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Completion Report

(01/07/2024-30/6/2025)

Evaluating the ecological impacts of microplastic pollution on blue carbon ecosystems in Hong Kong using molecular fingerprints

The Hong Kong University of Science and Technology

I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorisation has been obtained in respect of information owned by third parties.

Any opinions, findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.

Signature: 

Date: 29/08/2025

(i) Executive Summary (1-2 pages)

Hong Kong has a lengthy coastline that supports a diverse range of blue carbon ecosystems (BCEs), including mangroves, seagrass meadows, and tidal flats. These BCEs serve multiple purposes, such as maintaining biodiversity, nurturing fisheries, protecting shorelines, promoting tourism, and facilitating public education and conservation research. Against the backdrop of global warming and national policies on carbon peaking and carbon neutrality, BCEs are also recognized as a natural means of carbon sequestration. Therefore, the conservation of BCEs holds great significance. As an international metropolis, Hong Kong experiences frequent human activity and urban development that can significantly impact the environment of BCEs, particularly the composition of organic matter in sediments. Factors such as microplastic pollution can affect the health of BCEs. Plastics are organic polymers of high molecular mass and are generally resistant to decomposition. Thousands of polymers over a wide range of densities and textures have been synthesized in recent decades. Peri-urban coastal areas are regarded as major reservoirs of plastics, mainly in the form of microplastics. As carbon-rich (C-rich) components, the C content of different microplastic ranges from 38 to 92%, and microplastics can release DOM into the aquatic environment through leaching. According to recent estimates, the annual leaching of DOM from marine plastic waste can reach 23,600 tons. Assessing how these microplastic-derived DOM affect the environment and nutrient cycles of BCEs is challenging. This has hindered the efforts of the government, academia, and industry in BCEs conservation. Therefore, scientific research is needed to develop precise diagnostic methods. To comprehensively assess the impacts of microplastics on dissolved organic matter (DOM) in Hong Kong's coastal wetlands, we strategically selected four representative sampling sites within the Hong Kong Special Administrative Region. These sites encompass four typical coastal wetland ecosystems: unvegetated tidal flats, mangroves, and seagrass meadows. We meticulously monitored the physicochemical properties and DOM contents of sediments from these wetlands. Based on these data, we estimated the organic carbon and nitrogen stocks in the sediments of all three locations. In parallel, under controlled laboratory conditions, we conducted leaching experiments using artificial seawater to investigate the dynamics of dissolved organic carbon (DOC) release from microplastics. The chemical composition of microplastic-derived DOM (MPs-DOM) was characterized using EEMs-PARAFAC and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS). We completed 180-day leaching experiments for three common plastic types—polyethylene (PE), polypropylene (PP), and polystyrene (PS). This approach allowed us to resolve the temporal changes in MPs-DOM profiles for different plastic types. Leveraging the

exceptional high resolution and mass accuracy of FT-ICR MS, we can precisely resolve the molecular formulas and features of DOM from both sediments and microplastics. This capability enables more accurate tracing of microplastic-derived DOM molecules and a robust assessment of their anthropogenic impacts. Ultimately, this study integrates field observations with controlled incubation experiments to identify and characterize potential microplastic-derived DOM within BCEs sediments. Although microplastic-derived DOM currently constitutes only a small fraction of the total DOM pool, it exhibits distinct spatial distributions. We hypothesize that, as microplastic pollution intensifies in the future, the contribution of microplastic-leached DOM to the overall sediment DOM pool in BCEs may increase significantly. Such an increase could fundamentally alter biogeochemical processes and pose potential environmental risks. This study represents the first systematic evaluation of the ecological significance of microplastic-derived DOM in Hong Kong's coastal wetland sediments. We anticipate that the project's findings will provide crucial decision support and baseline data for government agencies and other relevant stakeholders.

(ii) Project title and brief description of the Project

Project Title: Evaluating the ecological impacts of microplastic pollution on blue carbon ecosystems in Hong Kong using molecular fingerprints

Applicant Organization: The Hong Kong University of Science and Technology

Project Leader: Ding HE

Brief description of the Project

This one-year project aims to assess the ecological impacts of microplastic pollution on the sediment of Hong Kong's blue carbon ecosystems (BCEs), including mangroves, seagrass meadows, and tidal flats. We used the most advanced and rapid Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR MS) technology to investigate the properties of microplastic-derived dissolved organic matter (DOM) on a molecular level. This approach provided a precise understanding of the sources of DOM in sediment. Additionally, we evaluated the ecological impacts of microplastic pollution on the sediment of Hong Kong's BCEs by combining stable carbon and nitrogen isotopes of BCEs sediment with the DOM's chemical and physical properties. The results of this study will contribute to predicting and regulating material cycling in blue carbon ecosystems and informing the development of conservation and management policies for Hong Kong's BCEs.

(iii) Completed activities against the proposed Work Schedule

We conducted the research and related tasks regarding the tasks in the section 9 of application form:

1. Recruit one research assistants and one postdoctoral fellow: **Done**
2. Sediment Sampling: **Done**
3. Total organic carbon, total nitrogen, and isotopes analysis: **Done**
4. Microplastic leaching experiment: **Done**
5. Optical properties of DOM: **Done**
6. SPE experiment: **Done**
7. FT-ICR MS analysis: **Done**
8. Multiple research presentation: **Done**

(iv) Results/ descriptions on the completed activities with appropriate analysis, with the support of photos, videos, social media platform, etc., if any

1. Research background

Plastics are organic polymers of high molecular mass and are generally resistant to decomposition. Thousands of polymers over a wide range of density and texture have been synthesized in recent decades. The main types of plastics include polypropylene (PP), polyethylene (high-density polyethylene HDPE and low-density polyethylene LDPE), polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polystyrene (PS), each characterized by different densities and carbon (C) contents. Plastic pollution has been a major concern in the environment and ecology in recent year. Between 4.8 to 12.7 million tons of plastic waste are discharged into the marine environment annually (Worm et al., 2017), and most plastics are physically broken down into various sizes without significant degradation. Also, plastic industrial resin particles and toothpaste, cosmetics, and face wash contain microplastics that are released into the environment via rivers and sewage treatment plants (Auta et al., 2017). Peri-urban coastal areas are regarded as major reservoirs of plastics, mainly in the form of microplastics (MP), with sizes between 0.0001 to 5mm. With the increasing discharge of plastic wastes into the ocean, it is well established that MPs exist in all types of marine habitats and their inhabitants (Fischer et al., 2015). However, the role of MP in the coastal carbon cycle is poorly constrained. Current studies of MP mainly consider their abundance, mass, size, shapes, and types (Rillig, 2018; Rillig & Lehmann, 2020). Limited evidence indicates that the concentration of MP is potentially correlated with sediment C content (Chen & Lee, 2021). As C-rich components, the C content of different MP types ranges from 38 to 92% (Stubbins et al., 2021) and MP can release dissolved organic matter (DOM) into the aquatic environment through leaching. According to recent estimates, the annual leaching of DOM from marine plastic waste can reach 23,600 tons.

Coastal wetlands are typical areas to study the impact of MP pollution on the organic carbon cycle. Coastal areas with dense populations are strongly influenced by anthropogenic activities and are an important pathway for microplastic transport to the ocean. Hong Kong, with its 260 islands, is located at the eastern estuary of the Pearl River, Southern China (22.08° to 22.35° N, 113.49° to 114.31° E). Hong Kong has a total land area of 1,108 km^2 with a long coastline of 1,180 km and a diverse coastal ecosystem. As an international metropolis, Hong Kong has frequent human activities and MP pollution, which likely affect the environment of coastal water significantly, especially the composition of organic matter. Pervious data suggest that the

coastal areas in Hong Kong are the hotspot of MP pollution. The distribution debris covered every conner of the coastal water and habitats (Fok & Cheung, 2015; Lo et al., 2018). Sourced from land-based, maritime activities, river discharge and even atmospheric dust, plastic pollution, sewage discharge, and fuel leaking make coastal sediments vulnerable to contamination (Zhang., 2017; Zhang et al., 2020). These persistent organic pollutants, once buried, are almost impossible to remove from the coastal sediment (Martin et al., 2019; Yao et al., 2019). Sequestration in coastal sediments is regarded as an important and efficient removal process for organic pollution (Martin et al., 2019; Martin et al., 2020). However, it is challenging to assess how these anthropogenic activities affect the environment and C cycle of coastal areas. In addition, the surface of MP can support a high diversity of microorganisms' community, forming spatial hotspots for microbial degradation and modification of DOM in the aquatic environment. MP-derived DOM can influence the transport and transformation of organic carbon through multiple mechanisms.

The coastal area is also a hotspot for organic carbon deposition and plays an important role in C sinks. C contained in MP can directly form part of the C reservoir in the receiving waters and can increase the measured total organic carbon concentration. As an emergent anthropogenic pollutant, whether MP is making a hidden contribution to coastal C cycling (Stubbins et al., 2021) is of significant management importance. The molecular level is the key to elucidating the reaction pathways and deciphering the geochemical reactivity of DOM in different environmental matrices. DOM molecules within coastal wetland sediments can reflect the properties and sources of organic matter, especially in peri-urban coastal wetlands vulnerable to microplastic pollution. This makes DOM molecules an ideal indicator for detecting anthropogenic impacts on coastal wetlands. A comprehensive study of the nature and composition of sedimentary DOM and their relationship with microplastic-derived DOM is necessary. Understanding how the DOM dynamics of sediments from coastal wetland habitats respond to the microplastic pollution will help elucidate the future C sequestration capacity of peri-urban coastal wetlands. These data are also essential for improving the conservation and restoration of coastal wetlands and establishing a C sequestration baseline for further managing highly urbanized coastal areas.

Spectrophotometric techniques are widely used to assess the composition of different sources of DOM in estuaries (Li et al., 2015; Yamashita et al., 2015). However, relying solely on the optical properties of DOM is insufficient to demonstrate its molecular characteristics and biogeochemical processes. With the development of Fourier transform ion cyclotron resonance

mass spectrometry (FT-ICR MS), it has become possible to precisely measure the mass of DOM and assign molecular formulas to individual mass spectral peaks (He et al., 2020; Wang et al., 2019). The result of FT-ICR MS can summarise the chemical composition and characteristics of DOM. For example, compounds with carbon, hydrogen, and oxygen are usually more abundant in terrigenous DOM, while the relative proportion of heteroatomic compounds (including elements with nitrogen, sulfur, and phosphorus) increases under anthropogenic impacts (Wagner et al., 2015), and provide a molecular perspective in characterizing DOM source and transport. Therefore, we will apply FT-ICR MS for the first time in Hong Kong coastal wetlands to analyse DOM molecular composition and properties from coastal wetland sediments. In this study, we will focus on the linkages between DOM molecular and MP pollution along the Hong Kong coastline. The potential importance of different factors will also be evaluated by considering relevant environmental factors and bulk properties in the surrounding areas.

2. Methods

2.1.Sampling Sites

Sampling efforts across the Hong Kong SAR have successfully collected 10 sediment cores, comprising 170 layers of subsamples from nine coastal wetlands: Mai Po (MP), Tung Chung (TC), Shui Hau (SH) and Ting Kok (TK) **(Figure 1)**. These sites represent a wide array of blue carbon ecosystems throughout the region, each with unique characteristics and ecological importance.

MP, a Ramsar site (site number: 750) managed by WWF-Hong Kong since 1983, is in Deep Bay and spans a total area of 1,500 hectares. This site includes three primary blue carbon ecosystems: tidal flats, mangroves, and *gei wai* (tidal aquaculture ponds), with the mangroves dominated by seven species, namely *Kandelia obovata*, *Avicennia marina, Aegiceras corniculatum, Bruguiera gymnorhiza, Excoecaria agallocha, Acrostichum aureum,* and *Acanthus ilicifolius*. MP is not only critical for its biodiversity, hosting numerous migratory birds as part of the East Asia-Australasia Flyway, but it also faces significant threats from the rapid urbanization surrounding Deep Bay.

TC, located in Tung Chung Bay on Lantau Island, represents a successful example of mangrove restoration. Following disturbances caused by the construction of Hong Kong International Airport, this mangrove ecosystem has been revitalized, with distinct zones dominated by different species. The waterfront zone is primarily composed of *Avicennia marina* shrubs, while

the landward zone features taller trees such as *Kandelia obovata* and *Excoecaria agallocha*. TC serves as a vital study area for understanding restoration success and the resilience of mangrove ecosystems.

SH (22.13° N, 113.55° E) is located on the south coast of Lantau Island. Although this site is located on the west coast of Hong Kong, as a south-facing embayment it is usually not directly affected by the Pearl River estuary. Two small streams run down from the catchment to the beach, and these are considered as primary freshwater inputs to the bay. The salinity in SH ranges from 8 to 24. Located far from urbanized areas, SH is regularly visited by tourists and local research groups. While the environment is relatively intact, it is still subject to pollution, such as anthropogenic wasted discharges from local as well as inputs from the Pearl River catchment. Tidal flats in SH are dominated by sand and cover an area of 0.2 km2. Tidal flats there are protected from strong waves. Consequently, the soft, sheltered nature of the tidal zone and the accumulation of organic debris result in a high diversity of organisms. In Hong Kong, it is rare to find such extensive sheltered sand flats with a relatively unmodified land-sea transition of habitats.

TK is situated in Tolo Harbour, a semi-enclosed bay known for its distinct environmental conditions. TK, home to the fourth-largest mangrove forest in Hong Kong, is characterized by its shrub-like mangrove communities, which have adapted to the sandy substrates and higher salinity levels of this oceanic-influenced environment.

Sediment cores were obtained in nine important coastal wetlands using a Kajak corer (KC-Denmark) with a diameter of 52 mm (at least 30cm), from the mangroves and their tidal flats in target areas (for MP and TC, we further collected additional sediment cores from *gei wai* (traditional fish pounds in Hong Kong with mangroves) and seagrass meadows, respectively. After collection, each core was immediately transferred to the laboratory and sliced into between 10 and 11 intervals. The top 10 cm of each core was sliced into 2-cm intervals, while the 10 to 20 cm section was sliced into 4-cm intervals, and the remaining portion was sliced into 5-cm intervals. We also record relevant environmental parameters in the field. A total of 10 sediment cores with 170 layers of subsamples were obtained and stored at -20 °C before further processing.

2.2.Bulk analysis of sediment samples

In the laboratory, approximately 5 g of fresh sediment from each sample were freeze-dried until constant weight. All litter and detritus from freeze-dried samples were removed before they were ground and then passed through a 2-mm sieve. For each sample, approximately 20 mg of the ground material were weighted in silver capsules, and inorganic carbon was removed by 6 M HCl. After drying, the total OC (OC), total nitrogen (TN) content, the OC stable isotopes ($\delta^{13}C$) and nitrogen stable isotopes ($\delta^{15}N$) values of different sediment samples were determined by a continuous flow EuroVector EA-Nu Perspective isotope-ratio mass spectrometer.

2.3.Microplastic Experiment

Two types of MPs (i.e., PE and PP) with diameters of ~5 mm and ~250 μm, namely, PE large (PE-L), PE small (PE-S), PP large (PP-L), and PP small (PP-S), were purchased from Yangli Electromechanical Technology Co. Ltd. (Shanghai, China). Infrared spectroscopy and scanning electron microscopy of these MPs were conducted to confirm the polymer types and surface morphology. All MPs were thoroughly washed with alcohol and deionized water three times to remove residual organic substances before use. These MPs were chosen based on their prevalence in the global plastic market, with PE and PP accounting for 26.3% and 18.9% of total plastic demand, respectively, ranking them first and second. In addition, these two types of MPs were widely detected in global surface seawater owing to their lower densities (~0.9 g/cm^3), making them more prone to sunlight irradiation. Other analytical grade chemicals purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China) were used without further purification. To prepare the artificial seawater, electrolytes were weighted and dissolved in ultrapure water (resistivity >18.2 MΩ·cm) and filtered through a 0.22 μm filter membrane.

The aging experiments were conducted in a chamber equipped with two orbital shakers and two UV lamps while maintaining a constant temperature of 20 ± 0.5 ℃. The shakers were set to operate at 80 rpm to continuously simulate ocean currents, and the light intensity of UV irradiation was set to 0.3 mW/cm^2 to simulate the continuous photoaging process. The effects of microorganisms on the release of MPs-DOM can be ignored due to the sterilization seawater used and bacterial inactivation under UV irradiation. All artificial aging experiments for each type of MP were conducted in triplicate. For each batch, 10 g of pristine MPs were initially added into a pre-cleaned glass flask containing 150 mL of artificial seawater (32 PSU). The aging experiment

was conducted over a period of 180 days and samples were withdrawn on 7, 14, 21, 28, 35, 50, 90, 110, 130, 150, and 180 days, respectively. The collected suspension was then passed

through a 0.22 μm filter, and the weathered MPs were obtained on the membrane surface before tests. Meanwhile, leachates passing through 0.22 μm filter were collected and stored in the dark at 4 ℃ before analysis. In addition, to avoid plastic cross contamination, all vessels used in this work are glassware and combusted at 450 ℃ for 2 h before use.

2.4.Optical analysis of DOM

To analyse the characteristics of MPs-DOM, fluorescence spectral measurements were performed using an Aqualog absorption-fluorescence spectrometer to generate EEMs. The humification index (HIX) indicates humic substance content, which positively correlated with the aromaticity of DOM. HIX is the ratio of the area of 435-480 nm to the area of 300-345 nm in the emission spectrum at an excitation wavelength of 254 nm, and an increase in HIX indicates a higher degree of DOM decay. The biological index (BIX) indicates autotrophic productivity. BIX is the ratio of the fluorescence intensity at emission wavelengths of 380 nm and 430 nm and excitation wavelength of 310 nm, and values in the range of 0.6-0.7 indicate a low proportion of autochthonous sources of DOM, and values above 0.8 indicate strong autochthonous properties. fluorescence index (FI) is the ratio of the fluorescence intensity at an emission wavelength of 470 nm to the fluorescence intensity at an excitation wavelength of 520 nm at 370 nm, and has been widely used to indicate DOM for terrestrial (FI < 1.4) and microbial (FI > 1.9) inputs. These indices provide insights into aromaticity, humic substance content, autotrophic productivity, and sources of DOM. Additionally, all EEMs were subjected to parallel factor analysis (PARAFAC) using the DOMFluor toolbox.

For molecular characterization of BCEs DOM and MPs-DOM, solid-phase extraction (SPE) was conducted. Briefly, PPL cartridge was activated with 20 mL HPLC grade methanol and balanced with 20ml acidified Milli-Q water (pH = 2). To increase the extraction efficiency, sample was preacidified to pH 2 with HCl and then passed through the rinsed PPL cartridge under gravity at a flow rate of approximately 2 mL/min. The cartridge was subsequently rinsed with 20 mL pH = 2 HCl and Milli-Q water to remove salt. After completely dried in a nitrogen atmosphere, the samples were eluted with 5 mL methanol (LC-MS grade) into combusted brown glass vials and kept in the dark at -20 ℃ prior to FT-ICR MS measurement.

The extracted samples were analyzed using FT-ICR MS. In this analysis, a portion of the extract was adjusted to 40 mg/L (on a DOC basis) and injected into the 15 T electrospray ionization

source of the Apex-ultra X FT-ICR MS. Molecular formulas were assigned to peaks meeting specific criteria, such as signal-to-noise ratios and mass detection errors. Here, DOM molecular formulas (CHO, CHON, CHOS, CHOP, CHONS, CHONP and CHOSP) in the mass range m/z 100 to 1000 Da were assigned for peaks with signal-to-noise ratios greater than 6 and with an absolute mass detection error of ±1 ppm (Yi et al., 2023). A total of 9984 unique formulas were finally assigned (elemental limitation of $^{1}H_{1–200}$, $^{12}C_{1–100}$, $^{14}N_{0–3}$, $^{16}O_{1–40}$, $^{31}P_{0-1}$ and $^{32}S_{0–1}$) for the DOM extracts and the relative peak intensity of each molecule was normalized to all assigned peaks (Yi et al., 2023). The aromaticity of DOM compounds was represented using a modified aromaticity index (AI_{mod}) and double bond equivalents (DBE). A series of index was introduced to further understand the characteristics of DOM, including the molecular stability boundary labile (MLB_{labile}) (D'Andrilli et al., 2015), and the nominal oxidation state of carbon (NOSC). Compounds were classified as unsaturated aliphatic compounds (UA, $1.5 < H/C < 2.0$), peptides ($1.5 < H/C < 2.0$, $O/C \leq 0.9$ and $N > 0$), carboxyl-rich alicyclic molecules (CRAM, $0.3 < DBE/C < 0.68$, $0.2 < DBE/H < 0.95$ and $0.77 < DBE/O < 1.75$), polyphenols ($0.5 \leq AI_{mod} \leq 0.66$) and polycyclic condensed aromatics (PCAs, $C > 15$ and $AI_{mod} > 0.66$). To further understand the characteristics of DOM, the 't-peaks', which is calculated from 184 terrigenous DOM molecules was also introduced in this study. To indicate the intensity-weighted values of those parameters, a suffix of "wa" was appended to *m/z*, H/C, O/C, AI_{mod} and DBE. For example, the intensity weighted m/z was presented as m/z_{wa}.

3. Results

3.1. Bulk and Molecular Characteristics of Sediments in Four Hong Kong Coastal Wetlands

We compared bulk parameters across habitats and found that vegetated coastal wetlands have higher organic carbon (OC) and nitrogen (N) contents than unvegetated tidal flats. Limited water exchange in ponds or gei wai during tidal cycles tends to promote the accumulation of plant-derived detritus (e.g., from mangroves or seagrasses), which accentuates these differences. This pattern is especially pronounced in vegetated areas: OC and N are significantly higher than in unvegetated areas and exhibit a stronger terrestrial signal (more depleted $\delta^{13}C$ and more enriched $\delta^{15}N$) (**Figure 2**).

This pattern reflects vegetation's dual role in organic matter supply and sedimentary processes. On the one hand, mangroves and seagrass beds continuously deliver plant detritus and labile organic matter to sediments through leaf fall, root turnover, and biomass production. On the

other hand, vegetated zones create microenvironments (reduced flow velocity, enhanced particle flocculation, and abundant microbial communities) that favor organic matter accumulation and preservation, thereby increasing sedimentary carbon and nitrogen stocks. Restricted water exchange also reduces the removal or rapid dispersion of organic material, promoting local carbon sequestration and stability.

Different vegetation types exert distinct controls on C and N attributes: mangroves typically show a stronger terrestrial signature (more depleted $\delta^{13}C$ and more enriched $\delta^{15}N$), whereas seagrass beds in more marine-influenced settings often have a relatively greater autochthonous (marine) organic matter contribution. Overall, Hong Kong's mangroves and seagrass beds tend to have higher OC and N in their sediments than unvegetated tidal flats; in most coastal wetlands, vegetated sediments exhibit more depleted $\delta^{13}C$ and more enriched $\delta^{15}N$ (**Figure 2**). These findings have important implications for assessing coastal wetlands' role as carbon sinks and for designing conservation and management strategies.

Moreover, it should be noted that the sedimentary differences caused by vegetation structure and water-exchange regimes may also influence the accumulation and distribution of microplastics. Complex root networks and bioturbation in vegetated areas can enhance particle and microplastic retention, while low-flow, high-flocculation conditions favor microplastic deposition and burial. Therefore, evaluations of coastal wetland ecosystem functions should also consider their capacity to trap and store microplastics and other pollutants, to inform more comprehensive pollution control and ecological restoration measures.

We utilized FT-ICR MS to characterize the DOM at a molecular level in sediment samples collected from coastal wetlands. **Figure 3**, taking the three typical habitats in Mai Po as an example, visually demonstrates the differences in DOM molecules both vertically (with depth) and among different habitats. Our research further reveals that the composition and characteristics of DOM molecules in Hong Kong's coastal wetlands exhibit significant and complex regular variations in both vertical (with depth) and horizontal (across habitats) directions.

In the vertical direction, DOM molecules show a gradual evolutionary trend with increasing depth. Overall, the diversity and total number of DOM molecular formulas (**Figure 4**) generally decrease with increasing sediment depth; simultaneously, the weighted mean molecular weight

(m/z_wa, **Figure 5**) of DOM also shows a downward trend. This indicates that DOM molecules in deeper sediments tend to be smaller and less diverse. Regarding chemical composition, as depth increases, the weighted mean hydrogen-to-carbon ratio (H/C_wa, **Figure 5)** of DOM generally decreases, while the weighted mean oxygen-to-carbon ratio (O/C_wa, **Figure 5**) and the weighted mean modified aromaticity index (AImod_wa, **Figure 5**) generally increase. This pattern suggests that deeper DOM tends to be more aromatic, more oxidized, and exhibits reduced aliphatic characteristics. This is typically attributed to the long-term microbial degradation and geochemical transformation of DOM in sediments, leading to the preferential decomposition of easily degradable aliphatic and carbohydrate-like substances, leaving behind more stable, condensed aromatic compounds.

In the horizontal direction, significant differences exist in the characteristics of DOM molecules among different coastal wetland habitats. Specifically, mangrove habitats (such as Mai Po and parts of Tung Chung) generally exhibit significantly higher diversity and greater numbers of various DOM molecular formulas (e.g., CHO, CHON, CHOS, **Figure 4**) compared to unvegetated tidal flats and seagrass meadows. This indicates that mangrove ecosystems, due to their high biological productivity, can input a richer and more diverse range of organic matter. In terms of molecular chemical characteristics, DOM from mangrove habitats typically has a higher weighted mean molecular weight (m/z_wa, **Figure 5**) and a higher weighted mean hydrogen-to-carbon ratio (H/C_wa, **Figure 5**), while exhibiting relatively lower weighted mean oxygen-to-carbon ratio (O/C_wa, **Figure 5**) and lower weighted mean modified aromaticity index (AImod_wa, **Figure 5**). This suggests that mangrove DOM tends to be characterized by larger molecules, more aliphatic components, and a lower degree of oxidation, reflecting the input of abundant, relatively fresh, and less degraded organic matter from their vigorous primary productivity. In contrast, the DOM molecular diversity and abundance in Ting Kok and Shui Hau are generally lower, and their molecular characteristics may tend to be more oxidized and aromatic. This could be attributed to different organic matter sources, hydrodynamic conditions, and microbial degradation processes in these habitats.

In summary, the composition and characteristics of DOM molecules in Hong Kong's coastal wetlands are influenced by degradation and transformation processes in the vertical dimension, leading to smaller and more aromatic forms. In the horizontal dimension, unique molecular diversity and chemical characteristics are observed due to differences in habitat types (particularly mangroves) and their associated biological inputs and environmental conditions.

3.2. Optical and Molecular Results of Microplastic Leaching Experiment

In the plastic leaching experiments DOC in the leachate increased continuously with incubation time, but clear differences were observed among plastic types and particle sizes (**Figure 6a**). Specifically, DOC from PE microplastics was lowest; PP microplastics produced the highest DOC among the three plastics and were significantly higher than PP macroplastics; PS showed the opposite pattern. Absorbance at 254 nm (a254) followed the same increasing trend as DOC (**Figure 6b**), indicating that both microplastics and macroplastics accelerate DOC release into the water via photodegradation. Compared with macroplastics, PE and PS microplastics exhibited lower HIX values (**Figure 6c**), suggesting a lower proportion of humic-like substances in their leachates, while PP showed no significant difference between sizes. BIX responses for PP and PS showed opposite patterns between particle sizes (**Figure 6d**), and all three plastics exhibited relatively high fluorescence index (FI) values before 50 days, indicating greater microbial degradability of the leachates (**Figure 6e**).

We applied 3D-excitation-emission matrices (EEMs) combined with Parallel Factor Analysis (PARAFAC) to all incubation samples and resolved five fluorescent components (**Figure 7**): C1 (Ex 260-270 / Em 310-320) and C4 (Ex 300 / Em 338) were protein-like components likely associated with microbial activity; C2 (Ex 295 / Em 410), C3 (Ex 240, 330 / Em 420) and C5 (Ex 240, 350 / Em 480) were humic-like components more related to terrestrial humic substances. The fluorescence intensities of all five components increased over the incubation period, indicating accelerated DOC release during leaching and photo-aging. Particle size and polymer type affected component release: small PP particles released more protein-like and humic-like components than large PP particles, whereas PE and PS generally showed no significant size-dependent differences or exhibited opposite trends. Notably, PP released more protein-like and humic-like substances overall than PE and PS, which may be attributable to its chemical structure: every other carbon in the PP backbone is a tertiary carbon and is more susceptible to abiotic attack (e.g., UV irradiation and thermal oxidation) than the secondary carbons in PE. Furthermore, the bond-dissociation energy sensitivity order (PE > PS > PP) (PE: 96 kcal/mol at 300 nm; PS: 90 kcal/mol at 318 nm; PP: 77 kcal/mol at 370 nm) indicates that chemical bonds in PP (e.g., C–C and C–H) require less energy to rupture, which helps explain its higher leaching activity. **Figure 8** shows the temporal variations of the five PARAFAC components during incubation.

In order to gain a better understanding of the molecular characteristics of microplastic-derived dissolved organic matter (MPs-DOM), we are conducting FT-ICR MS measurements. In this final report, we only present the molecular characteristics of MPs-DOM with a diameter of ~250 μm due to their environmental representativeness. As shown in Figure 9a, long-term UV exposure led to significant alterations in the leachates of MPs across several molecular parameters. The saturated compound intensity diminished for all three plastics. Specifically, for PE and PP, m/z_wa ($p < 0.05$, $R^2 = 0.93$ for PP and 0.61 for PE) and the relative intensity of unsaturated compounds ($p < 0.05$, $R^2 = 0.86$ for PP and 0.75 for PE) exhibited a marked increase, while AImod_wa and the relative intensity of aromatic compounds showed a noticeable decline ($p < 0.05$, $R^2 = 0.7$). However, PS-DOM displayed markedly different behavior. H/C_wa substantially reduced ($R^2 = 0.80$), while the relative intensity of highly unsaturated compounds surged, a contrast to the stable values observed for PE and PP ($p > 0.05$). Additionally, certain parameters, such as O/C_wa, MLBL_Intensity, and the relative intensity of unsaturated compounds, exhibited an opposite trend in PS compared to PE and PP, showing a decline in PS but an increase in the latter two. Furthermore, AImod_wa increased in PS ($R^2 = 0.84$), while it decreased in PE and PP. Overall, MPs-DOM in the early stages of UV exposure consists predominantly of smaller and highly saturated molecules. However, with long-term (180 days) irradiation, larger, more oxidized, and unsaturated molecules emerge, suggesting a progression from simple to complex molecular structures through photolytic and oxidative reactions over time. Notably, PS demonstrated distinct trends in MLBL_Intensity, AImod_wa, and the relative intensity of aromatic compounds, likely due to the presence of benzene rings in its structure, which increase its unsaturation and aromaticity. Consequently, the UV-induced changes in DOM properties for PS differ from those observed in polyolefins like PE and PP, which was further confirmed by PCA analysis (**Figure 9**).

Furthermore, the distribution of molecules with significant increasing trends ($\rho \geqslant 0.7$) varies across the three MPs-DOM types, with PS-DOM molecules (purple points) exhibiting lower H/C ratios compared to PP-DOM (green points) and PE-DOM (blue points) **(Figure 10a)**. Molecular composition analysis reveals that CHO compounds dominate among increasing PE-DOM, PP-DOM, and PS-DOM molecules, accounting for 98.0%, 55.4%, and 79.9%, respectively. The compound type categorization shows that increasing PE-DOM and increasing PP-DOM primarily consist of unsaturated aliphatic compounds (92.5% and 86.5%, respectively), whereas PS is predominantly composed of highly unsaturated and aromatic

compounds (90.8%), highlighting PS-DOM molecules' higher photodegradability, greater structural complexity, and stability (**Figure 10b**). The comparison between increasing MPs-DOM and overall MPs-DOM (**Figure 10c**) further underscores these trends: increasing PE-DOM and increasing PP-DOM molecules exhibit higher H/C_wa and lower NOSC_wa, DBE_wa, the relative intensity of CRAM, and AImod_wa (Mann-Whitney U-test, $p < 0.05$), indicating greater degradability compared to the overall PE-DOM and PP-DOM. This suggests that PP and PE leach relatively bio-labile molecules continuously during photoaging, which are more likely to enter short-term carbon cycling processes. In contrast, increasing PS-DOM shows elevated DBE_wa, the relative intensity of CRAM, and AImod_wa, which may persist longer in the environment and serve as a persistent contributor to the refractory dissolved organic matter (RDOM) pool, potentially influencing long-term carbon sequestration in aquatic ecosystems. These results emphasize the importance of considering plastic type when assessing the environmental fate of MPs-DOM, particularly the long-term ecological and biogeochemical implications of persistent compounds like those derived from PS-DOM.

3.3. Contribution of Microplastic Impact on Coastal Wetlands in Hong Kong

To assess the potential environmental presence of MPs-DOM in coastal wetland sediments, we projected 155 increasing molecules from PP-DOM, 152 from PE-DOM, and 465 from PS-DOM onto 102 natural sediment samples collected from four different coastal wetlands in Hong Kong (Mai Po, Tung Chung, Shui Hau, and Ting Kok). By calculating the number of detected MPs-DOM molecules of each type within the sediment molecular library (**Figure 11**) and their percentage relative to the total number of sediment molecules (**Figure 12**), we were able to comprehensively reflect their relative abundance in the samples and their contribution to the sediment DOM pool.

The research findings clearly reveal the unique distribution patterns and potential environmental significance of MPs-DOM in Hong Kong's coastal wetland sediments. In terms of spatial distribution, Mai Po wetland exhibits a significant enrichment of MPs-DOM. The number of detected molecules and their percentage contribution to total DOM for PS-DOM, PP-DOM, and PE-DOM are all notably higher than in other sampling sites, especially in the surface sediments. This suggests that Mai Po might be a "hotspot" for MPs-DOM, where its unique geographical location, hydrodynamic conditions, and proximity to human pollution sources could lead to a higher accumulation of microplastics and their leachates. In contrast, MPs-DOM detection numbers and percentages in other habitats like Tung Chung, Shui Hau,

and Ting Kok are generally lower, with more complex and varied patterns of change both among different plastic types and vertically. This likely reflects differences in microplastic input, depositional environments, and DOM biogeochemical processes across these distinct habitats.

Regarding vertical distribution, MPs-DOM in Mai Po shows a significant decrease with increasing depth. Both the number of detected molecules and their percentage contribution are primarily concentrated in the surface sediments. This phenomenon may indicate that MPs-DOM mainly accumulates in the surface layer of sediments, or that the anoxic conditions, different microbial communities, or dilution effects by natural DOM in deeper sediments lead to a reduction in their detected abundance. However, in other habitats like Tung Chung, Shui Hau, and Ting Kok, the vertical distribution patterns of MPs-DOM are more variable, sometimes showing peaks at deeper levels, which could be related to sediment burial processes, water transport, or specific biogeochemical conditions at those depths.

Further analysis of different plastic types of MPs-DOM reveals that PS-DOM generally has the highest number of detected molecules and percentage contribution, particularly in the surface layer of Mai Po. This might suggest that polystyrene microplastics are more prevalent in Hong Kong's coastal wetland environments, or that PS-DOM molecules are relatively more stable and less susceptible to degradation, making them easier to detect. Conversely, the detection numbers and percentages for PP-DOM and PE-DOM are generally lower than PS-DOM. While their distribution patterns across habitats show similarities to PS-DOM, their lower abundance could be related to the degradation characteristics, leaching kinetics, or actual environmental abundance of polypropylene and polyethylene microplastics.

Despite the detection of MPs-DOM at all sampling points, its contribution proportion to the total sediment DOM molecular pool is very small. As shown in Figure 11, the highest percentage contribution is typically below 0.1%; for instance, PS-DOM in Mai Po reached approximately over 0.1% at its peak, while PP-DOM and PE-DOM generally remained below 0.04%. This aligns with our expectation that "microplastic-derived DOM currently constitutes only a small fraction of the total DOM pool."

Although the current contribution is small, the clear detection of MPs-DOM carries significant potential implications. Firstly, it provides direct evidence that microplastic pollution leaves an

"anthropogenic fingerprint" within the natural DOM pool. This allows us to more precisely track the impact of microplastics on coastal wetland ecosystems and assess their dispersion and accumulation across different habitats and depths. Secondly, these non-naturally occurring DOM molecules, even in small quantities, could act as novel carbon sources or nutrients, potentially influencing local biogeochemical processes. This, in turn, could alter the composition and activity of microbial communities, affecting critical processes such as carbon and nitrogen cycling. For example, some microorganisms might utilize these molecules, while others might be inhibited. Finally, given the escalating trend of global microplastic pollution, the MPs-DOM distribution patterns and the small but detectable contribution revealed by this study provide crucial baseline data for future potential environmental risks. If microplastic pollution continues to intensify, the contribution of MPs-DOM to the overall DOM pool could significantly increase, potentially leading to more profound impacts on the function and health of coastal wetland ecosystems, and even triggering irreversible ecological changes. Therefore, continuous monitoring and in-depth research on MPs-DOM are essential to comprehensively evaluate its long-term ecological and environmental effects.

4. Project activities

To better document and promote our MEEF project, we have created a dedicated section on our laboratory website (https://hkustdinghe.github.io/meef/) that provides detailed information about the MEEF project and our work (**Figure 13**). Currently, our website receives around 150-200 visits per day. On our website, we showed the project objectives and technical approach of our MEEF project, alongside records and photos from our field sampling and laboratory analysis. This will help us exhibit relevant research information to the public and interested academic communities. Our research not only focuses on scientific research but also aims to inspire young people's interest in science and environmental conservation. To achieve this, undergraduate and MSC students are engaged in our project. They contribute to sediment sampling and in laboratory works (e.g., sample pretreatment, DOC, 3D-EEM, and FT-ICR MS measurements), gaining valuable hands-on experiences (**Figure 14**). In addition, to better promote our project results, we proactively shared our preliminary findings at various internal/internation academic conferences, including The 10th Bio-Organic Geochemistry Conference, The 6th National Symposium on Environmental Microplastic Pollution and Control, and Asia Oceania Geosciences Society (AOGS) 2025 Annual Meeting. (**Figure 15**). At the forum, the project participants, Dr. Yanjun Liu and Dr. Zhaoliang Chen gave an oral presentation on the project's progress and engaged in discussions with scholars, students, and

government officials involved in plastics pollution and coastal wetland research. In addition, the related experimental results were published in high-level journals (e.g., Chemical Geology, Environmental Science & Technology, and Water Research) (**Figure 16**). To further explain and disseminate our methods and findings related to the study of sediment DOM under MPs pollution, we have also created videos documenting our field sampling and laboratory analyses. These videos are now available on our website and receives significant view count (**Figure 17**). For more information about the project (e.g., introduction, photos and video), please find out on our lab website, https://hkustdinghe.github.io/meef/. In addition, a poster and a scientific lecture were conducted to introduce the outcome of the project to the public (**Figure 18**), and a WeChat (https://mp.weixin.qq.com/s/pL4zrFPwSLuS7qXtk2etSQ) and an Instagram accounts were established to promote and distribute the results of the Project (**Figure 19**).

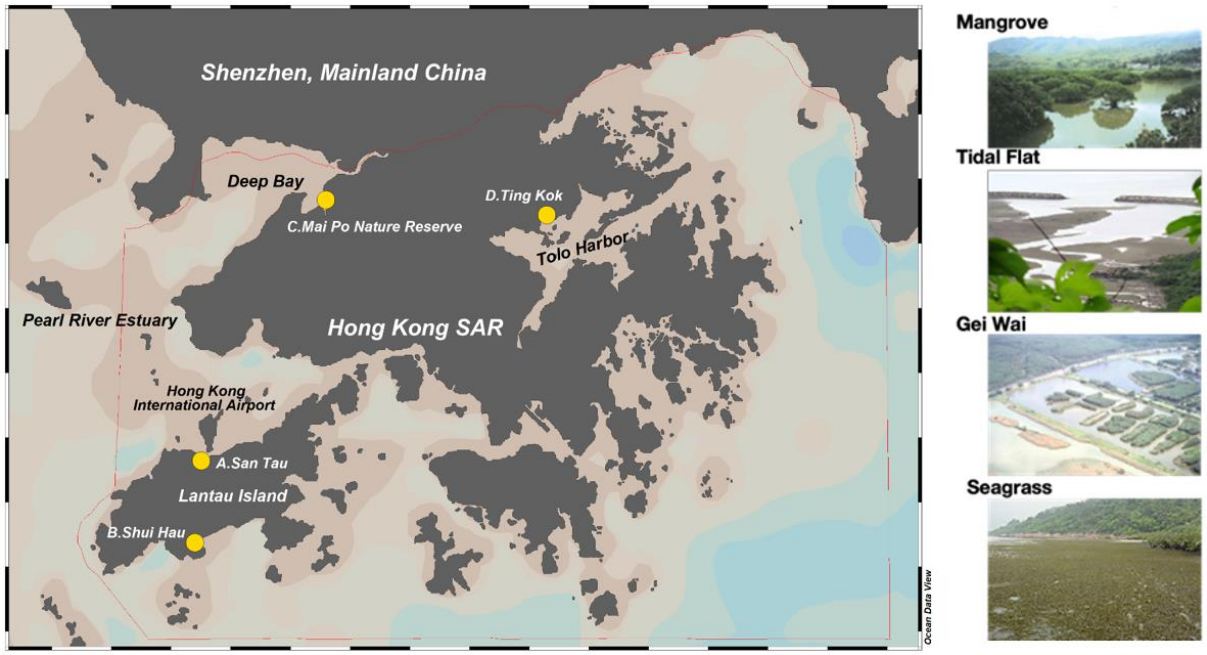

Figure 1. Sampling map for the project in Hong Kong. Yellow dots on the map indicated the locations of the study wetlands. The four pictures on the right are the 4 types of blue carbon ecosystems in Hong Kong.

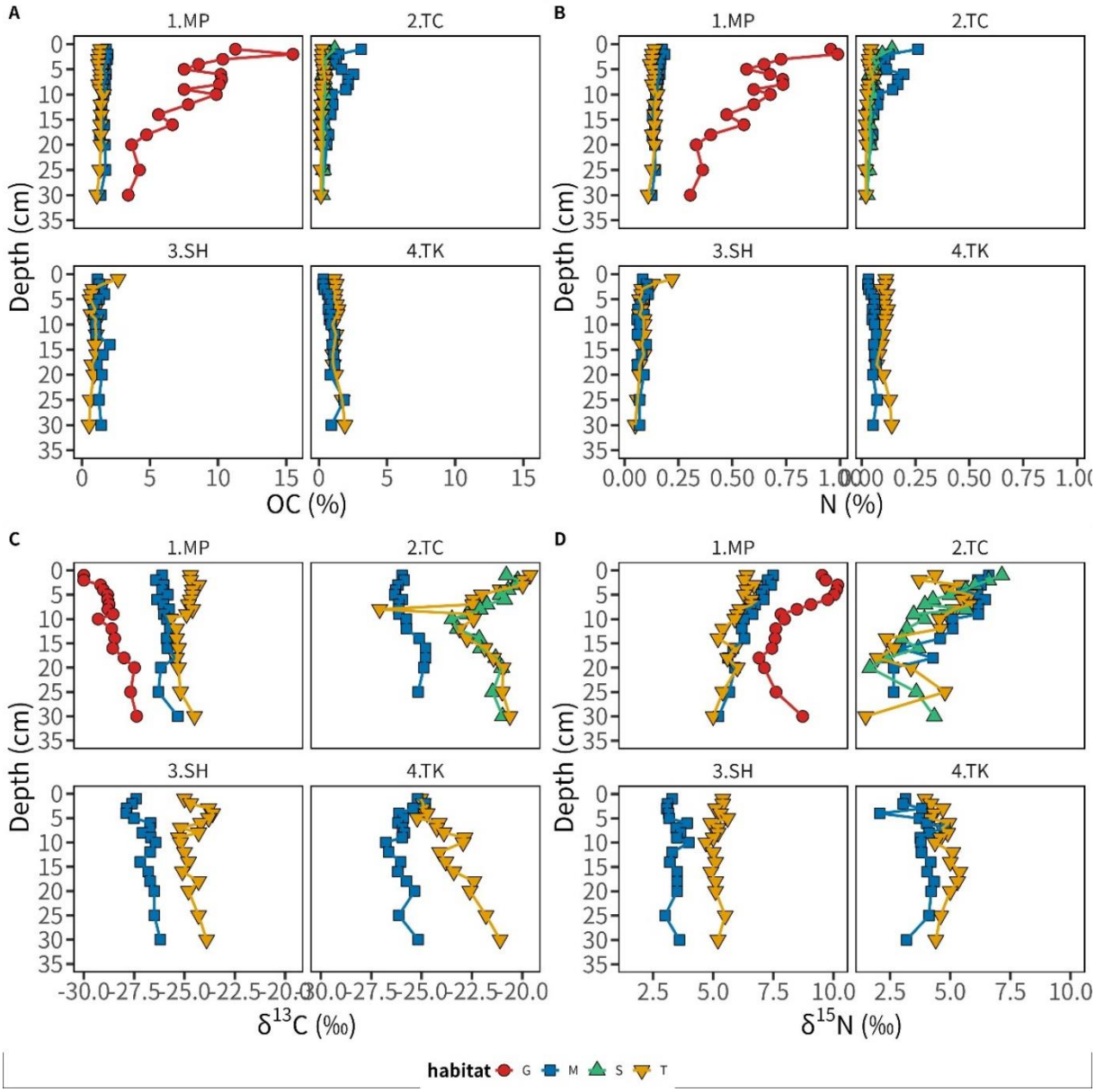

Figure 2. Vertical profiles and comparison of bulk characteristics including A) total organic carbon (OC); (B) total nitrogen (N); (C) $\delta^{13}C$ values; and (D) $\delta^{15}N$ values from gei wai (G, red), mangroves (M, blue), seagrass meadows (S, green) and tidal flats (T, yellow) in coastal wetlands.

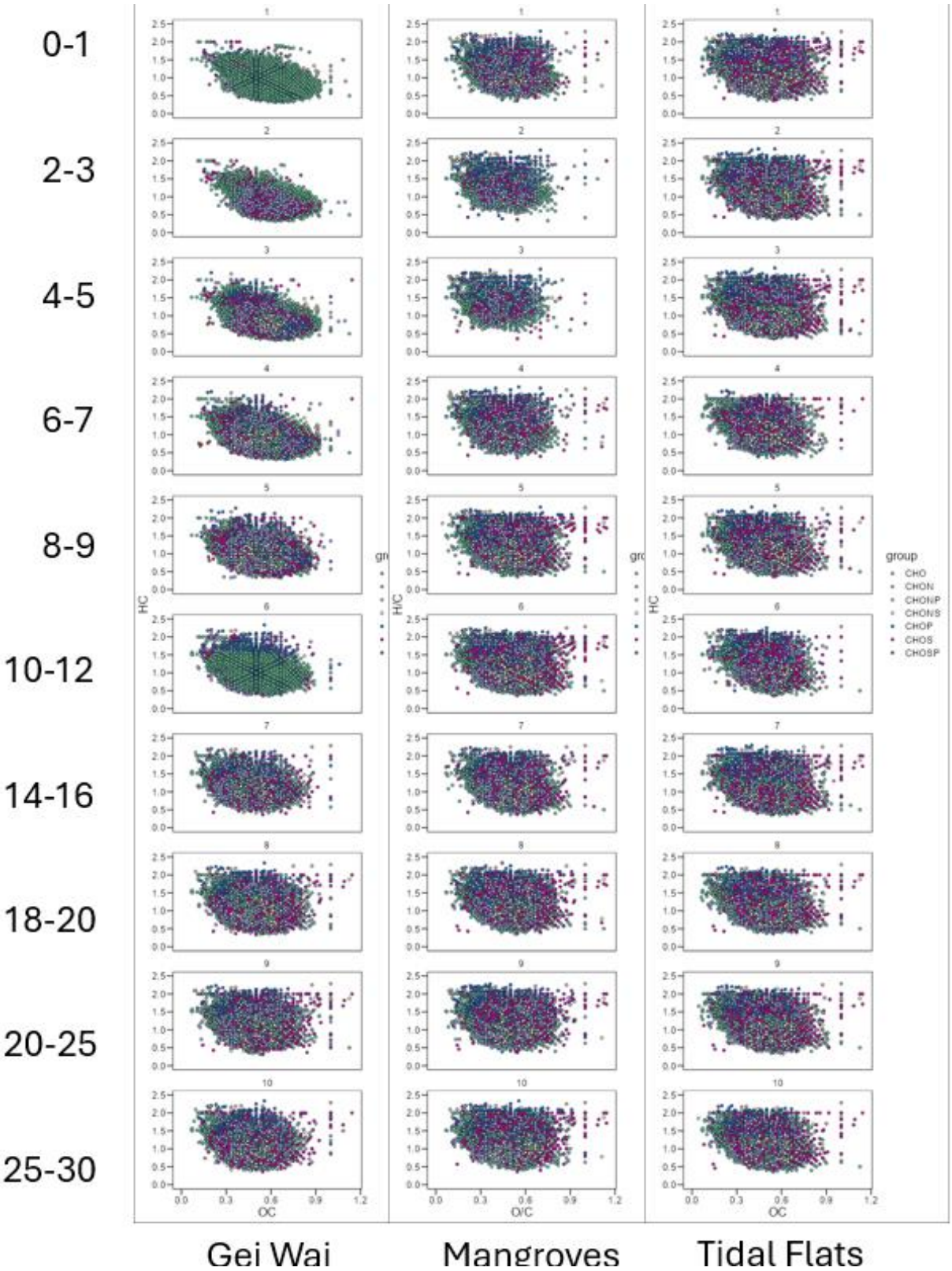

Figure 3. Using Mai Po as an example, we performed molecular characterization of sediment DOM from BCEs by FT-ICR MS. Each DOM molecule was plotted on a van Krevelen (V–K) diagram using its H/C and O/C ratios. This allows visualization of differences in molecular composition both vertically (with depth) and among habitats.

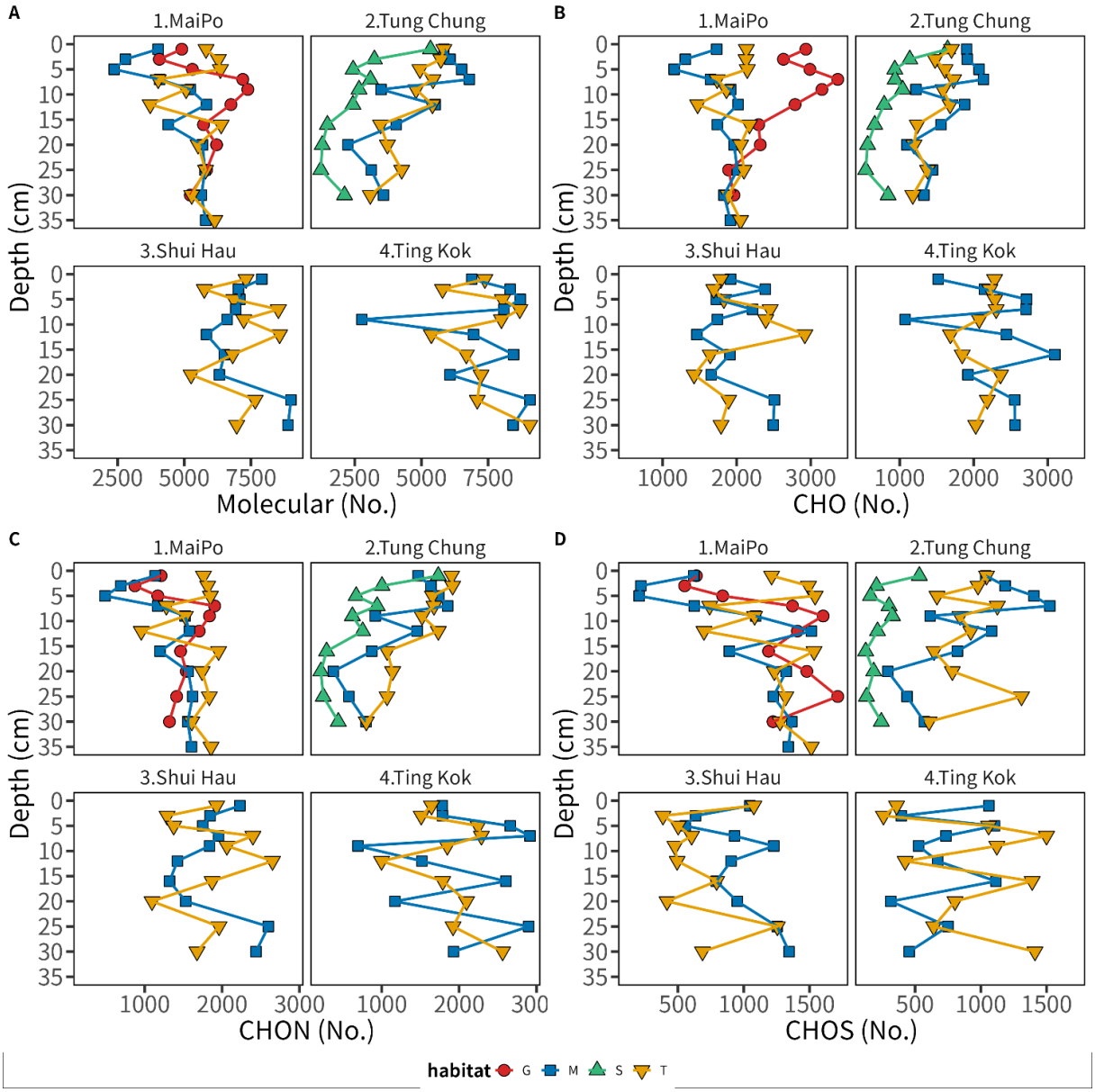

Figure 4. Variation in the total number of DOM molecular formulas and the counts of CHO, CHON, and CHOS classes with depth, and differences among habitats across different coastal wetlands.

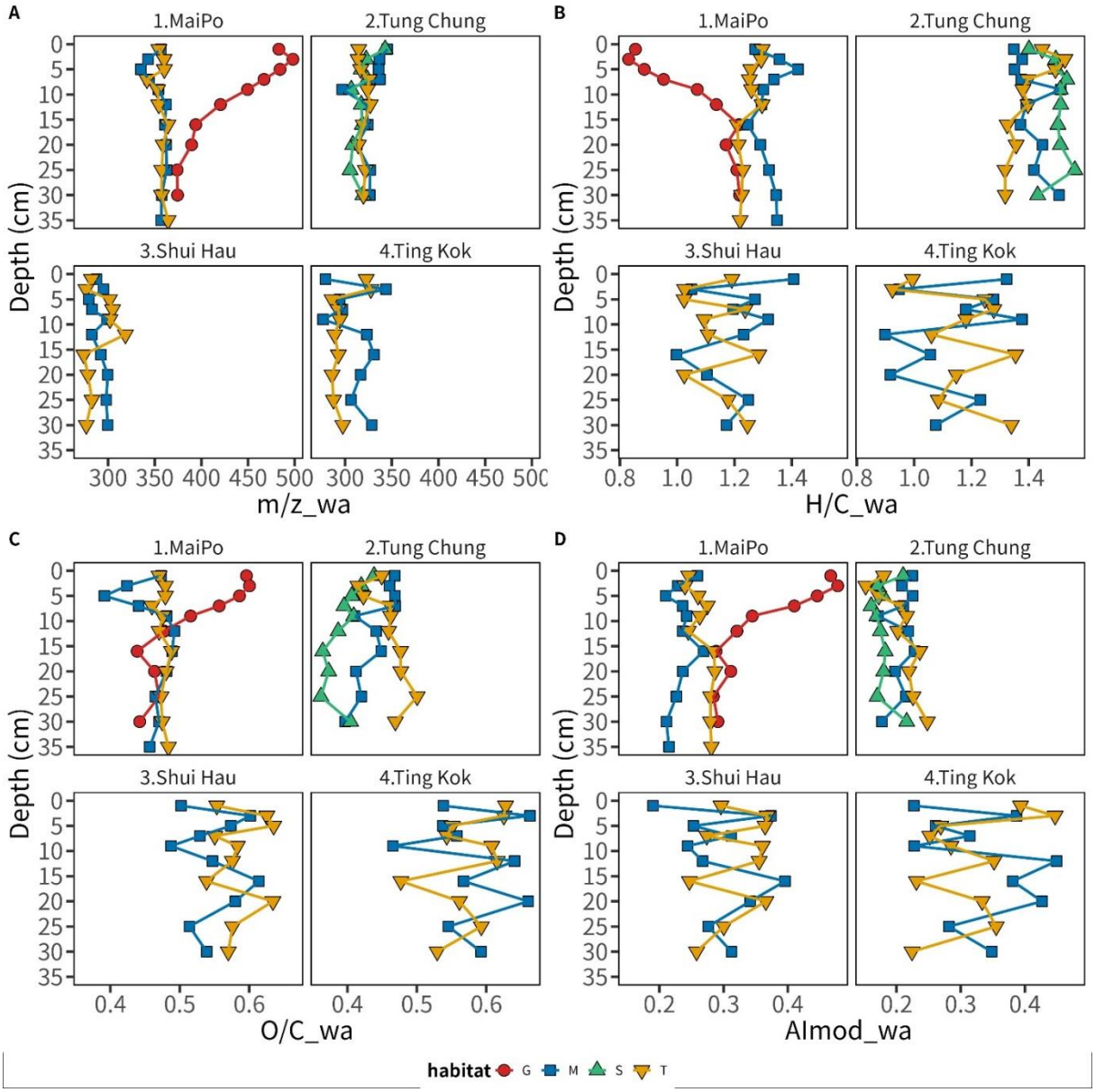

Figure 5. Vertical variations and habitat-specific differences in DOM molecular traits across coastal wetlands: weighted mean m/z (m/z_{wa}), weighted mean H/C (H/C_{wa}), weighted mean O/C (O/C_{wa}), and weighted mean modified aromaticity index (AI_{mod_wa}).

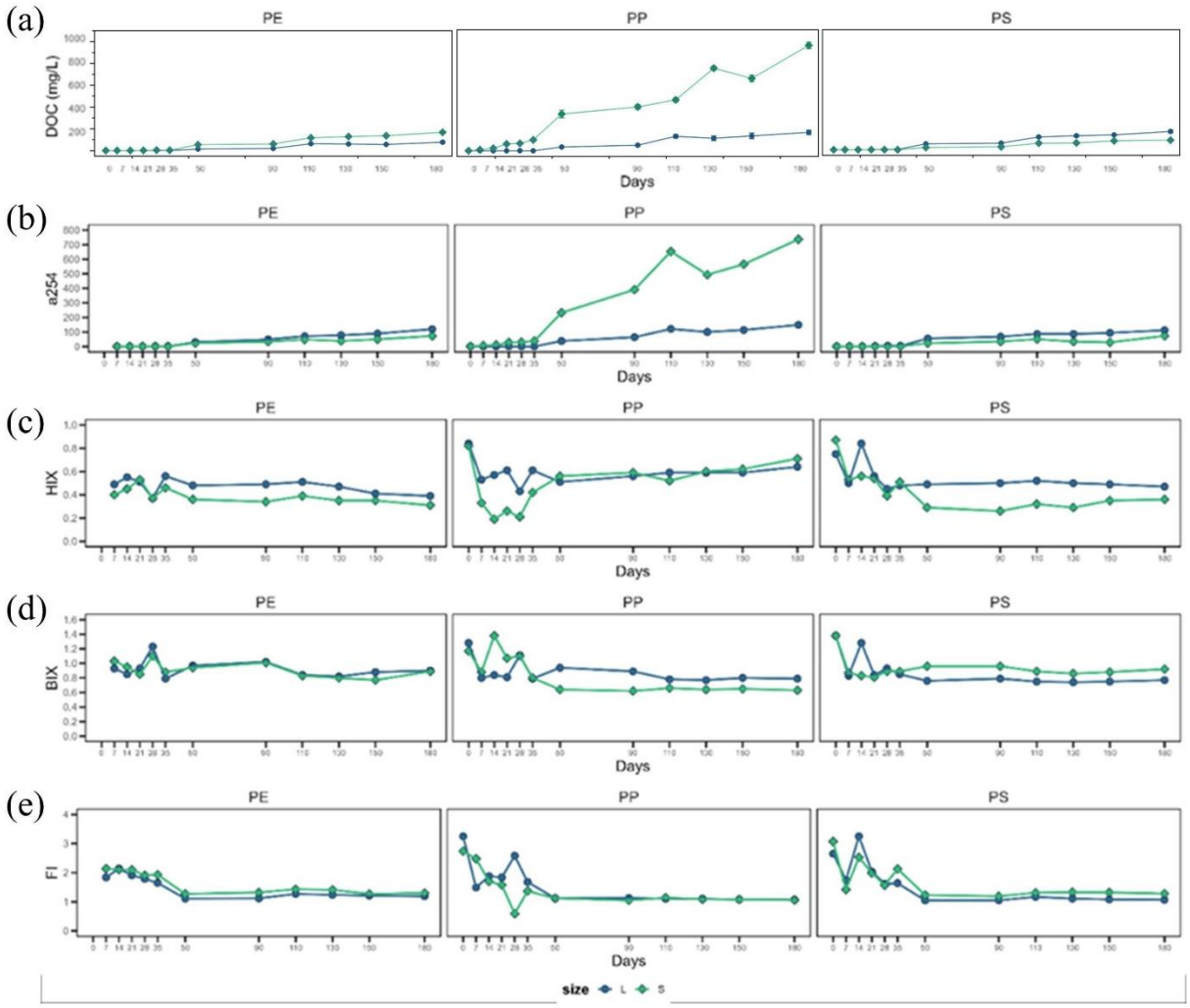

Figure 6. The variations of (a) DOC concentration, (b) absorbance at 254 nm (a254), (c) HIX, (d) BIX, and (e) FI over the cultivation period for three different types of microplastics (S) and microplastics (L).

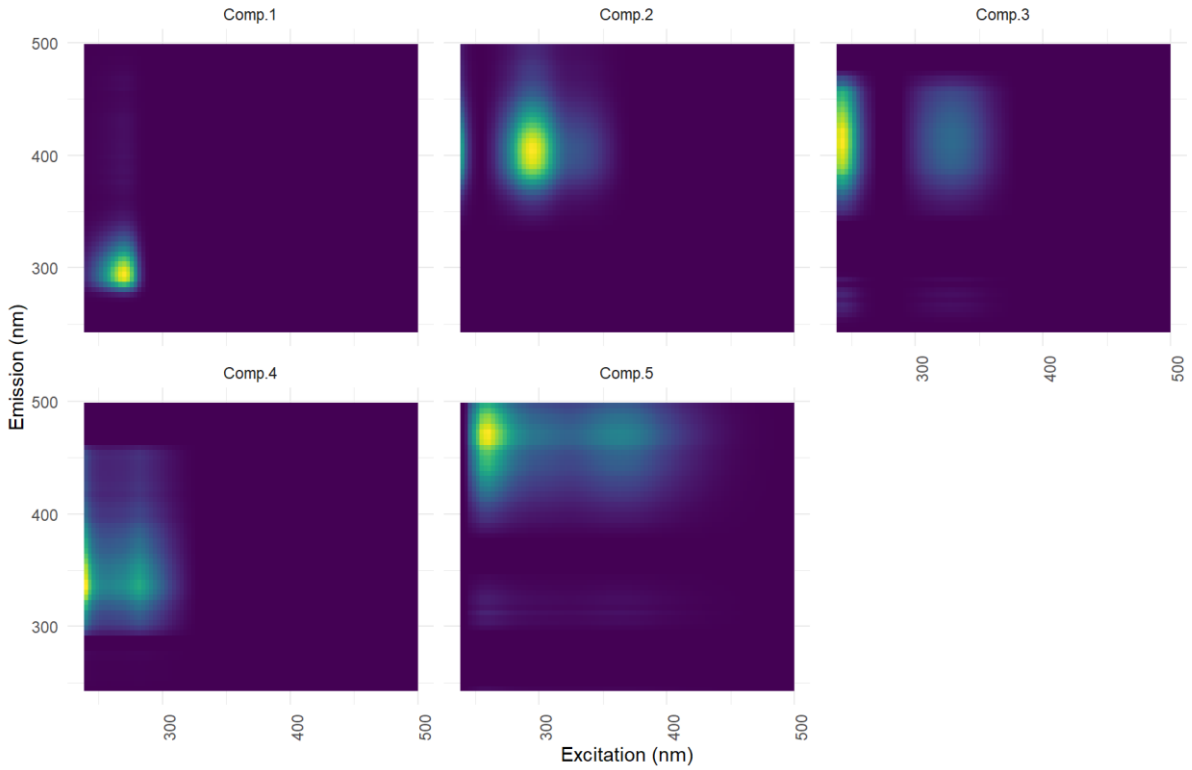

Figure 7. 3D-EEM spectra of five fluorescent components identified using the PARAFAC model. The five fluorescent components included protein-like substances (C1 and C4) and humic-like substances (C2, C3, and C5).

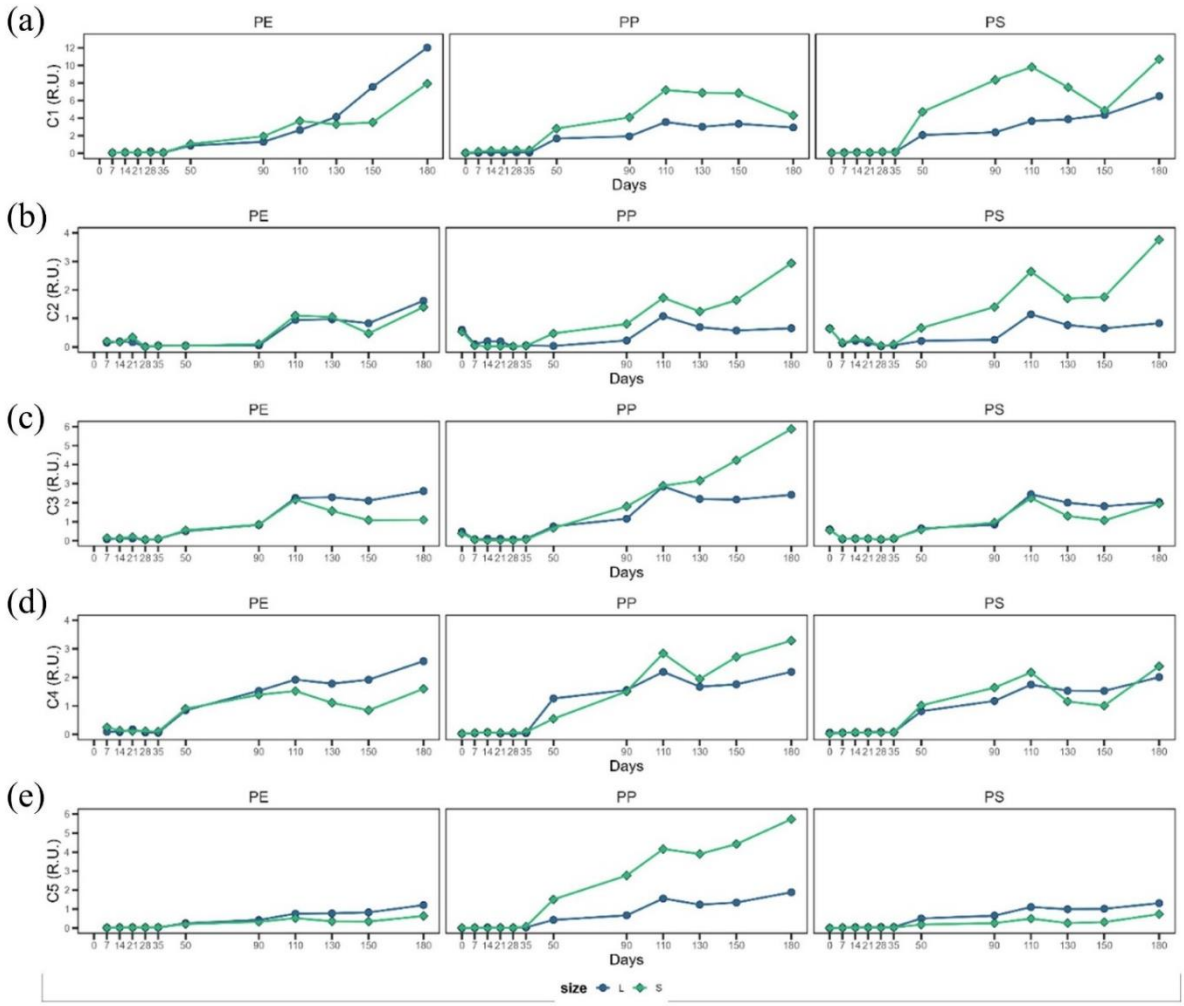

Figure 8. The variations of the intensity of components 1 to 5 (a-e) over the incubation period for three different types of microplastics (S) and macroplastics (L).

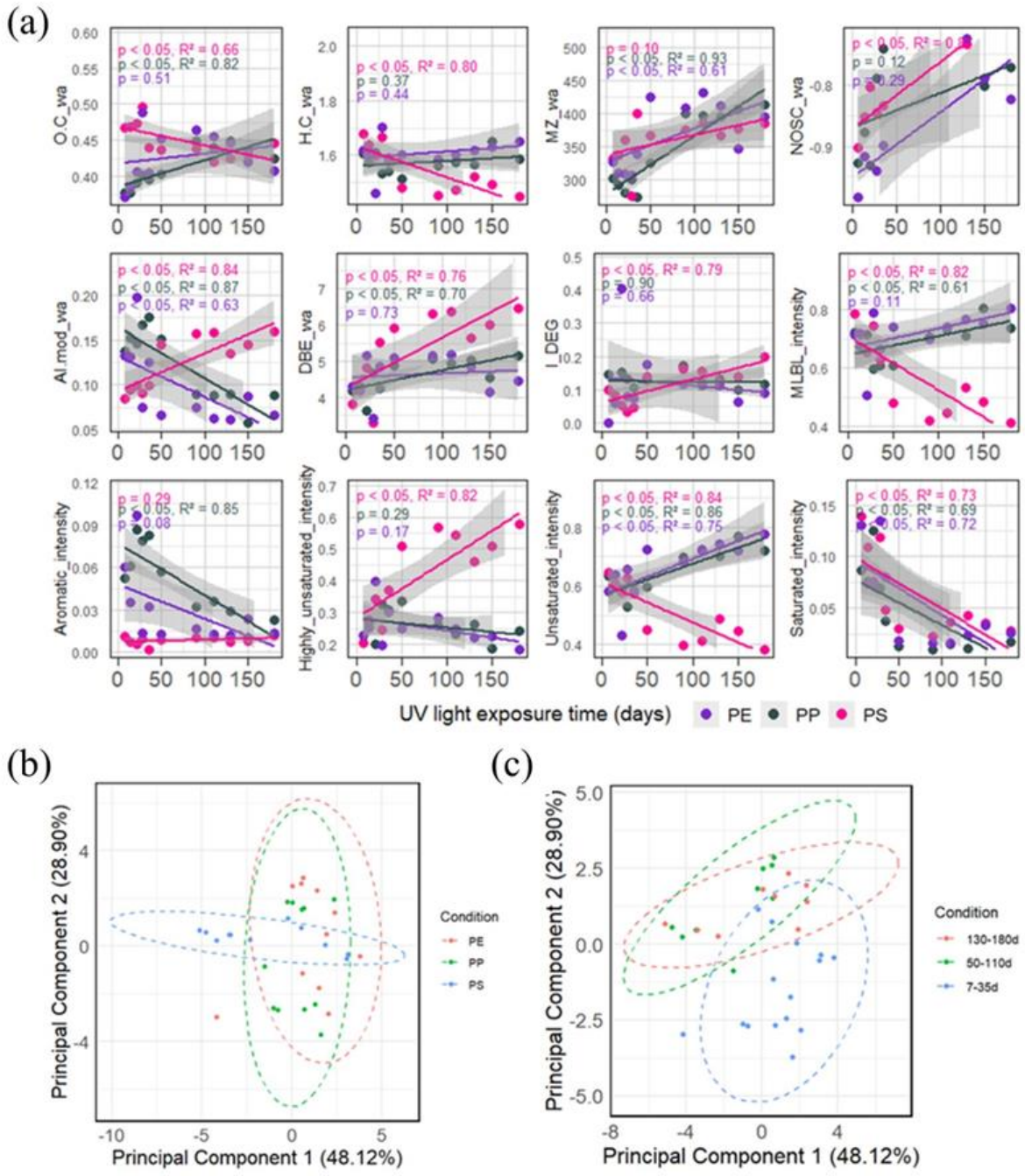

Figure 9. (a) Molecular characteristics of PE, PP, and PS-DOM. Principal component analysis (PCA) of molecular characteristics categorized by (b) microplastic type and (c) exposure duration.

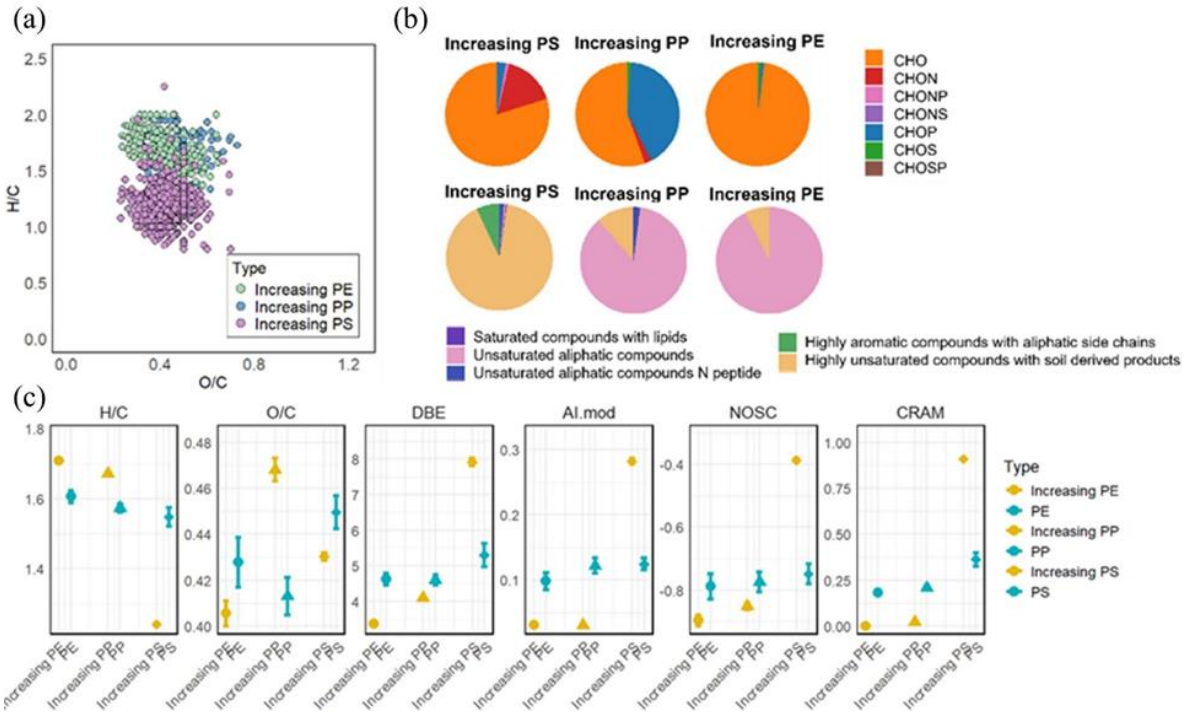

Figure 10. (a) Distribution of increasing MPs-DOM molecules on the VK diagram. (b) Proportion of various compound classes among the increasing MPs-DOM molecules. (c) Comparison of molecular properties between increasing MPs-DOM molecules and all MPs-DOM molecules.

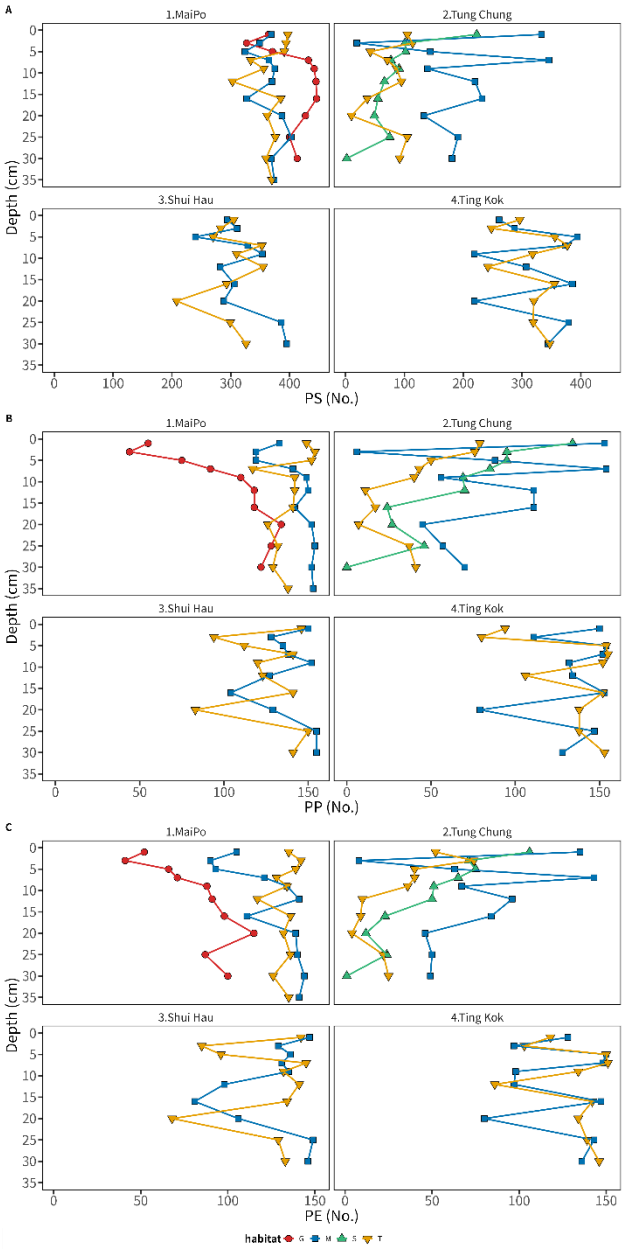

Figure 11. Microplastic-Derived Dissolved Organic Matter (MPs-DOM) and Their Detection Numbers in Coastal Sediments

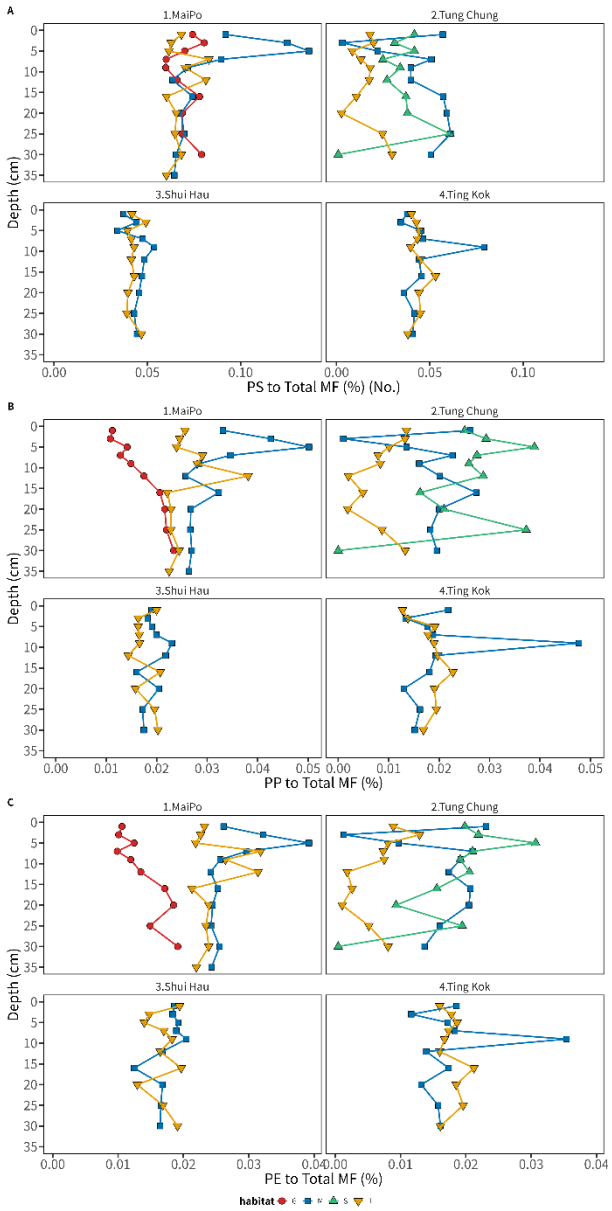

Figure 12. Percentage Contribution of Microplastic-Derived Dissolved Organic Matter (MPs-DOM) to the Total Dissolved Organic Matter Pool in Coastal Sediments.

HKUST DREAM Group

Department of Ocean Science, The Hong Kong University of Science and Technology

Hong Kong

Email

Google Scholar

ResearchGate

HKUST DREAM Group

Department of Ocean Science, The Hong Kong University of Science and Technology

Hong Kong

Email

Google Scholar

ResearchGate

HKUST DREAM Group

Department of Ocean Science, The Hong Kong University of Science and Technology

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Marine Ecology Enhancement Fund (MEEF)

Marine Ecology & Fisheries Enhancement Funds Trustee Limited
改善海洋生態及漁業提升基金信託有限公司

MEEF2024011

Project Title: Evaluating the ecological impacts of microplastic pollution on blue carbon ecosystems in Hong Kong using molecular fingerprints

Purpose of the Project

Sampling map for this proposed MEEF project Sampling sites are mainly located in four representative BCEs in Hong Kong: (A) San Tau, (B) Shui Hau, (C) Mai Po Nature Reserve, and (D) Ting Kok.

Field work and sample collection from typical BCEs in Hong Kong, including (a, b) tidal flats, (c, d) mangroves, and (e, f) seagrass meadows

Figure 13. A series of screen shots of the MEEF Project on our website.

Figure 14. Undergraduate students and Msc students were helping us work on the sediment sampling, 3D-EEM, and FT-ICR MS measurements.

Figure 15. Work presentation of project members in related academic conferences to promote the project results and draw public attention, including The 10th Bio-Organic Geochemistry Conference, The 6th National Symposium on Environmental Microplastic Pollution and Control, and Asia Oceania Geosciences Society (AOGS) 2025 Annual Meeting.

Figure 16. The related experimental results of this project were published in high-level journals.

Figure 17. A video documenting our field sampling and laboratory analyses.

Figure 18. A poster and a scientific lecture were conducted to introduce the outcome of the project to the public.

Figure 19. A WeChat and an Instagram account were established to promote and distribute the results of the Project.

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(v) Evaluation of the project's effectiveness in achieving the proposed objectives as well as the impact (benefits) of the Project.

This project effectively achieved its objectives by comprehensively investigating the bulk and molecular characteristics of sediments in Hong Kong's coastal wetlands, alongside the behavior and environmental presence of MPs-DOM. The study successfully revealed significant variations in OC and nitrogen N content, demonstrating that vegetated coastal wetlands exhibit substantially higher levels than unvegetated tidal flats due to plant detritus input and favorable microenvironmental conditions for organic matter accumulation and preservation. This finding contributes directly to understanding the fundamental characteristics and ecological functions of these critical ecosystems. A key objective achieved was the detailed molecular analysis of natural DOM. The project successfully elucidated distinct vertical and horizontal variations in DOM composition, showing that deeper sediments contain smaller, more aromatic, and oxidized DOM molecules, while mangrove habitats are characterized by larger, more aliphatic, and fresh DOM. These insights significantly advance our understanding of organic matter dynamics and transformation processes within coastal wetland sediments. The project also successfully met its objectives in characterizing the behavior of MPs-DOM. Experiments on microplastic leaching clearly demonstrated that DOC release varies significantly by plastic type and particle size, with PP microplastics showing the highest DOC production. Optical and molecular characterization of MPs-DOM effectively revealed that long-term UV exposure leads to the emergence of larger, more oxidized, and unsaturated molecules. A significant achievement was the identification PS-derived DOM's distinct molecular characteristics, including higher aromaticity and persistence, compared to PE and PP-derived DOM. This crucial finding highlights the critical role of plastic type in determining the environmental fate of MPs-DOM, providing a more nuanced understanding of microplastic pollution.

In terms of environmental impact, the project successfully applied these insights to natural sediment samples, confirming the widespread presence of MPs-DOM across all studied coastal wetlands. The identification of Mai Po as an MPs-DOM "hotspot," particularly in surface sediments, provides valuable geographical context and pinpoints areas of significant concern likely due to unique local conditions and proximity to human pollution sources. While the overall contribution of MPs-DOM to the total sediment DOM pool was found to be currently small (typically below 0.1%), its clear detection represents a profound benefit: it provides direct and undeniable evidence of an "anthropogenic fingerprint" within the natural DOM pool. This allows for more precise tracking of microplastic impact on coastal wetland ecosystems and assessment of their dispersion and accumulation. The broader benefits of this project are substantial. The findings underscore the potential for MPs-DOM, even in small quantities, to act as novel carbon sources or nutrients, potentially influencing local biogeochemical processes and microbial communities. This signals a crucial baseline for assessing future environmental risks as global microplastic pollution escalates, providing foundational data for long-term monitoring and risk assessment. Overall, the project's comprehensive approach and detailed molecular insights provide a robust framework for future research and directly inform strategic policy recommendations for the sustainable management and safeguarding of Hong Kong's invaluable coastal wetlands, ensuring their continued provision of essential ecosystem services in the face of emerging environmental challenges.

(vi) Summary and Way Forward

This study comprehensively investigated the bulk and molecular characteristics of sediments in Hong Kong's coastal wetlands, alongside the behavior and environmental presence of MPs-DOM. We found that vegetated coastal wetlands exhibit significantly higher OC and N content compared to unvegetated tidal flats, driven by plant detritus input and microenvironmental conditions that favor organic matter accumulation and preservation. Molecular analysis of natural DOM revealed distinct vertical and horizontal variations: deeper sediments contained smaller, more aromatic, and oxidized DOM molecules, while mangrove habitats were characterized by larger, more aliphatic, and fresh DOM, reflecting their high biological productivity. Furthermore, the study highlighted the capacity of vegetated areas, with their complex root networks and low-flow conditions, to enhance microplastic retention and burial. Our experiments on microplastic leaching demonstrated that DOC release varies significantly by plastic type and particle size, with PP microplastics showing the highest DOC production. Optical and molecular characterization of MPs-DOM revealed that long-term UV exposure leads to the emergence of larger, more oxidized, and unsaturated molecules. Crucially, PS-derived DOM exhibited distinct molecular characteristics, including higher aromaticity and persistence, compared to PE and PP-derived DOM, highlighting the critical role of plastic type in determining the environmental fate of MPs-DOM. Applying these insights to natural sediment samples, we detected MPs-DOM across all studied coastal wetlands, with Mai Po identified as a "hotspot" for MPs-DOM accumulation, particularly in surface sediments, likely due to its unique geographical location, hydrodynamic conditions, and proximity to human pollution sources. While the overall contribution of MPs-DOM to the total sediment DOM pool is currently very small (typically below 0.1%), its clear detection provides direct evidence of an "anthropogenic fingerprint" in the natural DOM pool. These findings underscore the potential for MPs-DOM to act as novel carbon sources or nutrients, influencing local biogeochemical processes and microbial communities, and signal a crucial baseline for

assessing future environmental risks as global microplastic pollution escalates. The insights gleaned from this study provide a robust foundation for future research and inform strategic policy recommendations for the sustainable management of Hong Kong's coastal wetlands.

Future Research Directions: A critical next step involves establishing a long-term monitoring program specifically designed to track the temporal dynamics and spatial distribution of MPs-DOM in coastal wetlands, with a focus on understanding the long-term ecological and biogeochemical implications of persistent MPs-DOM molecules, particularly those derived from polystyrene. Further research should also delve into the specific interactions between MPs-DOM and microbial communities, investigating how these novel carbon sources influence microbial activity, community structure, and key biogeochemical cycles (e.g., carbon and nitrogen cycling). Additionally, controlled experiments are needed to quantify the precise rates of MPs-DOM degradation and transformation under varying environmental conditions (e.g., anoxia, different temperatures, microbial consortia) to better predict their environmental persistence.

Policy and Management Recommendations: Based on these findings, we recommend a multi-faceted approach to mitigate the impact of microplastic pollution on coastal wetlands: **Enhanced Monitoring**: Integrate MPs-DOM analysis into existing environmental monitoring programs for coastal wetlands to provide early warning of increasing microplastic pollution and its associated chemical releases. **Source Reduction and Regulation**: Implement stricter regulations on the production, use, and disposal of plastics, particularly those identified as significant sources of persistent MPs-DOM (e.g., polystyrene), to reduce microplastic input into the environment. This necessitates stricter regulations on urban wastewater discharges and minimizing industrial and agricultural runoff. **Targeted Remediation Strategies**: Develop and implement targeted remediation strategies that consider the capacity of vegetated wetlands to

trap and retain microplastics and their leachates. This could include optimizing wetland design and management practices to enhance their natural filtering capabilities. **Public Awareness and Education**: Launch comprehensive public awareness campaigns to educate citizens about the environmental impacts of microplastics and the importance of responsible plastic consumption and waste management, fostering a collective effort towards pollution reduction. **Inter-agency Collaboration**: Foster stronger collaboration among government agencies, research institutions, and local communities to develop integrated management plans that address both natural organic matter dynamics and emerging pollutants like MPs-DOM in coastal ecosystems. Implementing an ecological compensation mechanism can also reward contributions to wetland protection, fostering sustainable practices.

By proactively addressing the challenges posed by MPs-DOM, Hong Kong can safeguard the health and ecological functions of its invaluable coastal wetlands, ensuring their continued provision of essential ecosystem services.

(vii) Audited statement of account

Audited statement of account is not disclosed due to confidentiality reasons.

(viii) A list of all project assets (as defined in Section 5.14) with photos (see Appendix 4) enclosed as an appendix to the completion report

NA. There are no project assets.

(ix) Staff attendance record in accordance with the attendance monitoring plan (see Section 5.17)

Staff attendance record is not disclosed due to confidentiality reasons.

(x) If applicable, recruitment record for all project staff employed under the project enclosed as an appendix to the completion report in accordance with the recruitment plan (see Section 5.17).

Recruitment record is not disclosed due to confidentiality reasons.