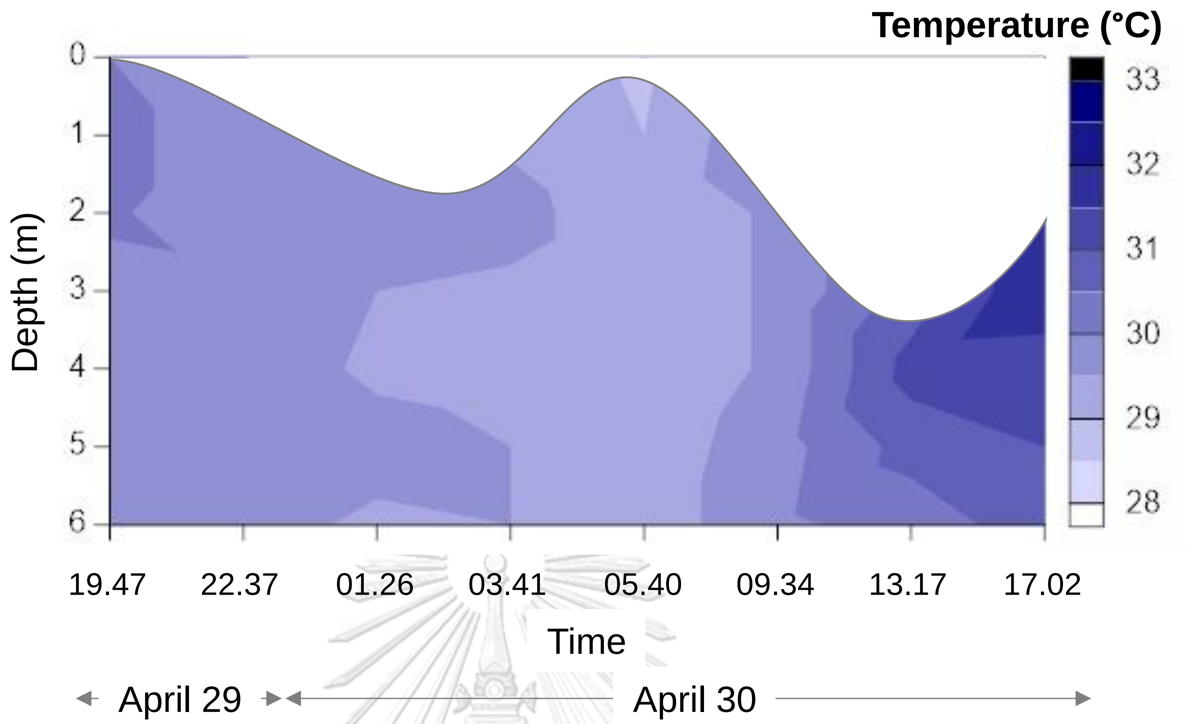


Figure 11 Variations of temperature (°C) in the water column during April 29 to 30, 2021 at the Chao Phraya River estuarine ecosystem.

4.3 Response of Tidal Current to Abundance and Characteristics of Microplastics

4.3.1 Abundance

The concentration of MPs in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from 0.44-16.93 pieces/L (Figure 12). At the high tides (19.47 and 5.40), MPs varied between 0.64-5.28 pieces/L, with an average of 2.06±1.54 pieces/L. While, at the ebb tides (22.37 and 09.34), MPs varied between 0.44-16.93 pieces/L, with an average of 4.03±4.23 pieces/L. For the low tides (01.26 and 13.17), MPs varied between 2.37-12.89 pieces/L, with an average of 6.25±4.47 pieces/L. Finally, MPs varied between 0.70-12.76 pieces/L, with an average of 3.44±3.34 pieces/L at the flood tides (03.41 and 17.02). As a result, the relatively high concentration of MPs occurred in different water layers, including 11.91 and 12.89 pieces/L at the depth of 3 and 4 m (low tide at 01.26), 16.93 pieces/L at 5 m bottom layer (ebb tide at 09.34), 12.83 pieces/L at 1 m depth (low tide at 13.17) and 12.76 pieces/L at 2 m depth (flood tide at 17.02). On the other hand, the relatively low concentrations were frequency observed at high tides (Figure 12). Additionally, when an average concentration of MPs during different tidal currents was compared, the results showed that the significant highest MP concentration occurred at low tide, while significant lowest concentration occurred at high tide, which arranged according to LT≥FT=ET≥HT (Figure 13). As a result, which indicated that the Chao Phraya River runoff was the key influence of MP contaminations. Moreover, the relationship between salinity and MP abundance was performed, however no significant correlation was found.

From the experiments, the researcher can conclusion the effects of tidal current can affect MPs in each water column depth. As mentioned, the lowest tide MPs comes from land flood into the ocean. As opposed to the highest tide when MPs come from the ocean push back to the land. Allows the researcher to know that the quantity plastic or MPs that accumulate found in large amounts of land use are more than plastic wastes from the ocean in every water column depth are significantly different. When compared to the time of low tide and differing at each depth level. That can be explained MPs into 4 tides such as 1) high tide (HT: 19.47 and 05.40), 2) ebb tide (ET: 22.37 and 09.34), 3) low tide (LT: 01.26 and 13.17), and 4) flood tide (FT: 03.41 and 17.02). The abundance of MPs found that predominant during ebb tide has a lot of MPs in water column and a slight increase of MPs in low tide. Otherwise, the MPs in flood tide and hide tide are less MPs than ebb tide and low tide in water column Figure 13.

That can be determined MPs during ebb tide (the water from land push down to the oceans) and the water low tide (the lowest tide that water is nearest to the bed water) affect to the MPs according to the expected results, when ebb tide can cause fresh water push down to the sea water that can be affected to the MPs from coast has floating to the ocean. Against the flood tide (water from ocean push back to the land) and when the water level increasing at the highest point is high tide (The highest tide) are less MPs. Same as the other study Beibu Gulf, South China (Zhang et al., 2020) the researcher found that MPs from the landward boundary (ranging from 520 ± 32 to 6040 ± 114 item/kg) has more MPs than seaward boundary (ranging from 80 ± 16 item/kg to 1020 ± 89 item/kg) from mentioned Tidal current can be affected to MPs.

From this study found that the total MPs that related to the tidal phenomena by low tide is significantly the most affect to MPs in the water column. So, the tidal current has affected the transportation of MPs. Tidal currents are in general leading order in coastal areas, which are particularly relevant for plastic transport and accumulation. The effect of tidal currents on the transport and distributions of floating microplastic in the open ocean (Zhang, 2017).

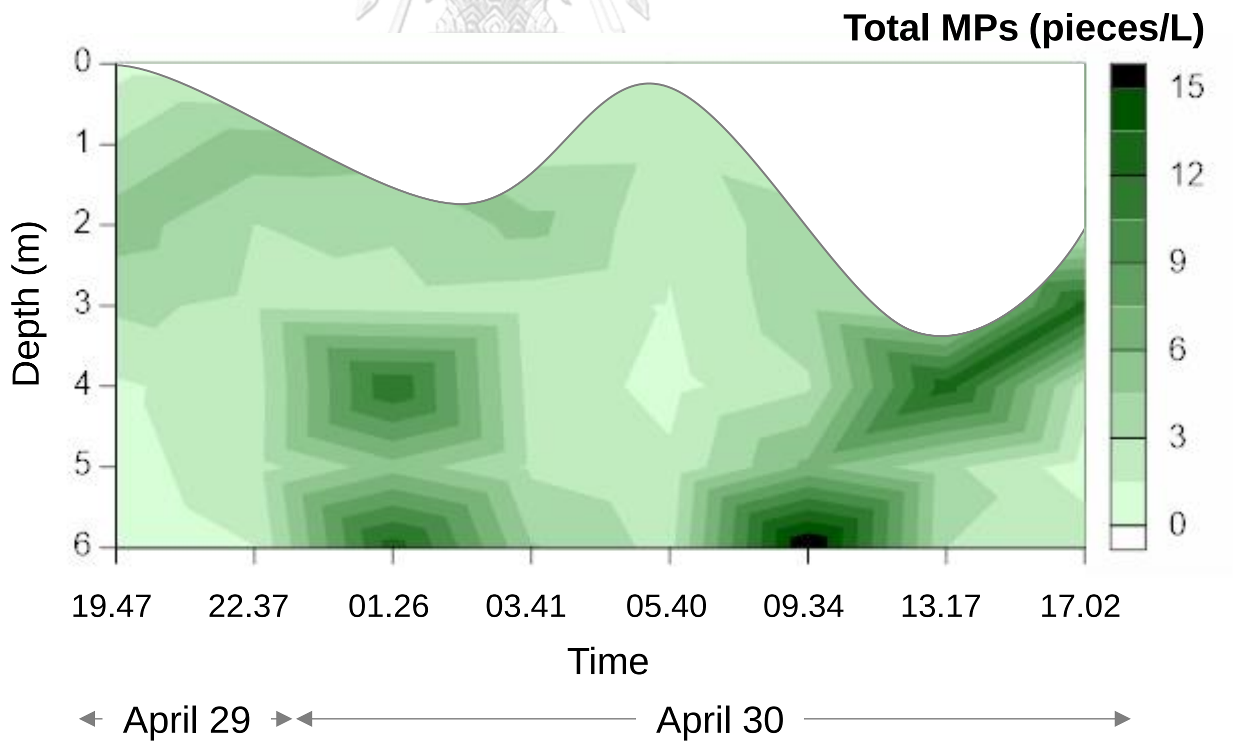
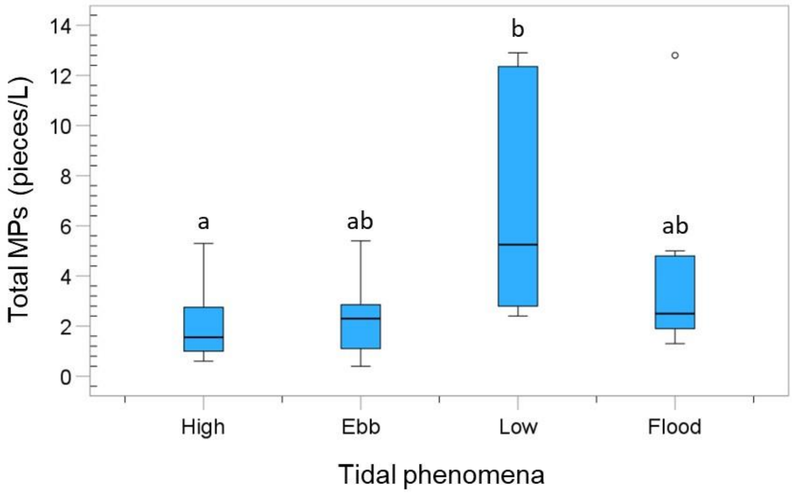


Figure 12 Abundance of MPs (pieces/L) in the water column during April 29 to 30, 2021 at the Chao Phraya River estuarine ecosystem.



Remark: Alphabet indicated the significant differences between high tide, ebb tide, low tide and flood tide using the DMRT analysis

Figure 13 A comparison of total of MPs (pieces/L) related to tidal phenomena in the water column.

4.3.2 Morphological characteristics of microplastics

1) Size fractions

The size fraction of MPs in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from 16-5000 µm (Figure 14). At the high tides (19.47 and 5.40) MPs size between 16-100 µm has 79%, 101-200 µm has 13%, 201-300 µm has 4%, 301-400 µm has 1%, 401-500 µm has 1% and more than 500 µm has 2%. While, at the ebb tides (22.37 and 09.34), MPs size between 16-100 µm has 69%, 101-200 µm has 17%, 201-300 µm has 8%, 301-400 µm has 2%, 401-500 µm has 1% and more than 500 µm has 3%. For the low tides (01.26 and 13.17), MPs size between 16-100 µm has 82%, 101-200 µm has 12%, 201-300 µm has 2%, 301-400 µm has 2%, 401-500 µm has 1% and more than 500 µm has 1%. Finally, size between 16-100 µm has 82%, 101-200 µm has 12%, 201-300 µm has 1%, 301-400 µm has 2%, 401-500 µm has 2% and more than 500 µm has 1%. At the Flood tides (03.41 and 17.02). As a result, the relative size of MPs occurred in different water layers. Overall, the most average size is 16-100 µm about 76-80% followed by 101-200 µm is 15%, 201-300 µm is 4%, 301-400 µm with 401-500 are 2% and 401-500 µm about 1% (Figure 15). In ebb tide has MPs size lower than the other about 70% that means when tidal current change to ebb tide has a little effect on MPs size 16-100 µm may cause the MPs size 16-100 µm sink down to the other depth. However, there was no significant difference in the relationship between tidal current and MPs size faction (% of size fractions is pieces).

That can be determined MPs size during tidal current has no effect on size faction, but the most found size of MPs is 16-100 µm were found about 80% in every sample size. That mean number of MPs on the has is very small size. That close to another research, the Weser estuary (Roscher et al., 2021) found the small size classes <100 µm, with 94.5% of the items being from the record of samples in The Weser Estuary, German.

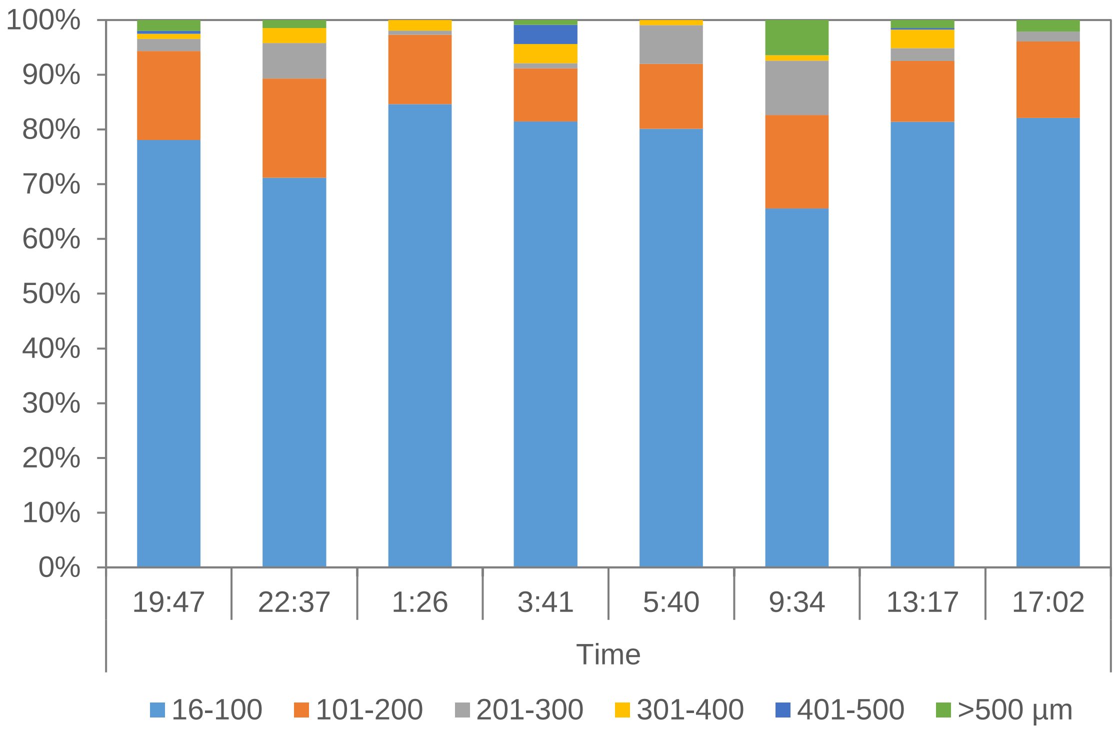


Figure 14 Size fractions of MPs in the water column during tidal fluctuations at the Chao Phraya River estuarine ecosystem.

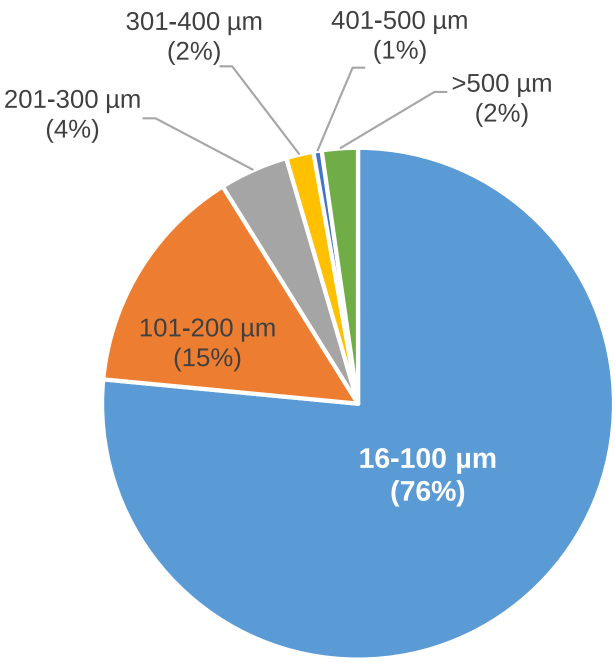


Figure 15 An average size fraction of MPs in the Chao Phraya River estuarine ecosystem.

2) Shape compositions

The shape composition of MPs in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from fragment, fiber, film, foam, and pellet (Figure 16). At the high tides (19.47 and 05.40) MPs shape Fragment has 84%, fiber has 10%, film has 4%, foam has 1% and pellet has 1%. While, at the ebb tides (22.37 and 09.34), MPs shape fragment has 80%, fiber has 14%, film has 4%, foam has 1% and pellet has 1%. For the low tides (01.26 and 13.17), MPs shape fragment has 81%, fiber has 8%, film has 7%, foam has 1% and pellet has 3%. Finally, MPs shape fragment has 85%, fiber has 8%, film has 5%, foam has 1% and pellet has 1%. at the Flood tides (03.41 and 17.02) (Figure 17). As a result, the relative shape of MPs occurred in different water layers, so the most average shape is a fragment about 82% followed by fiber is 10%, film is 6% and pellet is 2% otherwise, foam is less than 1% in every sample. The results shown the data samples are the same way as each any samples that there was no significant difference the relationship between Tidal current and MPs shape composition (% of shape compositions is pieces).

From the result, fragments contributed to a major proportion of all shapes that were found. These fragment microplastics might be generated by several anthropologic activities such as degradation from big plastics piece to the small size plastics which flow from river to estuary and finally flowing to the ocean. This process depends on many factors until plastics change to smaller size to fragment plastics. According to the previous research (Choong et al., 2021). Fragmented MPs are commonly found in rivers due to the deterioration and degradation of larger plastic products. Fiber MPs are used in the manufacture of synthetic fiber clothing, ropes, fishing lines, and other textile products. It comes from Pellets and film microplastics are commonly made from apparel decorations, plastic bags, food packaging, and other synthetic fiber materials. That the researcher found that MPs fragment accounted for 67.8% of total microplastic samples followed by fiber, film, pellet, and foam that same as this study which information is in the same direction.

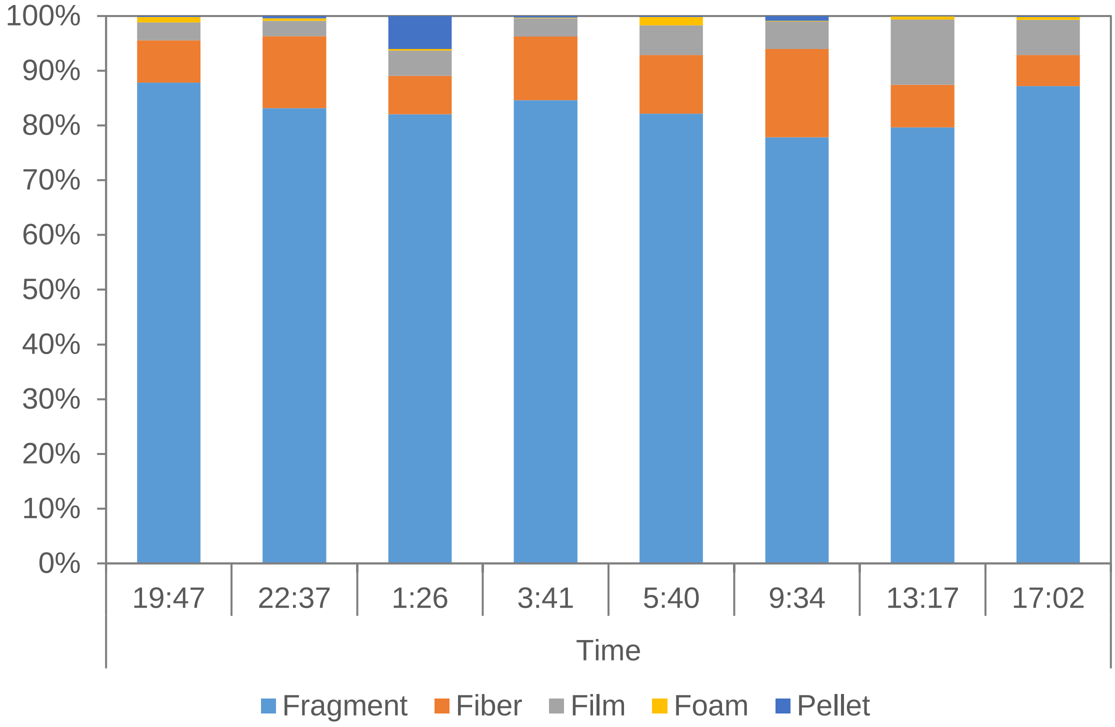


Figure 16 Shape compositions of MPs in the water column during tidal fluctuations at the Chao Phraya River estuarine ecosystem.

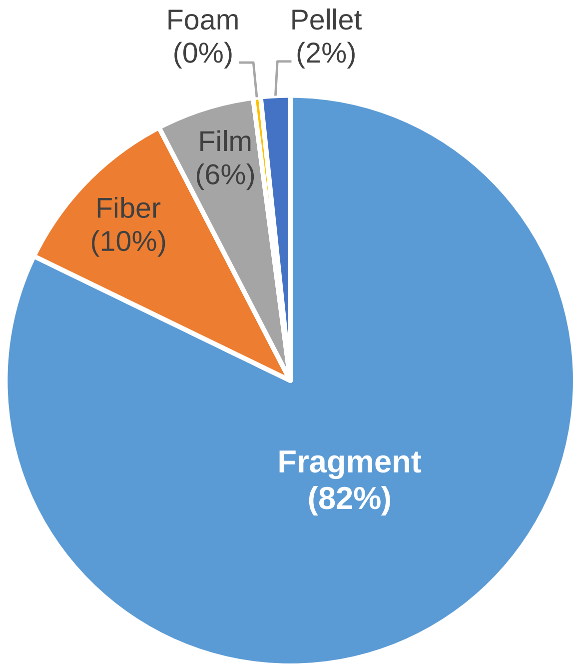


Figure 17 An average shape composition of MPs in the Chao Phraya River estuarine ecosystem.

3) Color detections

The color detections of MPs in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from blue, transparent, black, red, brown, white, green, and others. (Figure 18). At the high tides (19.47 and 05.40) MPs color blue has 29%, transparent has 15%, black has 26%, red has 16%, brown has 2%, white has 9%, green has 2% and others has 1%. While, at the ebb tides (22.37 and 09.34), MPs color blue has 41%, transparent has 27%, black has 12%, red has 9%, brown has 4%, white has 5%, green has 1% and others has 1%. For the low tides (01.26 and 13.17), MPs color blue has 34%, transparent has 20%, black has 15%, red has 19%, brown has 5%, white has 5%, green has 1% and others has 1%. MPs color blue has 43%, transparent has 19%, black has 19%, red has 4%, brown has 8%, white has 5%, green has 1% and others has 1%. At the Flood tides (03.41 and 17.02) (Figure 19). As a result, the relative color of MPs occurred in different water layers, So the most average color is blue about 38% followed by transparent is 22%, black is 16%, red is 12%, brown is 6%, white is 5%, green is 1% Otherwise, others is least than 1-0% in every sample (Figure 4.10). The results shown the data samples are the same way as each any samples that there was no significant difference the relationship between Tidal current and MPs color composition (% of color detections is pieces).

From the result, most color detection is blue color. That means plastics in Chao Phraya River mouth, Thailand has a lot of blue plastics followed by transparent. The distribution of microplastic color in the Chao Phraya River mouth is quite duplicate from a variety of other published data on freshwater and marine environments. But the results are similar to the Baram River, Malaysia that the dominant microplastic color in water samples was blue, accounting for 34.4% of the total microplastics, followed by black (28.8%) and others (Choong et al., 2021). Therefore, differences in plastic color may indicate the origin of the plastic material, color separation may not provide further evidence. For example, blue and black are associated with fishing-related materials and activities of standard colors. In addition, bright or light-colored microplastics in the aquatic environment are often ingested by aquatic organisms (Boerger et al., 2010).

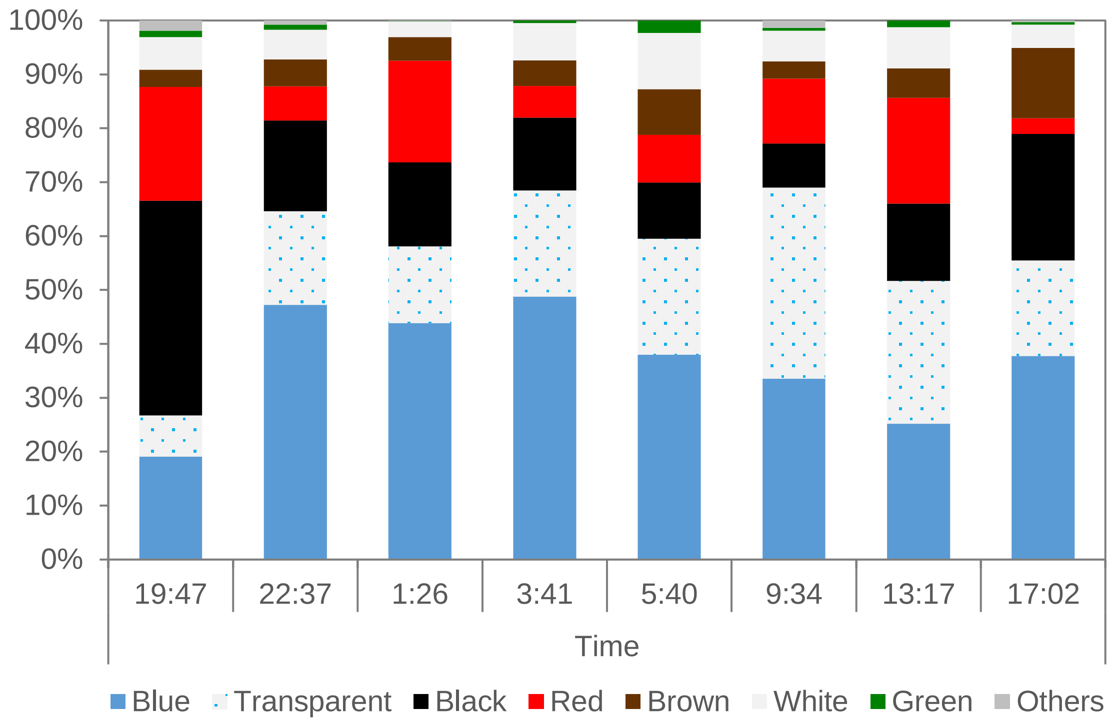


Figure 18 Color detections of MPs in the water column during tidal fluctuations at the Chao Phraya River estuarine ecosystem

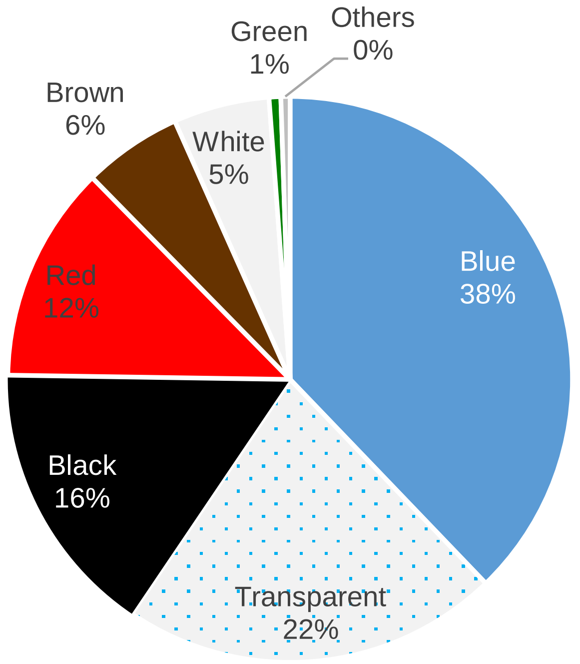


Figure 19 An average color detection of MPs in the Chao Phraya River estuarine ecosystem.

Table 4 A comparative analysis of MP characterizations in the Chao Phraya River estuarine ecosystem and different water worldwide.

Study area	Dominant characteristics (%)			Reference
	Size	Shape	Color	
The Chao Phraya River mouth, Thailand	16-100 µm (76%) 101-200 µm (15%)	Fragment (82%) Fiber (10%)	Blue (38%) Trans. (22%) Black (16%) Red (12%)	Present study
The Goulburn River, Australia	94.2±83.5mm (66.7%)	Fiber (95%) Pellet (5%)	-	(Nan et al., 2020)
Changjiang, Rstuary, China	500-1000 mm (67%) 1000-2500 mm (28.4)	Fiber (79.1%)	Transparent and coloured (70%)	(Zhao et al., 2014)
The inner Gulf of Thailand	125-300 µm (48%) 300-1000 µm (35%)	Fiber (35%) Fragment (34%)	-	(Vibhatabandhu & Srithongouthai, 2022)
Ciwalengke River, Indonesia	50-100 µm	Fiber (65%)	Brown	(Alam et al., 2019)
The Baram River Estuary, Malaysia	300-1000 µm	Fragment (67.8%) Fiber (18.7%)	Blue (34.4%) Black (28.8%) Transparent (18.1%)	(Choong et al., 2021)
The Chubut River Estuary, Argentina	0-1000 µm	Fiber (83%)	Transparent (44%) Blue (22%)	(Giarratano et al., 2022)
The Weser Estuary, German	>5000 µm (99.5%)	fragments (84.9%)	-	(Roscher et al., 2021)
Small-Scale Estuary, China	<2000 µm (99.5%)	Granules (45%) Fragments (40%)	Black (56.46%) Translucent (17.47%)	(Zhang et al., 2019)

4.3.3 Polymer composition

The polymer composition of MPs in the water column during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from PTFE (Polytetrafluoroethylene), PE (Polyethylene), PP (Polypropylene), TPV (Thermoplastic Vulcanizate), PS (Polystyrene), SEBS (Styrene-ethylene-butylene-styrene), EVA (Ethylene vinyl acetate), FEP (Fluorinated ethylene propylene), PA (Polyamide), EPDM (Ethylene-propylene diene monomer), PO (Polyolefin), PAA (Polyacrylic acid), TPU (Thermoplastic polyurethanes), PET (polyethylene terephthalate), PUR (Polyurethane) and Others. (Figure 4.20). At the high tides (19.47 and 5.40) MPs polymer PTFE has 25%, PE has 10%, PP has 9%, TPV has 14%, PS has 2%, SEBS has 3%, EVA has 10%, FEP has 7%, PA has 2%, EPDM has 18%, PO has 1%, PAA has 1%, TPU, PET and PU has lower than 1%. While, At the ebb tides (22.37 and 09.34) MPs polymer PTFE has 37%, PE has 23%, PP has 22%, TPV has 5%, PS has 8%, SEBS has 3%, EVA has 0%, FEP has 0%, PA has 2%, EPDM has 0%, PO has 0%, PAA has 0%, TPU, PET and PU has lower than 1%.For the low tides (01.26 and 13.17), PTFE has 39%, PE has 12%, PP has 12%, TPV has 6%, PS has 6%, SEBS has 8%, EVA has 2%, FEP has 2%, PA has 11%, EPDM has 1%, PO has 9%, PAA has 2%, TPU, PET and PU has lower than 1%. PTFE has 47%, PE has 13%, PP has 16%, TPV has 1%, PS has 3%, SEBS has 7%, EVA has 0%, FEP has 8%, PA has 6%, EPDM has 0%, PO has 0%, PAA has 0%, TPU, PET and PU has lower than 1%. At the Flood tides (03.41 and 17.02).

As a result, the relative polymer composition of MPs occurred in different water layers, So the most average polymer is PTFE about 36% followed by PE is 15%, PP is 14%, TPV is 7%, PS is 5%, SEBS-EVA-FEP-PA are 4%, EPDM-PO are 3% and Others is 1% (Figure 21). The results shown the data samples are the same way as each any samples that there was no significant difference the relationship between tidal current and MPs shape composition. But we can found some polymer are moreover in some water column depth such as high tide at 19.47 found that a lot of EVA and TPV (% of polymer compositions is pieces).

In this work, the chemical images of the polymer compositions were determined using Fourier Transform Infrared Spectroscopy (μ–FTIR) on wave numbers between 600 to 3800 cm^{-1}. To avoid analytical interference, the chemical image's H_2O and CO_2 bands were removed. When the chemical picture was compared to the database and found MPs, it was discovered that 90% of all particles had MPs, which had a matching degree of greater than 50%. Protein, wool, cotton, natural fibers, glass fiber, and glass wool were noted as non-MPs. During the monitoring period, non-plastic particles might contaminate the water samples. There are a variety of causes for the occurrence of these non-plastic particles. Due to insufficient processing time, for example, the non-plastic particles may only partially be digested. Additionally, the dried particles may bunch together and present additional digestion challenges.

From result MPs the average of the most polymer in water column depth is PTFE (Teflon) about 36% followed by PE 15% and PP 14%. That means PTFE is the predominance polymer type in The Chao Phraya River mouth. In Thailand, it was found that PTFE, which these plastics are widely used in a variety of industries. And is also the key to the new industrial world, such as food industry, chemicals, semiconductors, LCDs, scientific equipment, transportation and etc. Most people often understand that Fluoroplastic is Teflo which popular and widely used in Thailand. However, the Gulf of Thailand has a study of MPs polymer type. The researcher found that the most polymer type of MPs type in the surface Gulf of Thailand has PE was the major plastic component in the samples (27%) followed by Poly(ethylene:propylene) (PE/PP) was about 21% (Vibhatabandhu & Srithongouthai, 2022) Which difference from this study. Which at present, PTFE is more widely produced in Thailand. So that might be a factor of PTFE has found in large quantities. Teflon or PTFE is widely used in various fields, such as coating on any surfaces to prevent water or oil from sticking, for example, used to coat kitchen utensils, food packaging, clothing, glasses, wires, irons and roofs, etc. PTFE is insoluble and resistant to sunlight and rain, causing plastic waste problems when it breaks down into microplastics and flows into the sea. It is a very versatile material. Grade, in addition to reasonable prices (Dhanumalayan & Joshi, 2018). However, MPs polymer type of this study may be a difference in many factors such as time, place, time of high tide, low tide, sampling, lab and measurement.

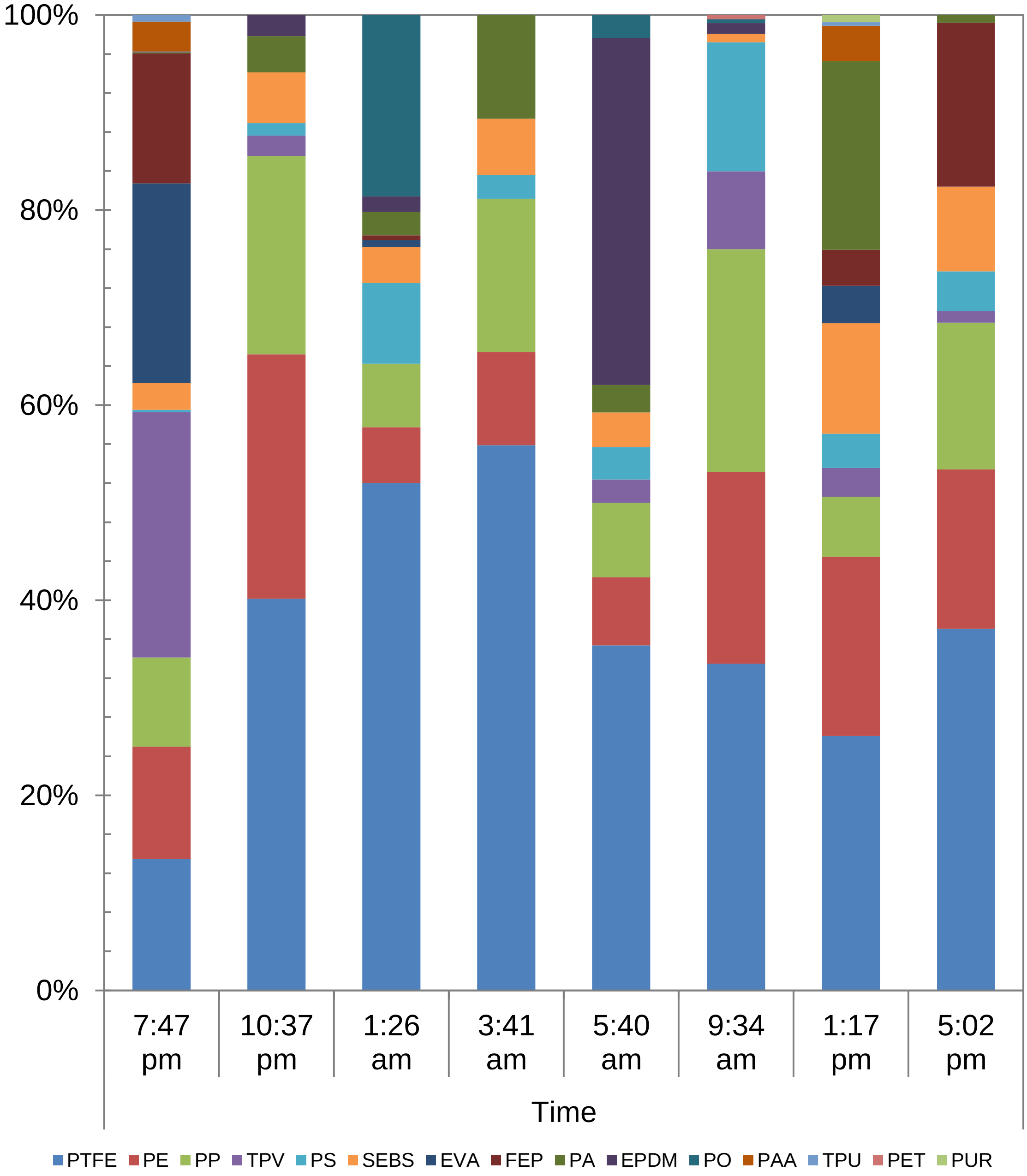


Figure 20 Polymer composition of MPs in the water column during tidal fluctuations at the Chao Phraya River estuarine ecosystem.

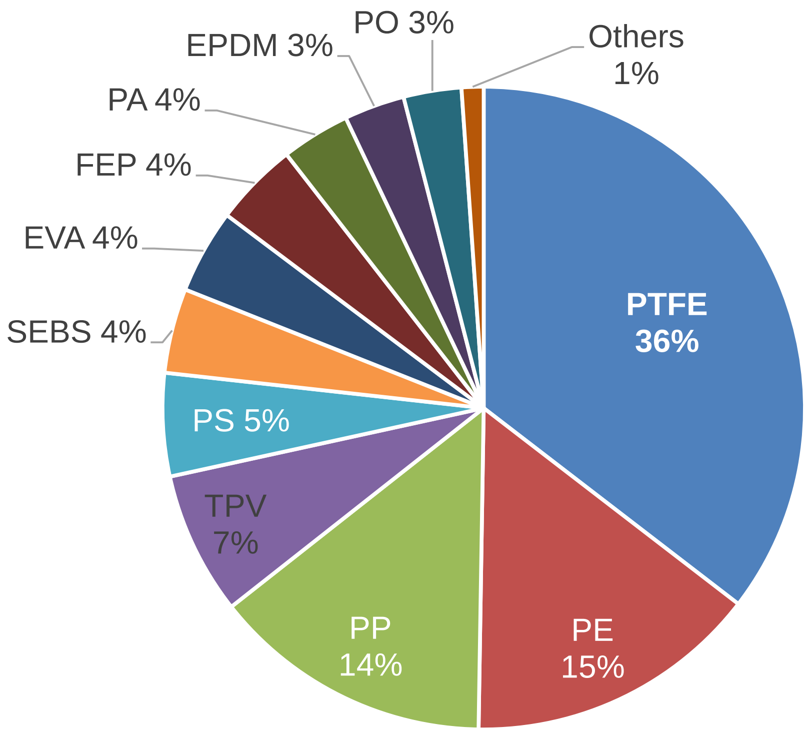
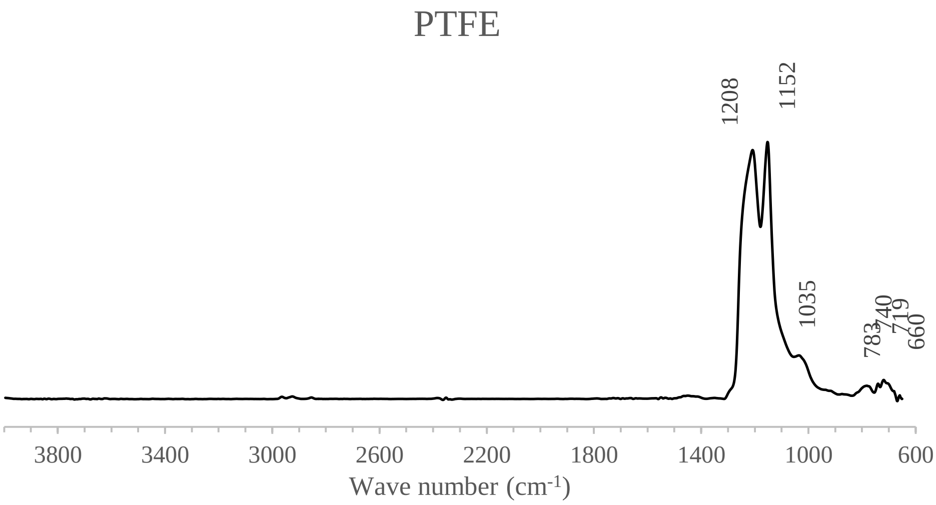
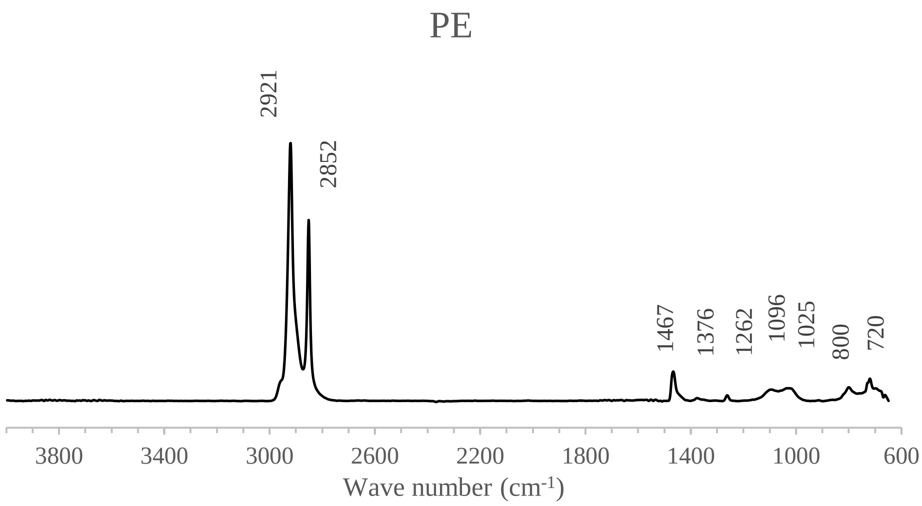
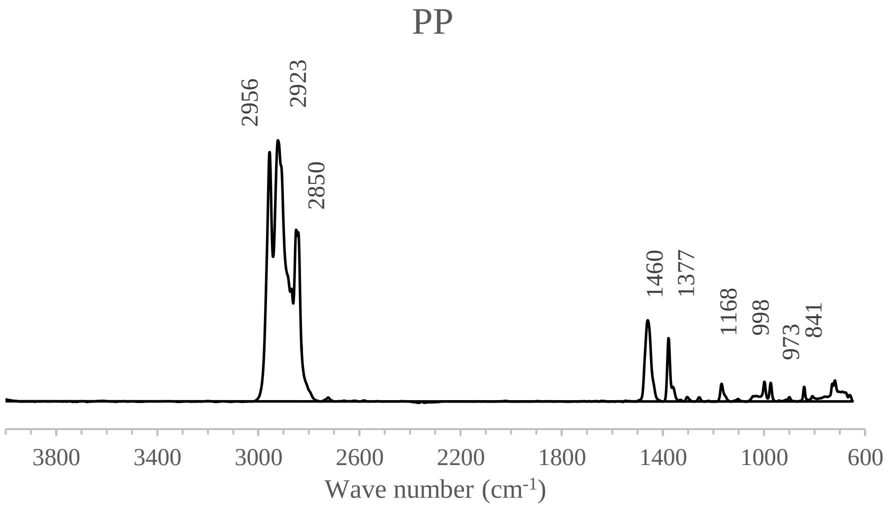


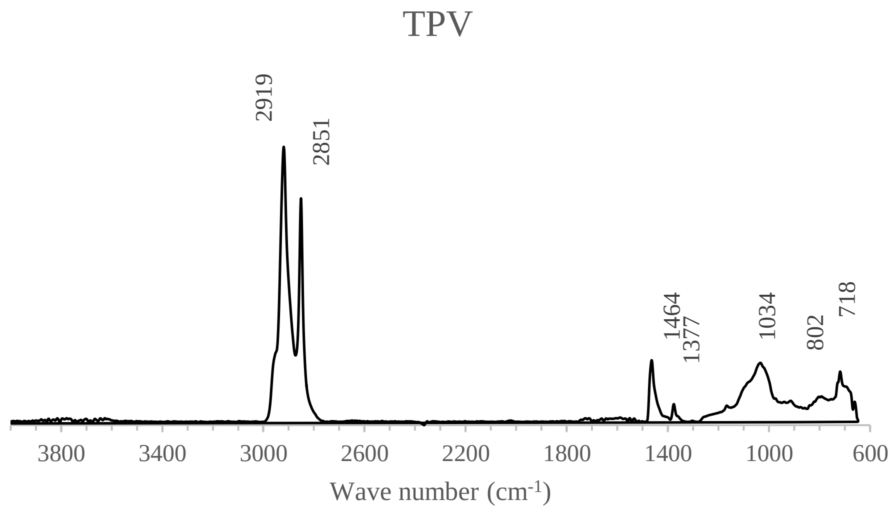
Figure 21 An average polymer composition of MPs in the Chao Phraya River estuarine ecosystem.

FTIR images of All detected µ-FTIR spectrum are shown in Figure 22. For PTFE, the peaks at 1210 and 1152 cm^{-1} for CF_2 stretching were the characteristic peaks of PTFE. On the other hand, in PP, characteristic peaks were observed at wavenumbers 2952-2850 cm^{-1} for C-H stretching, 1459 cm^{-1} for CH_2 bending, and 1377 cm^{-1} for CH_3 bending. Also, the peaks at wavenumbers 1168 and 807 were PP fingerprints. Nevertheless, chemical images also showed changes in the chemical groups of these observed MPs. For example, the chemical diagram of PP shows the hydroxyl group (broad peak at 3700-3100 cm^{-1} centered at 3400-3300 cm^{-1}), the carbonyl group (weak to moderate peak at 1810-1690 cm^{-1}). also showed. as a C-O bond (1200-1000 cm^{-1}) (Veerasingam et al., 2021).

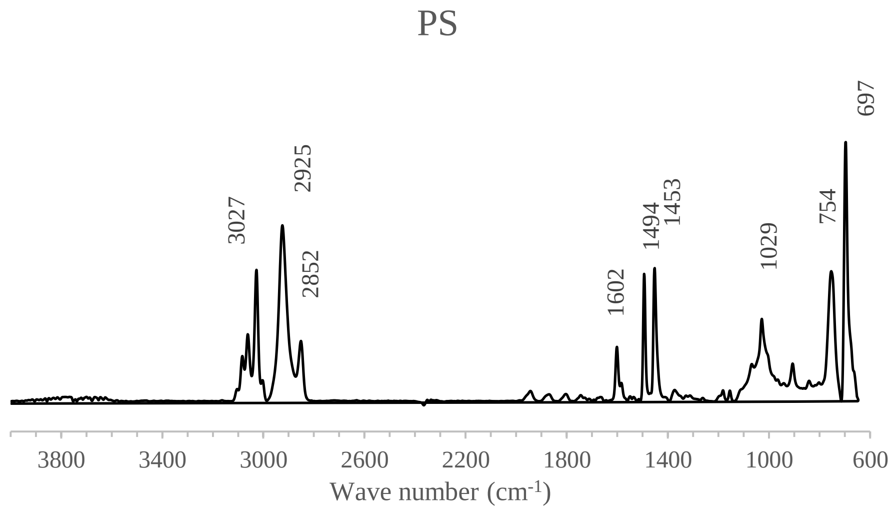

PTFE
1208
1152
1035
783
740
719
660
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)


PE
2921
2852
1467
1376
1262
1096
1025
800
720
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)

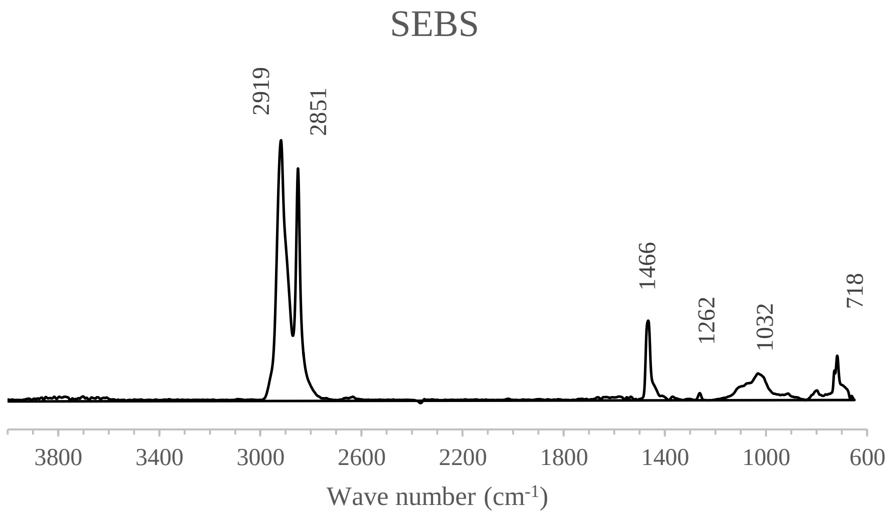

PP
2956
2923
2850
1460
1377
1168
998
973
841
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)

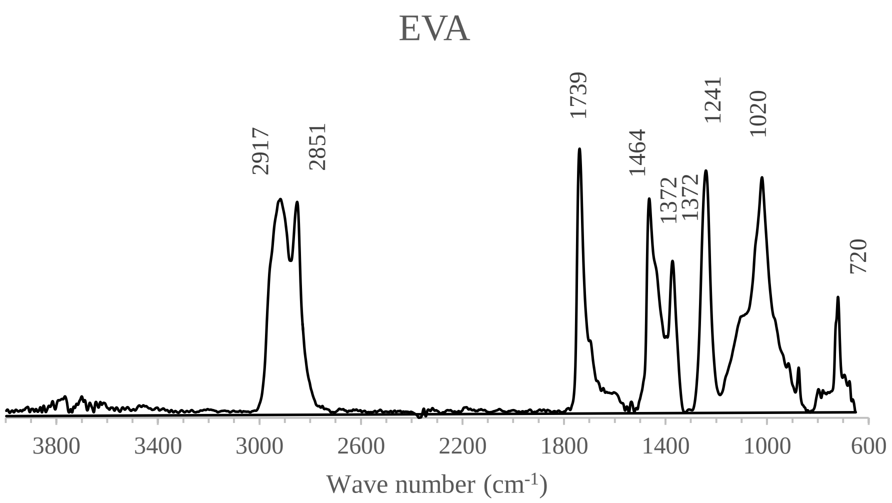


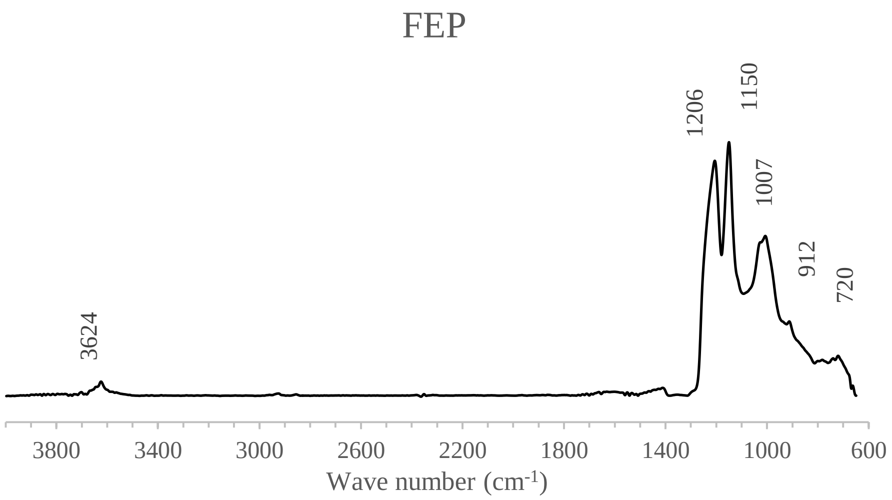
TPV
2919
2851
1464
1377
1034
802
718
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)

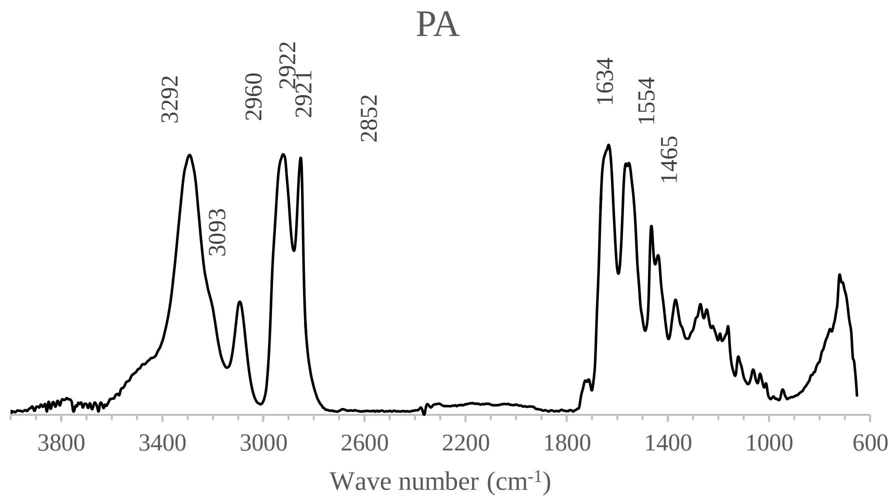


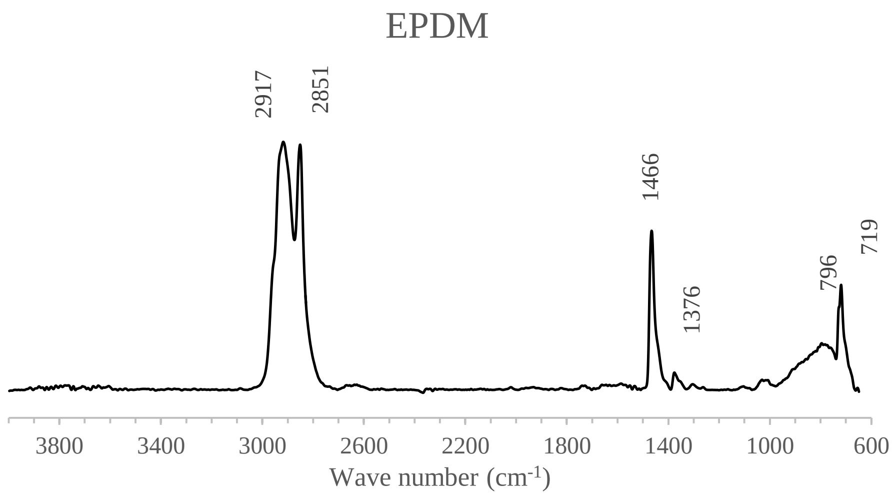
PS
697
2925
3027
2852
1494
1453
1602
1029
754
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)

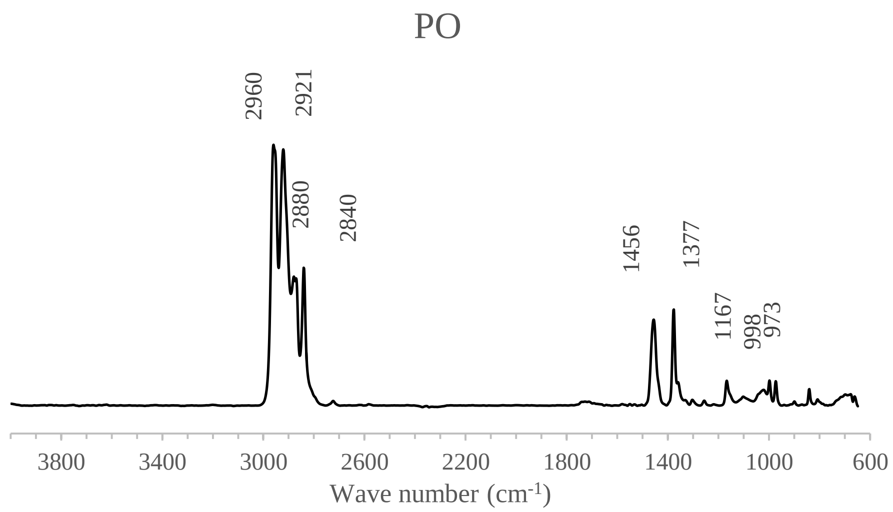

SEBS
2919
2851
1466
1262
1032
718
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)

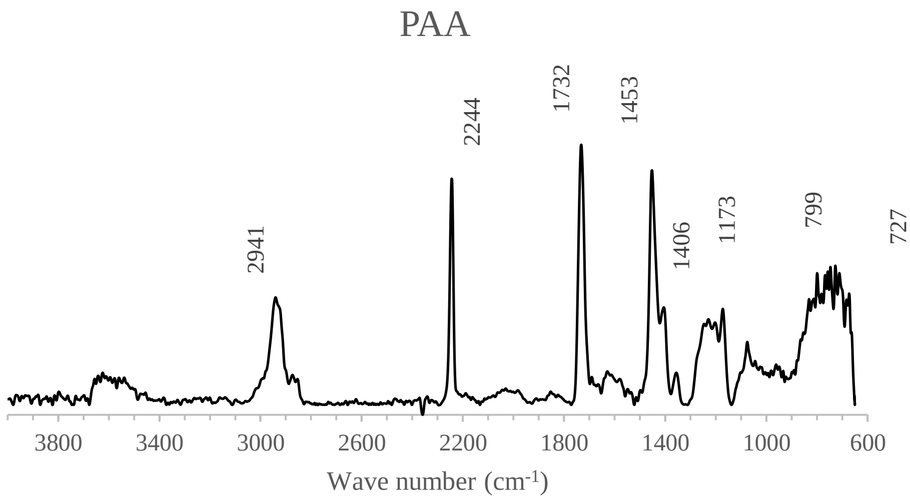

EVA
2917
2851
1739
1464
1372
1372
1241
1020
720
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)

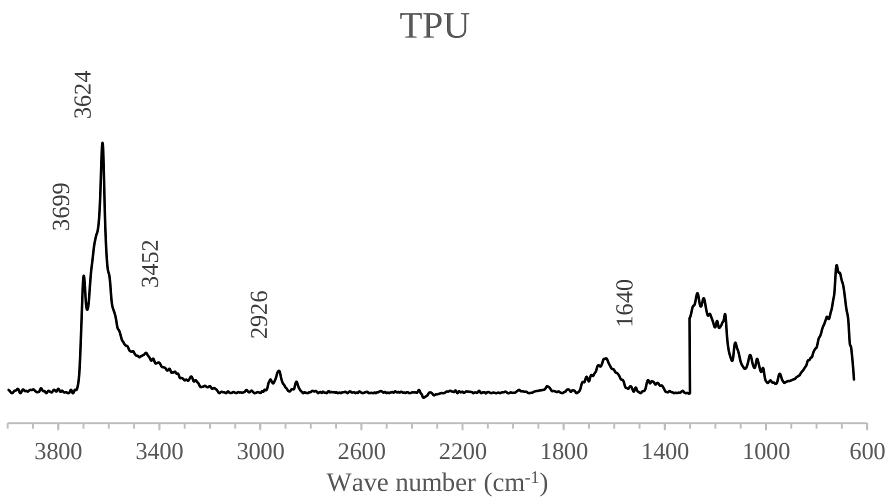

FEP
3624
1206
1150
1007
912
720
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)

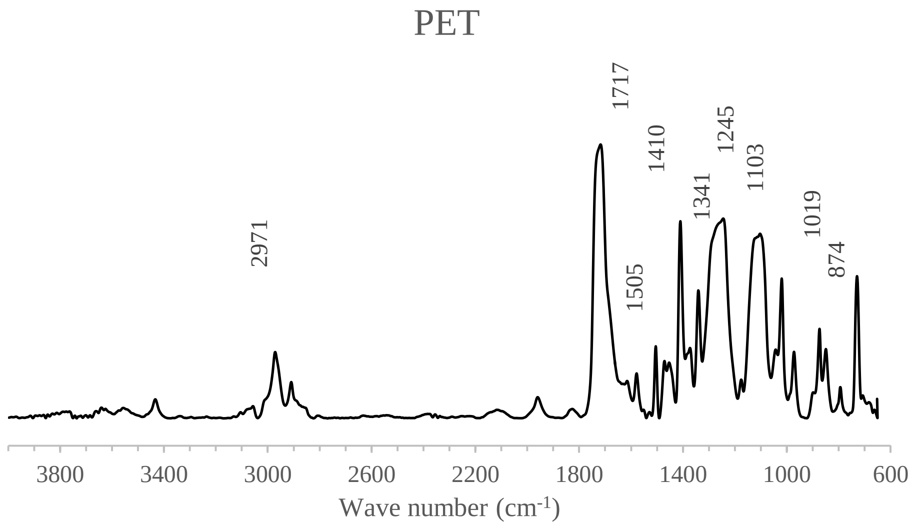

PA
3292
3093
2960
2922
2921
2852
1634
1554
1465
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)


EPDM
2917
2851
1466
1376
796
719
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)


PO
2960
2921
2880
2840
1456
1377
1167
998
973
3800
3400
3000
2600
2200
1800
1400
1000
600
Wave number (cm-1)


PAA
2941
2244
1732
1453
1406
1173
799
727
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)


TPU
3624
3699
3452
2926
1640
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)


PET
1717
1410
1245
1341
1103
2971
1505
1019
874
3800 3400 3000 2600 2200 1800 1400 1000 600
Wave number (cm-1)

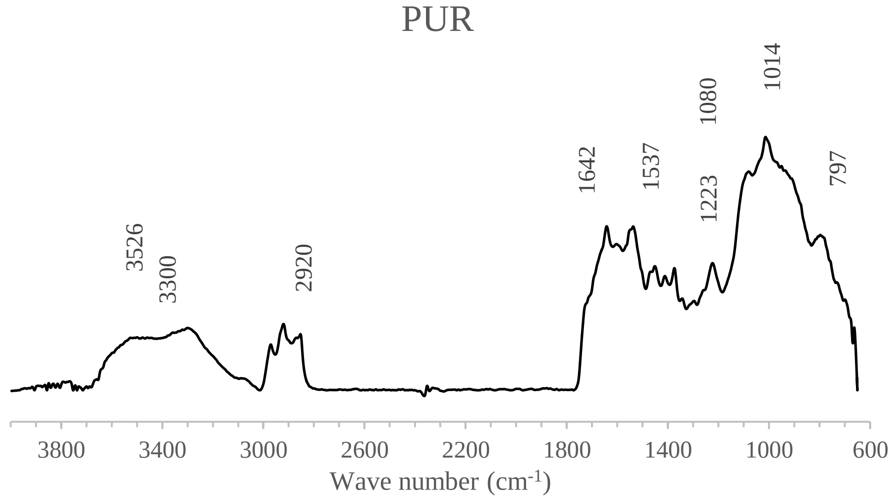


Figure 22 All detected µ-FTIR spectrum of MPs in the water column during the changes of tidal phenomena at lower estuary of the Chao Phraya River.

4.4 Deposition Rate of Microplastics onto the Surface Sediment

4.4.1 Total deposition rate

1) Deposition rate

Analysis of depositing MPs during a tidal cycle of April 29-30, 2021, the Chao Phraya estuary sediment trap deployment experiment is a new ongoing study in the river mouth to evaluate the deposition rate of MPs on surface sediments. According to the *in situ* experiment at the mouth of the Chao Phraya River, the total deposition rate of MPs is 446±108 pieces/m^2/h in 24 hours. Which MPs deposition rate of MPs for 24 hours. This is a new study in Thailand for observation of MPs deposition rate to compare sedimentation rates. There may be quite a few comparative data.

2) Size

Total average size of MPs deposition rate of April 29-30, 2021, the Chao Phraya estuary sediment trap for 24 hours. Found that MPs size <100 µm are about 98% from all sample followed by 101-200 µm about 1.74% which MPs size 201-300 µm, 301-400 µm and 500 µm are very low% of

MPs about 1-0% (% of size is pieces) (Figure 4.23). From the study, we found that the MPs data of size in deposition rate were similar to the MP water column depth which MPs 16-100 μm were the most common that we found.

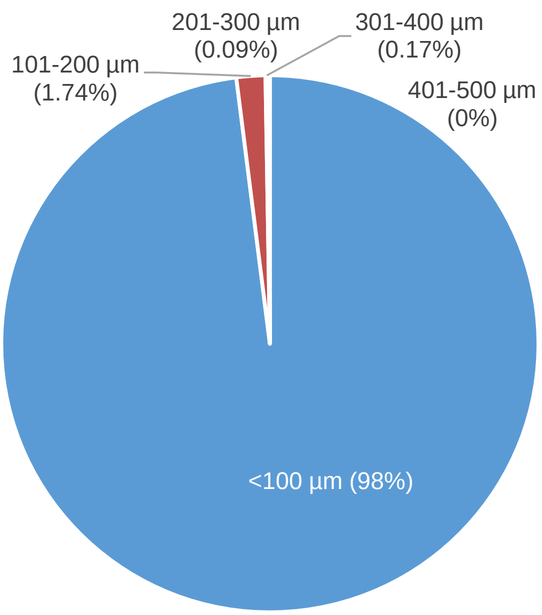


Figure 23 Size of MPs depositing onto the surface sediment in 24 hours at the Chao Phraya River estuary.

3) Shapes

Total Average shape of MPs deposition rate of April 29-30, 2021, the Chao Phraya estuary sediment trap for 24 hours. Found that MPs shape fragment about 94% followed by Film and Fiber with 2%, Foam and Pellet with 1% (Figure 24). That means the most shape that found in MPs deposition rate for 24 hours is fragment (% of shapes is pieces).

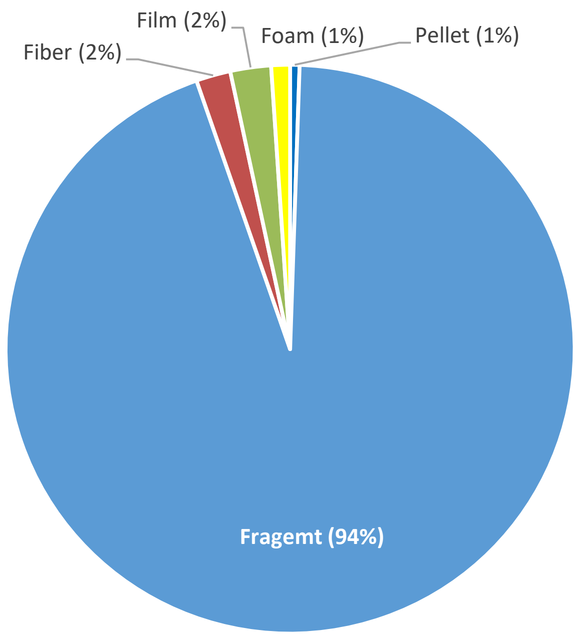


Figure 24 Shape of MPs depositing onto the surface sediment in 24 hours at the Chao Phraya River estuary.

4) Colors

Field experiments at the mouth of the Chao Phraya River showed that the color of the MPs was almost black at each high tide, followed by brown, transparent, white, red, blue, and other (Figure 25). As a result, the most color of the MPs deposition rate in 24 hours is black with 66% followed by brown with 14%, transparent with 10%, white with 5%, red with 4%, others with 1% but green and blue with 0%. The origin of microplastics was generated from secondary MPs. Samples may be affected. Color Black is the basic color of the industry. Black color was used for coated products for market appeal and fishing. Improving net fishing to camouflage sea life. Also, other colors may fade due to weathering, especially externally colored products. As a result, MPs in this area were mostly black (% of color is pieces).

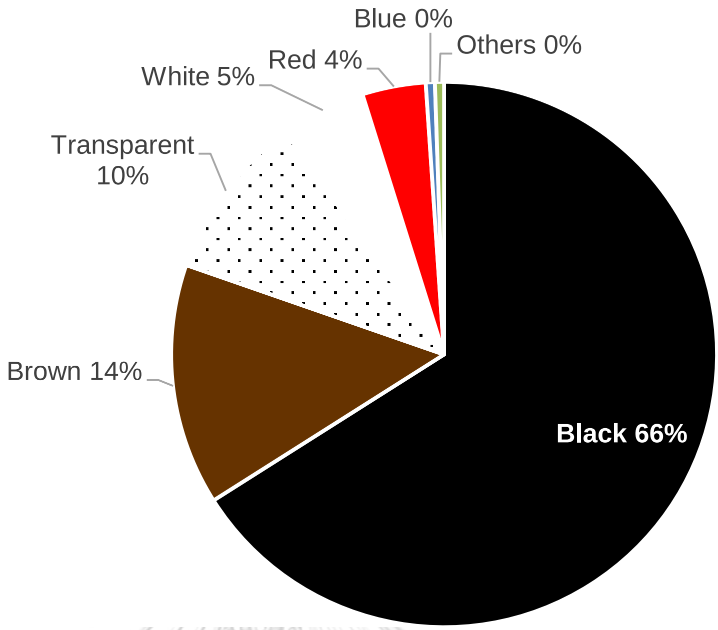


Figure 25 Color of MPs depositing onto the surface sediment in 24 hours at the Chao Phraya River estuary.

5) Polymer type of microplastic in deposition on surface sediment

From Analysis of the chemical composition of deposited MPs was discovered during tidal changes in the Chao Phraya River estuary using Fourier transform infrared microscopy (µ-FTIR). A total of 3880 particles were identified as MPs, corresponding to a detection success rate of 60%. According to micro-FTIR analysis, the chemical composition consisted of 9 different polymers, including PA (polyamide) is 46%, PE (polyethylene) is 28%, Epoxy Resin is 12%, PP (polypropylene) is 5%, SEBS (Styrene-ethylene-butylene-styrene) is 2%, TPU (thermoplastics polyurethane) is 2%, TPE (Thermoplastic Elastomer)-EVA (ethylene vinyl acetate)-PTFE (Polytetrafluoroethylene are 1% (% of polymer type is pieces) (Figure. 26).

In general, the polymer types of microplastics may reflect the usage patterns of plastic products and inadequate management of plastic waste. For example, PE is a common ingredient in plastic bags and containers (Crawford & Quinn, 2017). Regarding the composition of marine plastic litter, Thailand's

Pollution Control Department reports that plastic bags (mainly PE) account for 33.4% of the litter accumulating on beaches, coral reefs and mangrove areas. Additionally, PA is used in many industries. PA is commonly used in the manufacture of consumer products such as fishing nets, tendons, ropes, and fabrics, and some types are produced from PA (Li, 2018) that the remaining 10% to 25% of plastic is generated by human activities such as shipping, fishing, recreational and offshore industries that introduce large amounts of plastic waste into the marine environment. Fishing gear was dumped into the sea about 640,000 tons ago.

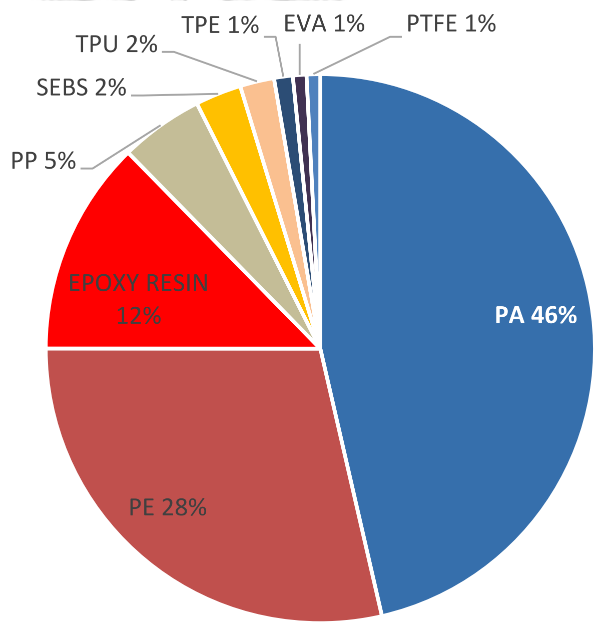


Figure 26 Polymer type of MPs depositing onto the surface sediment in 24 hours at the Chao Phraya River estuary.

4.4.2 Differential deposition rates during tidal change

In this study deposition rate of microplastics was compared 4 tide, total depositions rate of microplastics was 787 pieces/m^2/h during highest-low tide (20.00-01.00), 738 pieces/m^2/h during low-high tide (02.00-05.00), 1,401 pieces/m^2/h during high-lowest tide (06.00-13.00) and 533 pieces/m^2/h during lowest-high tide (14.00-17.00) (figure 27).

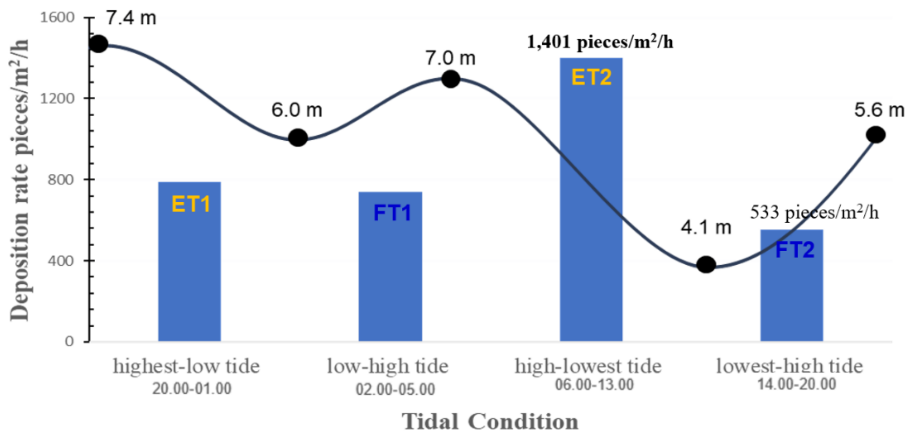


Figure 27 Comparative tidal current with total deposition rate of microplastics onto the surface sediment of the Chao Phraya River estuary.

While the deposition rate in 24 hours was 440 pieces/m^2/h. The sedimentation rate may change due to tidal currents and water flows all the time. The number of microplastics may increase or decrease at any time as well.

From the results found that high-lowest tide has the most MPs deposition rate that is different from other tide. Which means tidal current also effect to MPs deposition rate as much as MPs in the water column that mention before in 4.2 Response of Tidal Current to Abundance and Characteristics of Microplastics (Li et al., 2023).

1) Size compositions

The size compositions of MPs different deposition rate during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from 16-400 µm (Figure 28). At the high tides (20.00-01.00 and

06.00-13.00) MPs size between 16-100 µm has 95%, 101-200 µm has 3%, 201-300 µm has 1%, 301-400 µm has 0.5-1% and >400 µm has 0.5-1%. For the low tides (02.00-05.00 and 14.00-20.00), MPs size between 16-100 µm has 93%, 101-200 µm has 4%, 201-300 µm has 1%, 301-400 µm has 0.5-1%, >400 µm has 0.5-1%. As a result, the relative size of MPs occurred in different water layers. Overall, the most average size is 16-100 µm about 76-80% followed by 101-200 µm is 15%, 201-300 µm is 4%, 301-400 µm with 401-500 are 2% and 401-500 µm about 1% (in Figure 29). In ebb tide has MPs size lower than the other about 70% that means when tidal current change to ebb tide has a little effect on MPs size 16-100 µm may cause the MPs size 16-100 µm sink down to the other depth. However, there was no significant difference in the relationship between tidal current and MPs size faction (% of size is pieces).

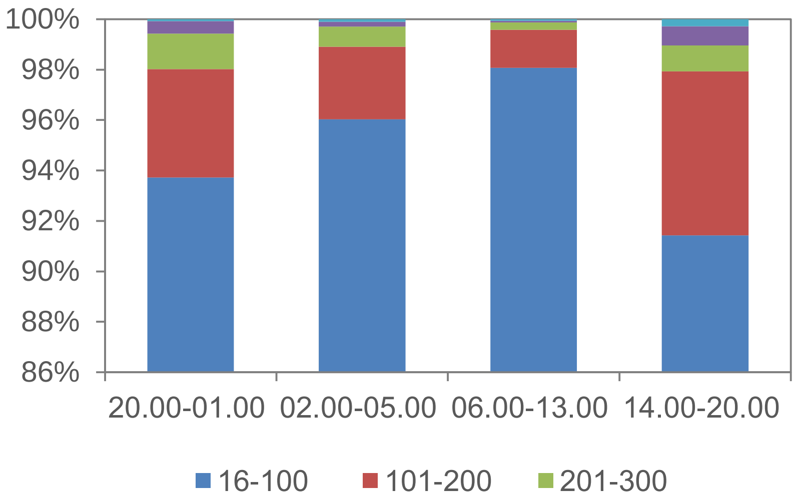


Figure 28 Size compositions of deposition MPs onto the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

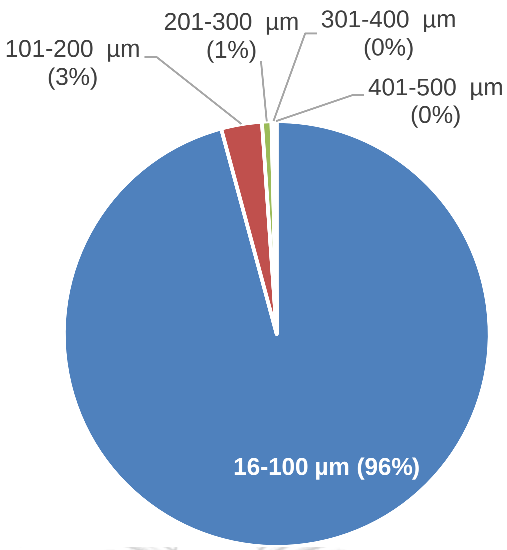


Figure 29 An average size fraction of deposition MPs onto the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

3) Shapes

The shape compositions of MPs different deposition rate during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from fragment, fiber, film, foam and pellet (Figure 30). At the high tides (20.00-01.00 and 06.00-13.00) MPs shape fragment is 80%, fiber is 12%, film is 1%, foam is 2-2.5% and pellet are 3.5%. For the low tides (02.00-05.00 and 14.00-20.00), MPs shape fragment is 83%, fiber is 9%, film is 3.5%, foam is 2-2.5% and pellet are 1% (% of shape is pieces). As a result, the relative shape of MPs occurred in different water layers. Overall, the most average shape is a fragment about 81% (Figure 31) which there was no significant difference the relationship between tidal current and MPs shape. That fragment can sink down to the deposition of a water column with tidal current (Choong et al., 2021).

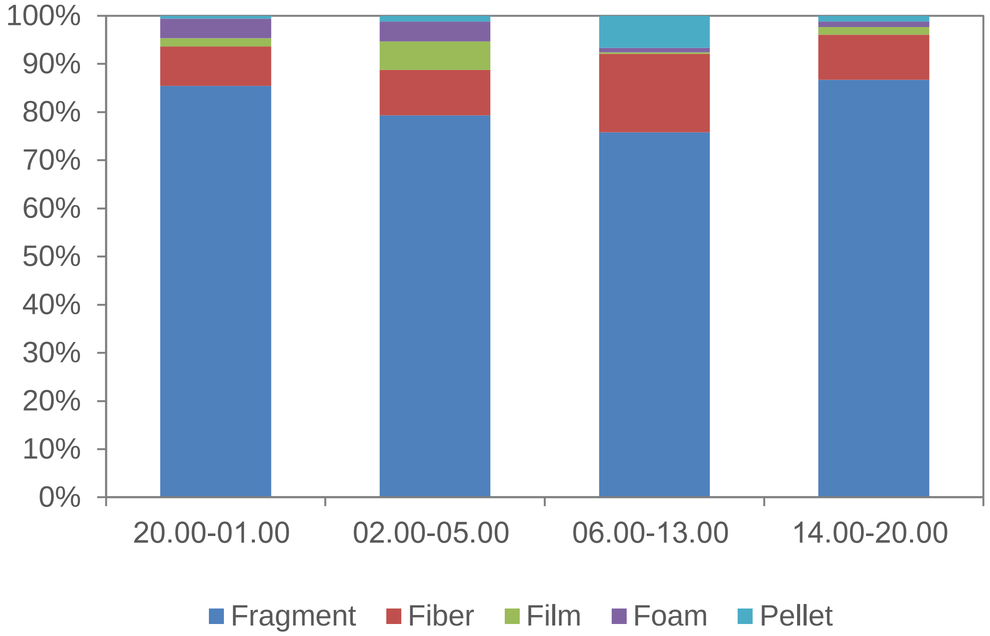


Figure 30 Shape variations of deposition MPs onto the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

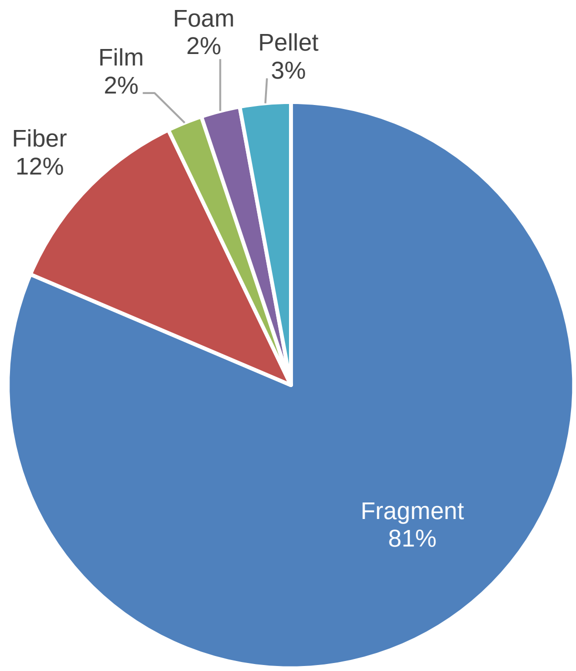


Figure 31 An average shape fraction of variations MPs onto the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

4) Colors

The colors detections of MPs different deposition rate during the changes of tidal current at the Chao Phraya River estuarine ecosystem varied from black, brown, transparent, white, red, blue and others. (Figure 32). At the high tides (20.00-01.00 and 06.00-13.00) MPs color black is 60%, brown is 18%, transparent is 8%, white is 7%, red is 3.5%, blue is 2% and others are 18%. For the low tides (02.00-05.00 and 14.00-20.00), MPs color black is 59%, brown is 11%, transparent is 12%, white is 8%, red is 2%, blue is 4% and others are 3%. As a result, the detection color of MPs occurred in different water layers. Overall, the most average color is Black about 59% (Figure 33). from the results, the most MPs color is black same as the other study that found black color of MPs the rankings were 56.46% (% of color is pieces) (Zhang et al., 2019).

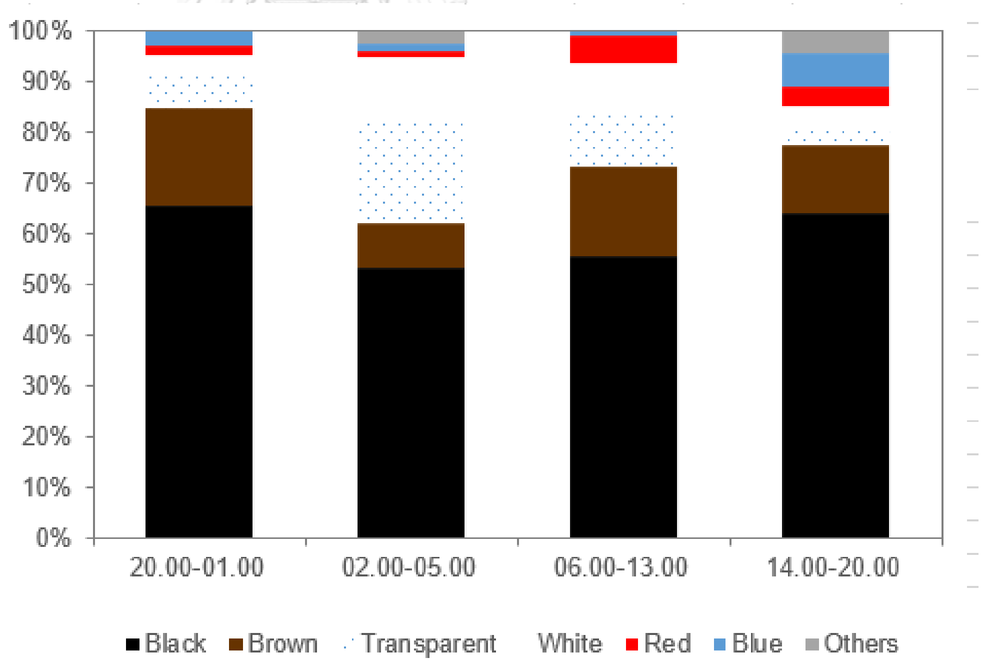


Figure 32 Color detections of deposition MPs on the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

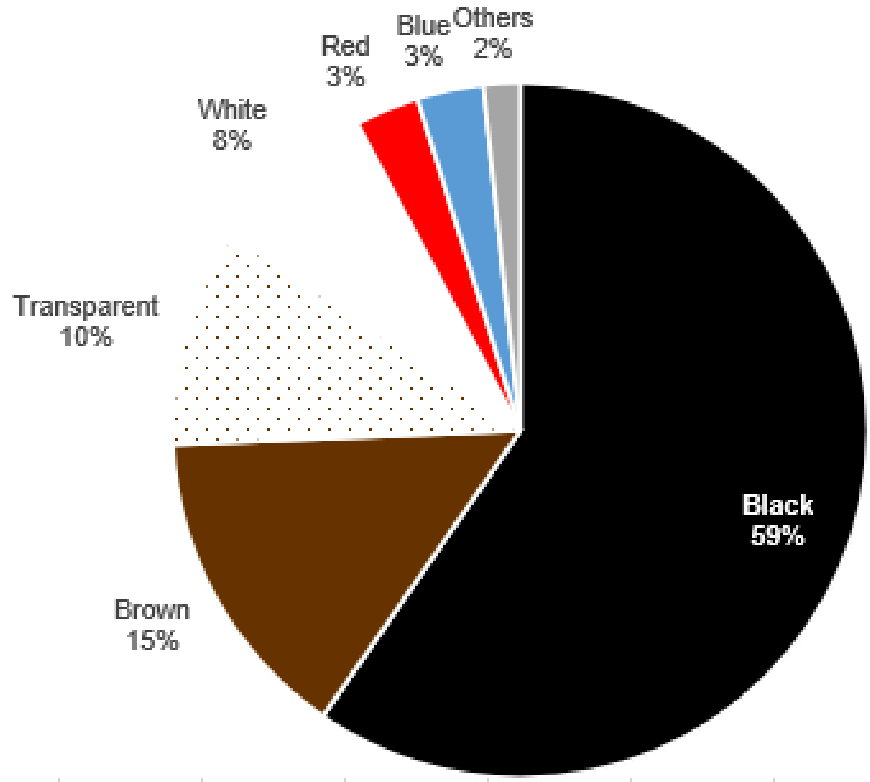


Figure 33 An average color detection of variations MPs on the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

5) Polymer type of microplastic in deposition on surface sediment

According to the deposition rate, found 4 main types of plastics, such as PA, PE, PP, ABS and others. At the high tides (20.00-01.00 and 06.00-13.00) MPs type PA is 61%, PE is 6%, PP is 1%, ABS is 2% and Non-plastics is 28%. For the low tides (02.00-05.00 and 14.00-20.00), MPs type PA is 43%, PE is 20%, PP is 11%, ABS is 1% and Non-plastics is 25% (Figure 34). As a result, polymer type of MPs occurred in different water layers. Overall, the most average polymer type is PA about 53% (% of polymer type is pieces) (Figure 35). but in low tide to high tide at 02.00-05.00 found that PE has more particle than others tide that mean may cause PE can come from ocean that tidal current has effect to the deposition of surface sediment. In Thailand PA plastic is widely used in almost everywhere such as conduits, cable glands, sports shoes, package for food, automotive industry, clothing, 3D printer, water pipe and air pipe.

In general, the polymer types of microplastics may reflect the utilization patterns of plastic products and the mismanagement of plastic waste. For instance, PE is the common component of plastic bags and containers (Crawford & Quinn, 2017). With respect to marine plastic debris composition, the Pollution Control Department of Thailand has reported that plastic bags (mostly PE) account for 33.4% of the debris accumulated on beaches, coral reefs, and mangrove areas. Moreover, PA was used in a range of industries. PA is commonly used to produce consumer products such as fishing nets, tendons, ropes, and also cloth some types may be the generated by PA. The colored particles were more likely to be mistaken for food by marine biota due to their appearance resembling that of low-trophic-level organisms (Boerger et al., 2010); (Browne et al., 2008); (Lusher et al., 2013).

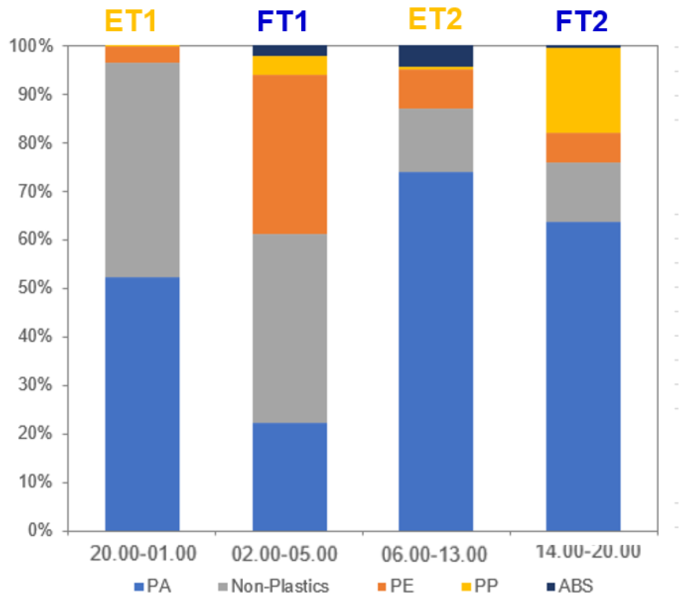


Figure 34 Polymer type composition of MPs on the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

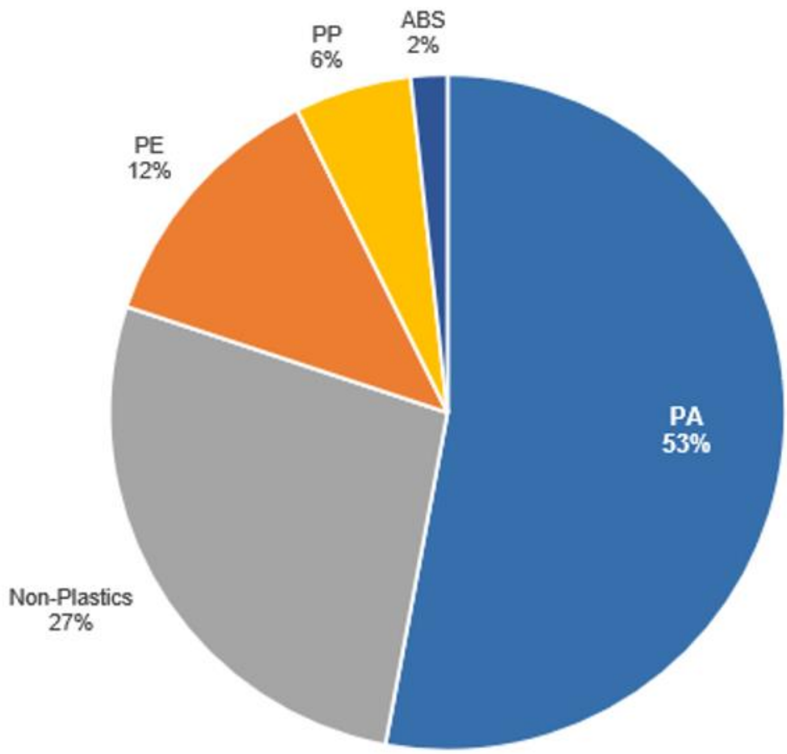


Figure 35 An average color detection of variations MPs on the surface sediment during tidal at the Chao Phraya River estuarine ecosystem.

4.5 Risk Assessment of Microplastics to the Chao Phraya River Estuarine Ecosystem

Table 5 Polymer of MPs detected in this study, including monomer, density, usage, and score.

Polymer	Abbre-viation	Monomer	Dens-ity (g/cm^3)	Main applications	Score[a]
Polytetrafluoroethylene	PTFE	Tetrafluoroethylene	2.2	Coat the surface of various kitchen utensils, etc.	NC
polyethylene	PE	Ethylene	0.91-0.96	Toys, bottles, pipes, house ware, etc.	11
Polypropylene	PP	Propylene	0.85-0.94	Food packaging, containers, etc.	1
Thermoplastic Vulcanizates	TPV	Copolymers (PP+EPDM)	9×10^5	Molded in a variety of ways like general plastic, etc.	NF
Polystyrene	PS	Styrene	1.05	Plastics cups, packaging, etc.	30
Styrene-ethylene-butylene-styrene	SEBS	Styrene	0.94	Increase durability of rubber, etc.	NF
Ethylene and Vinyl acetate	EVA	Ethylene and Vinyl acetate	0.92-0.97	Pipes, cable insulation, garden hoses, etc.	9
Fluorinated ethylene propylene	FEP	Tetrafluoroethylene	2.12-2.17	Coat the surface of various kitchen utensils, etc.	NF
Polyamide	PA	Adipic acid	1.14-1.15	Bearings, automotive applications, etc.	47
Ethylene propylene diene monomer	EPDM	Copolymers	0.86	Manufacture of rubber parts for automobiles, etc.	NF
Polyolefins	PO	Olefin	0.90-0.96	Resistance to heat and an array of common solvents.	11
Polyacrylic acid	PAA	Acrylic acid	1.15	Artificial tears to treat dry eye syndrome.	230
Thermoplastic polyurethanes	TPU	Copolymers	1.28-1.66	As a soft engineering plastic or as a replacement for hard rubber.	1,094
Polyethylene terephthalate	PET	Ethylene glycol+terephthalic acid	1.38	Textiles, packaging, and other applications.	4
Polyurethane	PUR	Polypropylene glycol	0.40-0.60	Upholstery, sports mats, packaging bags, etc.	13,844

a The value for the score of each polymer is taken from (Lithner et al., 2011).

NC (Not classified) the responsibility of the manufacturer making it impossible to know the ingredients and ratios in plastic production therefore cannot find the value.

NF for TPV-SEBS-FEP and EPDM are lacks ecological toxicity data, therefore its hazard score cannot be determined.

C_s^i is the observed concentration of MPs at each sampling location = 4.0 pieces/L.

C_b^i is the background concentration, which is the lowest concentration reported in Thailand = 0.1 pieces/L (Vibhatabandhu & Srithongouthai, 2022).

$$C_f^i = \frac{C_s^i}{C_b^i} = \frac{4}{*\,0.1} = 40$$

*background concentration of the lowest MPs nearby sample site from the inner Gulf of Thailand about 0.1-57.41 pieces/L in the dry season (Vibhatabandhu & Srithongouthai, 2022).

Table 6 Polymer risk assessment of MPs

Abbreviation	**Total percent of MPs (%)**	P_n	S_n	T_r^i	E_r
PTFE	36.69	0.37	-	0.00	0.00
PE	14.16	0.14	11	1.56	60.83
PP	12.92	0.13	1	0.13	5.01
TPV	5.22	0.05	-	0.00	0.00
PS	4.55	0.05	30	1.37	69.52
SEBS	5.22	0.05	-	0.00	0.00
EVA	3.13	0.03	9	0.28	7.56
FEP	4.28	0.04	-	0.00	0.00
PA	4.98	0.05	47	2.34	102.36
EPDM	5.07	0.05	-	0.00	0.00
PO	2.67	0.03	11	0.29	18.48
PAA	0.84	0.01	230	1.92	74.02
TPU	0.13	0.00	1094	1.43	46.51
PET	0.05	0.00	4	0.00	0.00

PUR	0.09	0.00	13844	12.78	688.74

Source: (Lithner et al., 2011).

From sum of E_r calculation is RI (potential ecological risk factor) is 1073, that means very high ecological risk in Chao Phraya River Estuarine. From the Risk assessment, the researcher found MPs Affecting the ecosystem in the Chao Phra River Estuary with a high risk of contamination Nevertheless, the risk of MPs is not just because of additives. Field monitoring and experiments have revealed that the persistence of organic pollutants and heavy metals can be a product of both plastic components and adherents on the surface of MPs (Antunes et al., 2013).

Under typical environmental conditions, the plastic particles that eventually end up in the surface water are not readily biodegradable. Because synthetic polymers degrade very slowly (in a few decades to several centuries, depending on the type of plastic and the environment), there will likely be an accumulation of microplastics in the aquatic environment for some time (Roex et al., 2013). The combination of these materials' persistence and the potential for accumulation in food chains is what principally contributes to the harm posed by microplastics. Microplastics are capable of accumulating in the body tissues and/or fluids of both people and animals, leading to negative health consequences (particle-toxicity). Microplastics have already been found in marine species including lugworms, barnacles, mussels, lobsters, petrels, and seals. According to a US pilot research (Bhattacharya et al., 2010), nanoplastics have a detrimental effect on the ability of green algae to photosynthesise. Additionally, human intestines can absorb ultrafine particles. These particles may then enter the lymphatic, cardiovascular, and vascular systems. These particles have the potential to have a number of physiological impacts, including alterations in gene expression and localized inflammation. According to a recent study, the placenta may transmit polystyrene particles up to 240 nm in diameter from the mother to the baby (Wick et al., 2010). Microplastics are a potential source for the introduction of infections, invasive species, and chemical pollutants since they are bigger pieces of trash. It is still unclear how plastic waste acts as a transport vector in freshwater environments.

Finally, the presence of microplastics in the aquatic environment might also pose additional dangers since the chemical additives that were used to improve the plastic's qualities could leak into the surrounding environment (Browne et al., 2011).

The microplastics may also bind to other chemical pollutants. By ingesting fish, shellfish, and/or crustaceans, organisms may take up the microplastics, posing a concern to both the ecosystem and human health (Leslie et al., 2011).

CHAPTER 5
RESEARCH CONCLUSION

The Master's Thesis describes the results of Influence of tidal current on microplastics in Chao Phraya River estuary ecosystem the specific results of my deliberation can be concluded as follow:

5.1 Conclusion

This study paid attention to the water tidal current effect as well as the concentration and characteristics of microplastics that were contaminated in the water column depth of Chao Phraya River Estuary during a cycle of the tidal. Furthermore, the influence of tidal current on microplastic concentration and microplastic characteristics was also focused on. As a result of the contamination with PUR, which is quite toxic, the lowest tide had a substantially larger ecological risk than previous tides, according to our attempt to conduct a risk assessment. These findings showed that the presence of composite MPs polymers in the water column of the Chao Phraya River estuary had a significant danger of contaminating this reservoir region while having a minimal impact on the biological environment. All results in this study were concluded as follows:

5.1.1 Concentration of microplastic contamination

Microplastics were found from all water samples, microplastic concentration varied between 0.2-7.8 pieces/L. The average microplastic was 4.0±3.8 pieces/L. For the low tides (01.26 and 13.17), MPs varied between 2.37-12.89 pieces/L, with an average of 6.25±4.47 pieces/L. As expected, the different tide showed the different amounts of microplastic. The average microplastic concentration at flood tide and ebb tide were 4.03±4.23 and 3.44±3.34 pieces/L, respectively. This Average result showed that the amounts of microplastic increased as the water level decreased.

5.1.2 Characteristics of microplastics contamination

1) Size of microplastics

In this study, the sizes of observed microplastics were divided into five sizes. Nevertheless, microplastic sized 16-100 µm was the major microplastic size (76-80%), followed by microplastic sized 101-200 µm (15%). Similar to the overall size, at flood tide and ebb tide, microplastic sized 16-100 µm size was the most common size that was found. By the way, microplastic sized 301-400 µm and 401-500 µm were the least common size that were found at flood tide and ebb tide, respectively. The changing of tidal had an influence on each color as well. To specify, the increase of water level caused increased observation of microplastic sized 201-300, 301-400, 401-500 and more than 500 µm size, on the other hand, the other sizes decreased.

2) Shape compositions

In this study, the most common shape that was found was fragment (82%), followed by fiber (10%), film (6%), pellet (2%) and foam (<1%), respectively. The difference of shape composition was also noticed between flood tide and ebb tide. At flood tide, fragments were the most common shape and foam with pellet was the least common shape. At ebb tide, fragment was the most common shape and foam with pellet was the least common shape. The fluctuation of tidal affected the distribution of each shape. To explain, the increase in water level caused more fragment and fiber microplastics to be noticed, on the other hand, film, pellet, foam decreased.

3) Color detection

Color of microplastic contamination Microplastics were observed in various colors. From all samples, blue showed the most proportion (38%), on the other hand, others color showed the slightest proportion (< 1%). At flood tide, blue was the most portion. The blue color was the most portion at ebb tide. Nevertheless, at both ebb tide and flood tide, green showed the least amount compared to the other colors. The changing of tidal affected the distribution of each color. To specify, the increase of water level caused more blue, black, and transparent microplastics to be found, on the other hand, red, brown, white, green and others color microplastics decreased.

4) polymer type composition

Among all identified microplastics, PTFE accounted for the largest proportion by 36%, follow by PE (15%), PP (14%), TPV (7%), PS (5%), SEBS- EVA-FEP-PA (4%), EPDM-PO (3%) and Others (1%) respectively.

For the different tide occurrence, at flood tide, PTFE was the most common type of all types followed by PE. At ebb tide, PTFE was also the most common type, followed by PE same as flood tide. The changing of tidal had an influence on each polymer type of microplastics as well. To specify, the increase of salinity, which referred to flood tide occurrence, caused increased observation of PTFE, PE, PA while the others decreased.

5.1.3 Deposition Rate of Microplastics Contamination onto the Surface Sediment

Contamination of microplastics in surface sediment. In this study deposition rate of microplastics was compared 4 tide, total depositions rate of microplastics was 787 pieces/m^2/h during highest-low tide (20.00- 01.00), 738 pieces/m^2 /h during low-high tide (02.00-05.00), 1,401 pieces/m^2 /h during high-lowest tide (06.00- 13. 00) and 533 pieces/m^2/h during lowest-high tide (14.00-17.00). While total deposition rate in 24 hours was 440 pieces/m^2/h.

5.1.4 Physical characteristics of depositing microplastics

1) Size of microplastics

In this study, the size composition of microplastics was classified into 5 sizes. The size of microplastics was 16-100 µm, 101-200 µm, 201-300 µm, 301-400 µm and >400 µm. However, microplastics size 16- 100 µm was found mostly. Furthermore, microplastics size >400 µm was the least that found. But, in low to high tide, 301-400 µm were the least. While the total size of microplastics in 24 hours was 16-100 µm too.

2) Shape compositions

In this study, shapes of microplastics were classified into 5 shapes, including fragment, fiber, film, foam, and pellet. The most shape of microplastics were found was fragment. Whereas the pellet shape was the least that found in three tides. But, during high-lowest film and foam was the least found that. While the total shape of microplastics in 24 hours was fragment about 94% followed by film and fiber with 2%, foam and pellet with 1%.

3) Color detection

In this study, color was detected 7 colors, including color black, brown, transparent, white, red, blue and others. The dominant color of microplastics was color black. Followed by brown in other tide and color transparent in low-high tide. And the total color detection of microplastics in 24 hours was black followed brown, transparent, white, red, blue, green same as mentioned during tidal current.

4) Chemical characteristics of deposition microplastics

In this study, a total number of 5935 particles are identified as microplastics, which 50% of success rate identification. The chemical composition was consisting of 22 polymer types including polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE), polyamide (PA), polyurethane (PU), poly(methyl methacrylate) (PMMA), polystyrene (PS), polyvinyl alcohol (PVA), polyethylene glycol (PEG), polyvinylidene difluoride (PVDF), styrene- ethylene-butylene-styrene (SEBS), phenol-formaldehyde (PF), polyphthalamides (PPA), thermoplastics polyurethane (TPU), poly(methyl vinyl ether- co-maleic anhydriedes (PVM), thermoplastics vulcanizate (TPV), acrylonitrile butadiene styrene (ABS), poly acrylonitrile (PAN), ethylene methacrylic acid (EMMA), polyethylene terephthalate (PET), ethylene acrylate copolymer (AEM) and polybutadiene rubber (BR).

In the study revealed that the major composition of PA (59%), PE (12%), PP (6%) and ABS (2.l%). While the total polymer type of microplastics for 24 hours during tidal current with PA followed by PE, Epoxy Resin, PP, SEBS, TPU, TPE, EVA and PTFE.

5.1.5 Risk of microplastics to the Chao Phraya River estuarine ecosystem

As a result, there is a significant ecological risk is very high in the Chao Phraya River Estuarine. The study's findings showed MPs provide a very high risk to the environment in the Chao Phra River Estuary at low tide periods suggested that surface runoff, everyday life, and river confluence are the key factors influencing pollution. Contaminated with PUR, a hazardous substance. This finding showed that the presence of composite MPs polymers in the water column of the Chao Phraya River estuary had a significant danger of contaminating this reservoir region while having a minimal impact on the biological environment.

5.2 Research Suggestions

1) Environmental and risk suggestion

This study showed that microplastics that were contaminated in the Chao Phraya River Estuary were tidal current can affect microplastics from river discharge. So, the associated authorities should rapidly take charge of dealing with plastic waste from the land that is disposed to the river. With risk assessment the researcher found considerable ecological risk in this study. The presence of microplastic indicates that marine plastic debris has fragmented. Even the dominant characteristics of microplastics, which can imply their origin, were shown in this study as well. So, the source of microplastics detected is plastics waste was generated from humans' activities, such as waste from fishing and improper management of plastic waste. I'm recommended to priorities the regulatory measures to reduce waste plastics from humans' activities and strengthen the measures to ensure proper disposal of plastic waste by residents, tourists, and fisher. Thus, I am hopefully that the observation from this study can make more understanding of microplastic contamination and lead to more effective management and prevention of the microplastic problem. Besides, the public should be able to access any information about this crisis to increase the realization of the microplastic issue and raise awareness to reduce and avoid plastic usage of plastics.

2) Research suggestion

To prevent the errors from losing the microplastics, increasing the volume of the samples as well as decreasing the pore size of the plankton net during the sampling process should be considered. By focusing on collecting accurate samples and collecting more samples which in differences water column depth and also in microplastics in sediment depth will make the data more accurate and detailed.

5.3 Future Research

From the conclusion that tidal current can be affected to the influence of MPs to estuary in water column depth, also the deposition rate of surface sediment according to various reasons as follows:

1. This will lead to an investigation of the plastics in sediment depths with tidal current effect on the sediment or not and the origin of the plastics from the manufacturing site. To warn or avoid including reducing the use of plastic further.
2. From the experiment, we were able to assess the risk that the amount of microplastics found in the area can affect the ecosystem or not? And can also be used as preliminary data to further lead to further investigation of plastics in the marine ecosystem.
3. Through this experiment, we can predict the direction and source of plastic waste that breaks down into microplastics at different depths, which can be used to study about MPs in river and ocean ecosystems in order to be able to link further study.

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