Occurrence, Composition, and Relationships in Marine Plastic Debris on the First Long Beach Adjacent to the Land-Based Source, South China Sea

Peng Zhang®, Shan-Shan Wei, Ji-Biao Zhang *, Zhou Ou, Yu-Qin Yang and Ming-Yue Wang

College of Chemistry and Environmental Science, Guangdong Ocean University, Zhanjiang 524088, China; zhangpeng@gdou.edu.cn (P.Z.); weishanshan1@stu.gdou.edu.cn (S.-S.W.); ouzhou1@stu.gdou.edu.cn (Z.O.); woo@stu.gdou.edu.cn (Y.-Q.Y.); wangmingyue1@stu.gdou.edu.cn (M.-Y.W.)

* Correspondence: zhangjb@gdou.edu.cn; Tel.: +86-0759-2383300

Received: 27 July 2020; Accepted: 17 August 2020; Published: 28 August 2020

Abstract: Land-based sources are the key sources of plastic debris, and mismanaged plastic debris can eventually enter the ocean via marine beaches. In this study, the spatial distribution and amount of plastic debris in the land-based source input zone of First Long Beach (FLB), China, which is a major tourist attraction, were first investigated. By using field investigation, sand samples were collected from two sections on FLB adjacent to land-based sources in December 2019, and the plastic debris in the sand samples was quantified and characterized in the laboratory. The amount of plastic debris ranged from 2 to 82 particles/m² on this marine sand beach. There was a significant difference in plastic debris amount between the transects along the land-based source input zone (p < 0.05) due to the impacts of wind, ocean currents, and waves. The most abundant size of plastics was 0.5–2.5 cm (44.4%). Moreover, the most common color was white (60.9%). The most abundant shape of plastic debris fell into the fragment category (76.2%). The plastic debris amounts were significantly correlated with multiple sizes. Our results show that land-based wastewater discharge is a large plastic debris source on FLB under coastal water tide variation. Reduction strategies should be carried out by tracing the various land-based sources of plastic debris.

Keywords: spatial distribution; plastic debris; marine beach; land-based source input; reduction strategies

1. Introduction

With the development of society and the economy, the rapidly increasing demand and production of plastic debris has become a global environmental issue [1–5]. Global plastic production has increased exponentially over the last decades and is expected to further increase [4–7]. Recently, the worldwide production of plastic reached 300 million tons [8]. Land-based sources are the key sources of plastic debris, and mismanaged plastic debris can eventually enter the ocean via inland waterways, wastewater outflows, and transport by wind, wave and tides [3,7,9–13]. When plastic debris enters marine environments, it can influence water quality and become a threat to marine biology [14–16]. Therefore, marine plastic debris has become an emerging issue for food security, food safety, and human health [17–20]. Plastic debris and its fragments have several negative impacts on the environment. Recently, the European MSFD technical subgroup on Marine Litter [21] proposed a unified, size-based nomenclature of macro- (>2.5 cm), meso- (0.5–2.5 cm), and microplastic (1 µm–5 mm). Macro-sized plastic debris can be fragmented to meso-sized debris and then further break down into micro- and nano-sized plastic debris [22–24]. Because plastic debris is resistant to decomposition in coastal water, it can have serious impacts on the marine environment [1,8,19,25].

Beaches, as the transportation zones between land and ocean, are subjected to plastic debris pollution. There is an increasing number of studies investigating plastic debris on beaches because of
the pollution level of plastic debris in beach sand [18,26–32]. Accumulation of plastic debris on beaches is widespread [33–39]. Beach exposure, width, and slope have been found to be key parameters in sandy beach ecology. In addition, the spatial distribution of plastic debris on beaches can be affected by many factors, such as wind, ocean currents, river input, coastal landscape, population level, and sand properties [18,40,41]. The surface sediment of marine beaches is regularly mixed by natural events or anthropogenic activities, leading to organic matter content and sand grain size variations [27]. The transport of particles, whether sand or plastic, is a function of their size, color, shape, and density, and they can interact in the transport process [27]. For instance, plastic aggregation with organic matter might play an important role in microplastic transport and fate [42,43]. However, the horizontal transport paths of plastic debris in aquatic and terrestrial environments are still poorly understood [44]. The evidence currently suggests that the vast majority of plastic debris pollution on marine beaches originates from land-based sources, specifically wastewater discharge. Although the land-based plastic debris source input is the most important source of beach plastic debris pollution, the transportation of plastic debris from land to beach along the land-based source wastewater discharge outlet has scarcely been studied. In addition, the characteristics of plastic debris in land-based source can provide useful information in tracking the source and biological effects. For example, one of the factors often considered to influence the consumption of marine debris is color, as specific colors might attract predators when resembling the color of their prey [45]. On the one hand, plastic shape can partly provide information on their origin. Fragments are thought to originate mainly from hard plastics via fragmentation [46]. On the other hand, there is a tendency toward increasing toxicity with decreases in particle size [47].

The transportation of plastic debris from land to sand beach and then into coastal waters is a key process by which plastic debris enters coastal waters. Identifying and eliminating the sources of plastic debris to beaches are crucial to reducing the social, environmental, and economic impacts of this form of pollution. With the development of society and the economy, the sand beaches around the South China Sea are used frequently for multiple recreational purposes [39]. First Long Beach (FLB) is one of the most popular recreational destinations. It is located in the east of Donghai Island, Zhanjiang City, Guangdong Province, and faces the South China Sea with a north–south trend (Figure 1). The beach is 28 km long, and its width fluctuates within about 100–300 m with the tide level. Additionally, the coastline along the Donghai Island is densely populated and human activities are increasing intensively, especially the marine aquaculture wastewater discharge into the coastal water [48,49]. At sightseeing spots, beach cleaning is performed regularly, but the land-based source waste is rarely cleaned, leading to plastic debris accumulation about 100 m from the shore. In addition, the transport pathway is complex. On the one hand, according to the characteristics of tidal changes, plastic debris may migrate to the lower transects under the action of tides and coastal currents during high tide or spring tide. On the other hand, under the action of a northeast monsoon during low tide, plastic debris on the surface will also migrate to the lower transects. However, the spatial distribution and amount of plastic debris in the land-based source input zone of FLB have not yet been reported.

Therefore, we collected plastic debris samples and classified multiple sizes of discharge along the land-based source wastewater discharge outlet on FLB, China (Figure 1), to explore the impacts of land-based wastewater discharge on the spatial distribution, amount, and relationships of multiple types of plastic debris on FLB in this study. Field investigations were conducted during December 2019. The objectives of this research were (1) to investigate the spatial distribution of plastics debris, (2) to determine the characteristics of plastic debris along the land-based source wastewater discharge outlets on the two FLB transects, (3) to analyze the associations among plastic debris amount, sand grain size fraction, and organic matter (OM), and (4) to determine whether a reasonable correlation exists between microplastic debris and more easily investigated larger plastic debris along the land-based source wastewater discharge outlets on FLB. This study provides the first baseline information of plastic debris and recommends reduction strategies for FLB cleanup implementation adjacent to the land-based sources in the South China Sea.
Based source wastewater discharge outlets on FLB. This study provides the first baseline information of plastic debris and recommends reduction strategies for FLB cleanup implementation adjacent to the land-based sources in the South China Sea.

Figure 1. Geographical location of the First Long Beach (FLB) and marine sandy beach sampling stations along the land-based wastewater outlet.

2. Materials and Methods

2.1. Study Area and Sampling Stations

As the developing area of Zhanjiang, the Donghai Island has a population of 202,000 inhabitants and covers an area of 401 km$^2$ (Figure 1). The FLB, located in the east of the island, is a microtidal, wave-dominated beach. There are more than 100 million tourists visiting FLB for its scenery every year. However, with the socio-economic development of Zhanjiang, there are many aquacultural breeding bases of abalone, prawn, and shellfish. The many marine aquaculture areas expanding in Donghai Island have caused the land-based wastewater to discharge onto the FLB in recent years (Figure 2). The nearest wastewater outlet is about 1 km away from the scenic area. Land-based wastewater stream input mainly originates from the adjacent aquaculture and household source discharge. The mass of water transported has changed along with changes in human activities. In addition, owing to an absence of wastewater treatment capacity, the domestic wastewater is directly discharged randomly into the coastal water. The debris can be seen everywhere in the adjacent zones of wastewater on the beach. We examined the two transects, during periods of low tide, along the land-based wastewater discharge outlets, on 26th December, 2019 (Figure 2). The 10 sampling stations were placed in the two transects, which are nearest to the land-based source wastewater pathway and cover the tidal space zones. Therefore, the wastewater transport pathway and marine beach characteristics of tidal influence were considered in these locations. Information acquired from these sampling stations is shown in Table 1.
We then moved the sampling frame towards the dry beach sand until the line of vegetation coverage was reached. To keep the sampled area constant, a frame made of PVC tubes was used. The sand was collected from the surface within the square by using a metal scoop during low tide for nearly 2 h. We tried to keep the sampling depth as constant as possible at 1 cm. The sand was then sieved through a 1 mm metallic sieve and collected in aluminum foil bags. Between samplings, the instruments were rinsed with seawater.

Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

In field sampling, we took a square sampling area of 1.0 × 1.0 m at each station. Samples from 10 stations were collected for plastic analysis along the land-based wastewater discharge outlets. Previous studies have operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms [3,51]. The targeted microplastic size range was confined to 1–5 mm in this study [51]. We classified three size classes: “microplastics” (1–5 mm) (hereafter, “microplastics” refers to large microplastics), “mesoplastics” (5–25 mm), and “macroplastics” (>2.5 cm). To explore the multiple plastic debris size relationships, the “macroplastics” (>2.5 cm) were further classified by (2.5–5 cm), (5–10 cm), and (>10 cm), respectively.

Beach sampling procedures were modified from a standardized method, details of which have been published previously [50]. Field data collection was carried out on the two transects along the sewage outfall, with 5 stations each—A1, A2, A3, A4 and A5 on one side of the stream and B1, B2, B3, B4, and B5 on the other side of the wastewater stream, respectively (Figure 1). Based on the tidal change, the low-tide line located in the key area of FLB studied was determined to perform the sampling. The high tide lines A3 and B3 were identified by assessing the end of the wet sand marks. We then moved the sampling frame towards the dry beach sand until the line of vegetation coverage reached A1 and B1. In the middle areas, A2 and B2 were selected. We then moved the frame towards the coastal water line until the seawater line, A5, and B5 were acquired, respectively. The middle of the low tide and high tide line was the intertidal zone, which is represented by A4 and B4 along the land-based wastewater discharge outlets.

Table 1. Sampling stations information of the marine sandy beach in the field investigation.

| Stations | Latitude  | Longitude  | Marine Beach Zones |
|----------|-----------|------------|--------------------|
| A1       | 21°26.20′ | 110°32.21′ | Dry beach zone     |
| A2       | 21°25.52′ | 110°32.29′ | High tide zone     |
| A3       | 21°24.83′ | 110°32.67′ | Middle tide zone   |
| A4       | 21°23.89′ | 110°32.16′ | Intertidal zone    |
| A5       | 21°23.82′ | 110°32.38′ | Low tide zone      |
| B1       | 21°25.57′ | 110°32.64′ | Dry beach zone     |
| B2       | 21°25.11′ | 110°32.71′ | High tide zone     |
| B3       | 21°24.21′ | 110°32.74′ | Middle tide zone   |
| B4       | 21°23.42′ | 110°32.81′ | Intertidal zone    |
| B5       | 21°22.92′ | 110°32.05′ | Low tide zone      |
at 1 cm. The sand was then sieved through a 1 mm metallic sieve and collected in aluminum foil bags. Between samplings, the instruments were rinsed with seawater. Sand samples were transported back to our laboratory, dried at 60 °C over 24 h, and then stored in sealed glass bottles at room temperature until extraction [53,54]. Sieving, density separation and identification techniques are in accordance with the described protocols of analysis. [54,55]. In addition, the grain size of sand sediment analysis was performed according to the Specifications for Oceanographic Survey-Part 8: Marine Geology and Geophysics Survey (GB12763.8-2007) [56]. The OM content of the marine sand sediment was determined by the change in mass (loss on ignition) following incineration in a muffle furnace at 550 °C for 2 h.

2.3. Statistical Analysis

ArcGIS was used to map the monitoring stations and land-based source input location. The size distributions of the amount of the plastic debris were performed using Microsoft Excel 2010 and drawn using Origin Lab 9.0. The spatial differences in plastic debris amount were analyzed with a nonparametric Kruskal–Wallis test followed by a pairwise Mann–Whitney U test. Correlation between variables was determined by Spearman correlation between the environmental factors (sand grain size fraction and OM), and the amount of plastic debris size (1–5 mm, 5–25 mm, 2.5–5 cm, 5–10 cm, or >10 m) was determined using SPSS 22.0. Statistical analyses were carried out at a significance level of p < 0.05 for each correlation analysis.

3. Results

3.1. Spatial Distribution of Plastic Debris along the Land-Based Source Wastewater Discharge Outlet on FLB

There was a significant difference in the amount of plastic debris between Transects A and B along the land-based source input zone (p < 0.05) (Figure 3). The amount of plastic at the sampling points on the beach ranged from 2 to 82 particles/m^2, with 340 particles in all samples. The highest amount in Transect B was at B4, reaching 82 particles/m^2, accounting for 24.1% of all plastic particles; the lowest was at B5, with only 18 particles/m^2, accounting for 5.3% of all plastic particles. There were 76, 76, and 43 particles/m^2 at B1, B2, and B3, respectively. The highest amount in Transect A was at A1, with 32 particles/m^2, accounting for 9.4% of all plastic particles; the lowest was at A3, A4, and A5, with only 2 particles/m^2, accounting for 0.6% of all plastic particles. In addition, A2 had 7 particles/m^2. The average amount of plastic debris in both transects along the land-based source wastewater discharge outlet was 34 particles/m^2.

![Figure 3. Spatial distribution of plastic debris along the land-based source wastewater discharge outlet.](image-url)
3.2. Amount of Different Plastic Debris Size Classes along the Land-Based Source Wastewater Discharge Outlet on the FLB Two Sides

The amount and composition of plastic debris size along the land-based source wastewater discharge outlet in the two transects revealed marked differences (Figure 4). From the analysis of the investigation results, the amount in Transect B was significantly higher than that in Transect A (Figure 4), and the plastic debris in Transect B had more size classes than that in Transect A along the land-based source wastewater discharge outlet. In addition, only 5 cm or less of plastic debris existed in Transect A. In terms of plastic debris size classes, the amount of plastic debris was the highest, between 0.5 and 2.5 cm (Figure 4), accounting for 44.4% of all plastic debris in the sampling stations. There were 24 and 6.2 particles/m² of plastic debris in the two transects, accounting for 40.68% and 68.89%, respectively. Moreover, the microplastic debris accounted for 26.67% and 20% in Transects A and B, respectively. The amount of plastic debris that was >10 cm was the lowest in Transect B, and no plastic debris of size >5 cm was found in Transect A.

Figure 4. Amount of plastic debris size along the land-based source wastewater in the two transects.
3.3. Amount and Composition of Plastic Debris Color along the Land-Based Source Waste Water Discharge Outlets in the Two Transects

Most of the plastic encountered in the present study along the land-based source wastewater discharge outlets in the two transects was white (Figure 5). The plastic samples obtained in the sampling area contained the largest number of white plastic materials, accounting for 60.9%, and the amount was 37.2 and 4.2 particles/m² in Transects B and A, respectively (Figure 5). In total, there were 21 and 186 particles in Transects A and B, respectively. The brown color was the minimum, with only 1 plastic particle, which was found in Transect B. The amount of plastic of any given color was generally higher in Transect B than in Transect A; for example, plastics with red and green, with multiple colors, and without color (transparent) were all at least 10 times more abundant. White plastics were 8.8 times more abundant in Transect B compared with Transect A. However, pink plastics in Transect A were twice as abundant compared with Transect B. Furthermore, the amount of white plastic debris was significant and with a composition of fragments and macrofibers (0.942, 0.785, \( p < 0.01 \)) (Table 2). The amount of multiple-color plastic debris was significant and with a composition of fragments (0.664, \( p < 0.05 \)). In addition, the amount of black plastic debris was significant and with a composition of microbeads and macrofibers (0.813, \( p < 0.01 \)). The composition of microbeads was also significant and abundant with purple and pink colors, respectively.

![Figure 5. Amount of particles of plastic debris by color along the land-based wastewater on both sides of the beach.](image)

### Table 2. Spearman correlation coefficients between the amount of plastic debris by color and composition (\( n = 10 \)).

| Plastic Debris | Microbead | Fragment | Foam | Macrofibres | Film | Paint |
|----------------|-----------|----------|------|-------------|------|-------|
| White          | 0.498     | 0.942**  | 0.061| 0.785**     | −0.174|−0.174 |
| Multiple       | 0.300     | 0.664*   | 0.307| 0.504       | −0.261|−0.261 |
| Blue           | 0.102     | 0.486    | −0.157|0.481       | −0.309|−0.309 |
| Yellow         | 0.527     | 0.140    | −0.390|0.035       | 0.196 |0.196  |
| Transparent    | 0.166     | 0.041    | −0.391|−0.266      | 0.459 |0.459  |
| Red            | 0.456     | 0.275    | −0.039|0.313       | 0.459 |0.459  |
| Green          | 0.432     | 0.406    | −0.391|0.305       | 0.394 |0.394  |
| Black          | 0.813**   | 0.648*   | −0.325|0.428       | −0.218|−0.218 |
| Purple         | 0.675**   | 0.278    | −0.321|0.097       | 0.574 |0.574  |
| Pink           | 0.702*    | 0.009    | −0.247|−0.390      | 0.580 |0.580  |
| Brown          | 0.458     | 0.524    | −0.166|0.327       | −0.111|−0.111 |

Note: * Refers to the correlation is significant at \( p < 0.05 \) (two-tailed). ** Refers to the correlation is significant at \( p < 0.01 \) (two-tailed).
3.4. Composition of the Plastic Debris Shapes along the Land-Based Source Wastewater Discharge Outlet

In the collected samples, the greatest number of fragmented plastic debris particles was 37 in Transect A and 222 in Transect B, accounting for 82.2% and 75.3% of the plastic above 1 mm, respectively (Figure 6). In total, there were 259 fragmented particles, accounting for 76.2% of the plastic debris shapes. The second most common shape was the macrofibre, accounting for 14.1% of the total plastic debris, but no macrofibre-shaped plastic was found in Transect A. The 48 microfibre-shaped plastic debris particles were found in the samples collected in Transect B, accounting for 16.3% of the plastic debris in Transect B (Figure 6). The least common was the paint flake plastic, with only one particle. Plastic debris shaped as films were transparent, most of which were larger than 10 cm, and the rest of the plastic debris was between 5 and 10 cm. The plastic pollution in Transect A was in only three shape types: fragments, microbeads, and foams, accounting for 82.2%, 15.6%, and 2.2%, respectively. In comparison, the plastic shapes in Transect B included fragments, microfibers, foam, microbeads, films, and paint flakes, accounting for 75.3%, 16.3%, 4.7%, 2%, 1.4%, and 0.3%, respectively.

3.5. Relationships among Plastic Debris Amount, OM, and Sand Grain Size Fraction

Spearman’s rank correlation results among all sizes of particles of plastic debris, OM, and sand grain size fraction in the two transects showed that the total amount of plastic debris was most strongly correlated with sizes of 0.5–2.5 cm (0.913, \( p < 0.01 \)) and 5–10 cm (0.896, \( p < 0.01 \)) (Table 3). In addition, the total amount of plastic debris was correlated with sizes of 1–5 mm (0.706, \( p < 0.05 \)) and 2.5–5 cm (0.896, \( p < 0.05 \)). The total amount of plastic debris that was 5–10 cm had a higher correlation (0.789, \( p < 0.01 \)) with plastic debris that was 2.5–5 cm, compared with plastic debris that was 0.5–2.5 cm (0.758, \( p < 0.05 \)). Moreover, the total amount of 0.5–2.5 cm plastic debris had a higher correlation
(0.785, \( p < 0.05 \)) with 5–10 cm plastic debris than with 2.5–5 cm plastic debris (0.637, \( p < 0.05 \)). Plastic debris that was 1–5 mm or another size showed no significant correlation. Moreover, a significant relationship was observed between OM percentage (%) and sand grain sizes (%) of >2 mm and 2–1 mm, with \( p < 0.01 \) and \( p < 0.05 \) levels of significance, respectively.

4. Discussion

4.1. Cause of Different Spatial Distribution of Plastic Debris on the Land-Based Source Input Zone

Distribution in the marine environment is influenced by the density of the particles, the location of the sources, and conveyance with ocean currents and waves [25,57]. The land-based source of the beach has led to plastic pollution, and the hot spot of plastic debris is distributed along the high tide line and dry sandy beach. Human activities related to aquaculture wastewater discharge is the largest source at Donghai Island [48,49]. The occurrence of plastic debris along the beach shows consistency, and even zones of high and low accumulation [32]. During the investigation period, the greatest tidal height occurred at about 12:00 p.m., and the lowest was at about 5:00. The tidal variation impacts the plastic debris distribution along the land-based source wastewater discharge outlets. On the one hand, the closer the land-based outlets are, the higher the plastic debris load input on the sandy beach is. On the other hand, the coastal water currents can also transport plastic debris from the beach to the coastal water, which is a key process by which plastic debris enters coastal water. When the plastic debris is discharged into coastal water, the coastal water currents can transport the plastic debris to the high tide line on the beach. In addition, there were significant spatial differences between Transects A and B along the land-based source outlets (\( p < 0.05 \)). The higher amount in Transect B may be caused by the flow direction and the wind direction.

4.2. Comparison in the Amount of Plastic Debris with Other Beaches around the World

The mean amount of plastic debris along the land-based source wastewater discharge outlets on the FLB is higher than that on beaches at Sanniang Bay, Qinzhou, Cheung Sha Beach, Hongkong, Black Sand Beach, and Macau and, in Spain, at Gaviotas, Socorro, Tejita, Cristianos, and Arena (Table 3). This is caused by the land-based source wastewater discharge outlets on both sides of FLB. Land-based wastewater input was found to be a direct source of plastic debris in this study. Moreover, land-based wastewater input is not managed by the FLB tourism sector. Especially, fishery and domestic activities are important sources of plastic debris pollution in coastal areas but have drawn little attention in Donghai Island [49]. The total flux of plastic debris derived from land-based wastewater input should

| Study Areas | Plastic Debris Size [mm] | Amount [particles/m²] | Analysis Method | References |
|-------------|--------------------------|----------------------|-----------------|------------|
| Lover Beach, Zhuhai | 1–20 | 34.70 | | [39] |
| Sanniang Bay, Qinzhou | 1–20 | 14.0 | | [39] |
| Shiluo Kou, Weizhou | 1–20 | 178.0 | | [39] |
| Silver Beach, Beihai | 1–20 | 30.0 | | [39] |
| Cheung Sha Beach, Hongkong | 1–20 | 3.0 | | [39] |
| Black Sand Beach, Macau | 1–20, 1–5 | 13.0, 8205 (Dry season), 27,696(Rainy season), 238 (Dry season), 1.03 (Rainy season) | Sieve and count | [39] |
| Beaches in South Korea | 5–25 | 237 (Rainy season), 0.97 (Dry season), 2509.66 ± 5078.28 (Upper tidal zone) | Sieve and count | [58] |
| Heungnam Beach, South Korea | >2 | 473 ± 866 (Cross-section perpendicular to the shoreline.) | Sieve and count | [58] |
| Gaviotas, Spain | >2 | 11.68 ± 17.41 | | [32] |
| Almaciga, Spain | >2 | 154.66 ± 192.70 | | [32] |
| Portis, Spain | >2 | 2539.86 ± 3078.28 | | [32] |
| Socorro, Spain | >2 | 22.73 ± 66.43 | Sieve and count | [32] |
| Tejita, Spain | >2 | 1.50 ± 5.69 | | [32] |
| Puerto, Spain | >2 | 162.71 ± 342.91 | | [32] |
| Cristianos, Spain | >2 | 12.38 ± 49.93 | | [32] |
| Arena, Spain | >2 | 10.47 ± 27.71 | | [32] |
| FLB, China | >1 | 34 | Sieve and count | This study |

The mean amount of plastic debris along the land-based source wastewater discharge outlets on the FLB is higher than that on beaches at Sanniang Bay, Qinzhou, Cheung Sha Beach, Hongkong, Black Sand Beach, and Macau and, in Spain, at Gaviotas, Socorro, Tejita, Cristianos, and Arena (Table 3). This is caused by the land-based source wastewater discharge outlets on both sides of FLB. Land-based wastewater input was found to be a direct source of plastic debris in this study. Moreover, land-based wastewater input is not managed by the FLB tourism sector. Especially, fishery and domestic activities are important sources of plastic debris pollution in coastal areas but have drawn little attention in Donghai Island [49]. The total flux of plastic debris derived from land-based wastewater input should
be estimated using a local environmental monitoring scheme. In addition, the mean amount of plastic debris along the land-based source wastewater discharge outlets on the FLB is lower than it is on beaches in South Korea and on beaches in Spain—Almaciga, Poris, and Puerto. Moreover, the mean amount of plastic debris is the same as that of the climate regions in the South China Sea, such as Lover Beach, Zhuhai, and Silver Beach, Beihai (Table 3).

4.3. Amount of Plastic Debris Characteristics along the Land-Based Source Wastewater Discharge Outlets on the FLB

Most plastics were between 0.5 and 2.5 cm. This is consistent with previous studies in Silver Beach, Beihai [39]. Most of the plastic debris is small [35,39,59,60]. Due to the multiple sizes found at FLB, cleanup should consider the large proportion of plastic debris that is between 0.5 and 2.5 cm size. However, reduction strategies are not considered in practical implementation at present. The apparent wind-blown pattern varies with the size and density of the debris. Expanded particles of macroplastic debris were found predominately in Transect B in downwind areas. Indeed, similar patterns of transport have been reported in Hawaii, South Australia, and the Tamar Estuary [27,61,62]. Most of the plastic encountered in the present study along the land-based source wastewater discharge outlets on both sides of FLB was white. Similar results have been reported for Mumbai’s coastal beaches [35,39,59]. The colors of the plastic debris, especially the microplastics, can cause it to resemble food [63]. The amount of white plastic is likely reflected in the source of that plastic. According to a local resident, the local fishery and tourism at the beach in Donghai Island contributes to the higher deposition of plastic debris.

There were higher numbers of plastic debris in every category of shape in Transect A than Transect B. The small fragment plastic debris collected in this study indicated that the particles were likely from a land-based source. The scenic portion of FLB is only a small part of it, and most beach areas are not subject to daily cleaning. The plastic debris contamination in Transect A had only three shapes, namely, fragments, microbeads, and foams. It is worth noting that there are no fibrous plastic contaminants in the A transect on beach, and the amount of plastic beads is higher than on the left beach. It is possible that the low density plastic debris migrates to the left beach due to sea wind and tidal current. The high density plastic beads settle on the beach surface. At the same time, irregularly shaped fragments are abundant in the intertidal beach. This suggests that microplastics can originate from the fragmentation of larger items that cause even smaller particles of plastic debris [27,64]. This also shows that the plastic source may be contaminated by domestic sources, possibly also due to daily-use cosmetics.

From the result of the correlation between the amount of particles of plastic debris, OM, and the sand grain size fraction, a significant relationship was observed between different sizes of plastic debris ($p < 0.05$). Since the total amount of 5–10 cm plastic debris had a higher correlation ($0.789, p < 0.01$) with 2.5–5 cm plastic debris than with 0.5–2.5 cm plastic debris ($0.758, p < 0.05$), it may be caused by the same sources. Plastic debris that was 1–5 mm and plastic debris of other sizes showed no significant correlation, which may be because the microplastics in this area come directly from land-based wastewater discharge. However, there was no clear relationship between the sand grain size fraction distribution and the amount of plastic debris ($n = 10, p > 0.05$) because the investigating area is an active transportation zone between land-based input and coastal water influence. The sand grain size fraction distribution and the amount of plastic debris are all easily impacted by wind, tidal changes, and anthropogenic activities. In addition, there was no significant relationship between the OM percentage (%) and the amount of plastic debris ($n = 10, p > 0.05$). Because this may be caused by the small samples and the average clay content of the sediments, the chance of finding a significant relationship with the amount of microplastic is small [27]. However, a significant relationship was observed between OM percentage (%) and sand grain sizes (%) of >2 mm and 2–1 mm, with $p < 0.01$ and $p < 0.05$ levels of significance. This indicates that the OM is distributed in sand grains that are >2 mm and 2–1 mm. Consequently, further study should consist of a large scale investigation and more samplings of the FLB.
4.4. Recommendation Reduction Strategies for Cleaning Plastic Debris on the FLB

Management priorities on marine beaches are significantly associated with spatial characteristics [65,66]. Land-based wastewater discharge is one of the largest plastics debris sources of the FLB, and can have a great influence on the amount of plastic pollution in coastal water. Similar results have been found in urban rivers, estuaries, and other beaches [38,39,67–69]. Firstly, management marine beaches should focus on critical sources of land-based wastewater discharge and on multiple sizes of plastic debris in daily cleanups before wastewater entering coastal water. In addition, centered on plastic debris size, more attention should be paid to multiple sizes of plastic debris, as well as the different proportions of land-based sources (such as coastal aquaculture, rivers, and wastewater discharge outlets) [70–72]. Land and coastal aquaculture activities involving fisheries are important land-based sources that should attract more attention. Many large items are employed as fishing gear at Donghai Island, such as nets, ropes, and pots. Therefore, the implementation of mitigation strategies should be carried out at various land-based sources of plastic debris before wastewater entering adjacent marine sand beaches and coastal waters.

5. Conclusions

The land-based wastewater discharge impacts on plastic debris on the beaches along the coast of the FLB were investigated for the first time. The amount of plastic debris ranged from 2 to 82 particles/m² on marine sand beach. There were significant spatial distribution differences among sampling stations, and a significant difference in plastic debris distribution was observed among the transects and tidal zone on the marine beach (p < 0.05). The amount of plastic debris was higher in Transect B of the land-based wastewater on the beaches with the same wind and coastal current direction. The most abundant size of plastics was identified between 0.5 and 2.5 cm (44.4%). Moreover, the most common color was white (60.9%). The most abundant shape of plastic fell into the fragment category (76.2%). The amount of plastic debris was significantly correlated with multiple sizes, indicating that it originated from the same sources and was caused by the breakdown of larger sizes of plastic debris. Management marine beaches should focus on the land-based wastewater discharge adjacent critical areas and the multiple size of plastic debris plastics in daily cleanups before entering coastal water.

Author Contributions: Conceptualization, P.Z. and J.-B.Z.; methodology, P.Z. and J.-B.Z.; software, S.-S.W. and Z.O.; validation, Y.-Q.Y. and M.-Y.W.; formal analysis, P.Z., S.-S.W. and Z.O.; investigation, P.Z. and J.-B.Z.; resources, P.Z. and J.-B.Z.; data curation, S.-S.W., Z.O., Y.-Q.Y. and M.-Y.W.; writing—original draft preparation, P.Z.; writing—review and editing, P.Z. and J.-B.Z.; visualization, S.-S.W. and Z.O.; supervision, P.Z. and J.-B.Z.; project administration, P.Z. and J.-B.Z.; and funding acquisition, P.Z. and J.-B.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by R&D projects in key areas of Guangdong Province (2020B1111020004), Guangdong Ocean University’s (GDOU’s) University Scientific Research Fund for Ph.D Start-up, grant number (R18021), the Science and Technology Special Project of Zhanjiang city (2019B01081), University level quality engineering and teaching project of innovation Strong School Project of GDOU (524210443), the First-class Special Funds of Guangdong Ocean University (231419018), and the Innovation Strong School Project (230420021) of Guangdong Ocean University, the National Innovation and Entrepreneurship for Undergraduates (CXXL2020033).

Acknowledgments: The authors are grateful for the anonymous reviewers’ careful review and constructive suggestions to improve the manuscript. Thanks are given to R&D projects in key areas of Guangdong Province (2020B1111020004), Guangdong Ocean University’s (GDOU’s) University Scientific Research Fund for Ph.D Start-up, grant number (R18021), the Science and Technology Special Project of Zhanjiang city (2019B01081), University level quality engineering and teaching project of innovation Strong School Project of GDOU (524210443), the First-class Special Funds of GDOU (231419018), the Innovation Strong School Project (230420021) of GDOU, and the National Innovation and Entrepreneurship for Undergraduates (CXXL2020033).

Conflicts of Interest: The authors declare that there is no conflict of interest.
References

1. Andrady, A.L. The plastic in microplastics: A review. *Mar. Pollut. Bull.* 2017, 119, 12–22. [CrossRef]
2. Barnes, D.K.; Galgani, F.; Thompson, R.C.; Barlaz, M. Accumulation and fragmentation of plastic debris in global environments. *Philos. Trans. R. Soc. B.* 2009, 364, 1985–1998. [CrossRef]
3. GESAMP. Sources, fate and effects of microplastics in the marine environment: A global assessment. *Rep. Stud.* 2015, 90, 96.
4. Ostle, C.; Thompson, R.C.; Broughton, D.; Gregory, L.; Wootten, M.; Johns, D.G. The rise in ocean plastics evidenced from a 60-year time series. *Nat. Commun.* 2019, 10, 1622. [CrossRef]
5. Thompson, R.C.; Olsen, Y.; Mitchell, R.P.; Davis, A.; Rowland, S.J.; John, A.W.; McGonigle, D.; Russell, A.E. Lost at sea: Where is all the plastic? *Science* 2004, 304, 838. [CrossRef] [PubMed]
6. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* 2017, 3, e1700782. [CrossRef] [PubMed]
7. Jambeck, J.R.; Geyer, R.; Wilcox, C.; Siegler, T.R.; Perryman, M.; Andrady, A.; Narayan, R.; Law, K.L. Plastic waste inputs from land into the ocean. *Science* 2015, 347, 768–771. [CrossRef] [PubMed]
8. Prokić, M.D.; Radovanović, T.B.; Gavrić, J.P.; Faggio, C. Ecotoxicological effects of microplastics: Examination of biomarkers, current state and future perspectives. *TrAC-Trend. Anal. Chem.* 2019, 111, 37–46. [CrossRef]
9. Cole, M.; Lindeque, P.; Halsband, C.; Galloway, T.S. Microplastics as contaminants in the marine environment: A review. *Mar. Pollut. Bull.* 2011, 62, 2588–2597. [CrossRef]
10. Lebreton, L.C.; Van Der Zwet, J.; Damsteeg, J.W.; Slat, B.; Andrady, A.; Reisser, J. River plastic emissions to the world’s oceans. *Nat. Commun.* 2017, 8, 15611. [CrossRef]
11. Su, L.; Sharp, S.M.; Pettigrove, V.J.; Craig, N.J.; Nan, B.; Du, F.; Shi, H. Superimposed microplastic pollution in a coastal metropolis. *Water Res.* 2020, 168, 115140. [CrossRef] [PubMed]
12. Forsberg, P.L.; Sous, D.; Stocchino, A.; Chemin, R. Behaviour of plastic litter in nearshore waters: First insights from wind and wave laboratory experiments. *Mar. Pollut. Bull.* 2020, 153, 11023. [CrossRef] [PubMed]
13. Stocchino, A.; De, L.F.; Besio, G. Sea Waves Transport of Inertial Micro-Plastics: Mathematical Model and Applications. *J. Mar. Sci. Eng.* 2019, 7, 467. [CrossRef]
14. Law, K.L.; Thompson, R.C. Microplastics in the seas. *Science* 2014, 345, 144–145. [CrossRef] [PubMed]
15. Sun, X.X.; Liang, J.H.; Zhu, M.L.; Zhao, Y.F.; Zhang, B. Microplastics in seawater and zooplankton from the Yellow Sea. *Environ. Pollut.* 2018, 242, 585–595. [CrossRef]
16. Zhang, K.; Shi, H.; Peng, J.; Wang, Y.; Xiong, X.; Wu, C.; Lam, P.K. Microplastic pollution in China’s inland water systems: A review of findings, methods, characteristics, effects, and management. *Sci. Total Environ.* 2018, 630, 1641–1653. [CrossRef]
17. Barboza, L.G.A.; Vethaak, A.D.; Lavorante, B.R.; Lundebye, A.K.; Guilhermino, L. Marine microplastic debris: An emerging issue for food security, food safety and human health. *Mar. Pollut. Bull.* 2018, 133, 336–348. [CrossRef]
18. Kunz, A.; Walther, B.A.; Löwemark, L.; Lee, Y.C. Distribution and quantity of microplastic on sandy beaches along the northern coast of Taiwan. *Mar. Pollut. Bull.* 2016, 111, 126–135. [CrossRef]
19. Rochman, C.M.; Tahir, A.; Williams, S.L.; Baxa, D.V.; Lam, R.; Miller, J.T.; The, F.C.; Werrilangti, T.; Teh, S.J. Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Sci. Rep. UK* 2015, 5, 14340. [CrossRef]
20. Zhang, W.; Zhang, S.; Wang, J.; Wang, Y.; Mu, J.L.; Wang, P.; Lin, X.Z.; Ma, D.Y. Microplastic pollution in the surface waters of the Bohai Sea, China. *Environ. Pollut.* 2017, 231, 541–548. [CrossRef]
21. MSFD GES Technical Subgroup on Marine Litter. Monitoring Guidance for Marine Litter in European Seas, Draft Report; European Commission: Brussels, Belgium, 2013.
22. Bancin, L.J.; Walther, B.A.; Lee, Y.C.; Kunz, A. Two-dimensional distribution and abundance of micro-and mesoplastic pollution in the surface sediment of Xialiao Beach, New Taipei City, Taiwan. *Mar. Pollut. Bull.* 2019, 140, 75–85. [CrossRef] [PubMed]
23. GESAMP. Guidelines or the Monitoring and Assessment of Plastic Litter and Microplastics in the Ocean; United Nations Environment Programme: Nairobi, Kenya, 2019.
24. Hidalgo-Ruz, V.; Gutow, L.; Thompson, R.C.; Thiel, M. Microplastics in the marine environment: A review of the methods used for identification and quantification. *Environ. Sci. Technol.* 2012, 46, 3060–3075. [CrossRef] [PubMed]
25. Rezania, S.; Park, J.; Md Din, M.F.; Mat Taib, S.; Talaiekhozani, A.; Kumar Yadav, K.; Kamyab, H. Microplastics pollution in different aquatic environments and biota: A review of recent studies. *Mar. Pollut. Bull.* 2018, 133, 191–208. [CrossRef]
26. Álvarez-Hernández, C.; Cairós, C.; López-Darias, J.; Mazzetti, E.; Hernández-Sánchez, C.; González-Sálamo, J.; Hernández-Borges, J. Microplastic debris in beaches of Tenerife (Canary Islands, Spain). *Mar. Pollut. Bull.* 2019, 146, 26–32. [CrossRef] [PubMed]
27. Browne, M.A.; Galloway, T.S.; Thompson, R.C. Spatial patterns of plastic debris along estuarine shorelines. *Mar. Pollut. Bull.* 2010, 60, 3404–3409. [CrossRef] [PubMed]
28. Esiukova, E. Plastic pollution on the Baltic beaches of Kaliningrad region, Russia. *Mar. Pollut. Bull.* 2017, 114, 1072–1080. [CrossRef]
29. Karkanorachaki, K.; Kiparissis, S.; Kalogerakis, G.C.; Yiantzi, E.; Psillakis, E.; Kalogerakis, N. Plastic pellets, meso-and microplastics on the coastline of Northern Crete: Distribution and organic pollution. *Mar. Pollut. Bull.* 2018, 133, 578–589. [CrossRef]
30. Lee, J.; Lee, J.; Hong, S.; Hong, S.H.; Shim, W.J.; Eo, S. Characteristics of meso-sized plastic marine debris on 20 beaches in Korea. *Mar. Pollut. Bull.* 2017, 123, 92–96. [CrossRef]
31. Moreira, F.T.; Prantoni, A.L.; Martini, B.; De Abreu, M.A.; Stoiey, S.B.; Turra, A. Small-scale temporal and spatial variability in the abundance of plastic pellets on sandy beaches: Methodological considerations for estimating the input of microplastics. *Mar. Pollut. Bull.* 2015, 102, 114–121. [CrossRef]
32. Reinold, S.; Herrera, A.; Hernández-González, C.; Gómez, M. Plastic pollution on eight beaches of Tenerife (Canary Islands, Spain): An annual study. *Mar. Pollut. Bull.* 2020, 151, 110847. [CrossRef]
33. Browne, M.A.; Crump, P.; Niven, S.J.; Teuten, E.; Tonkin, A.; Galloway, T.; Thompson, R. Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environ. Sci. Technol.* 2011, 45, 9175–9179. [CrossRef] [PubMed]
34. Fok, L.; Cheung, P.K.; Tang, G.; Li, W.C. Size distribution of stranded small plastic debris on the coast of Guangdong, South China. *Environ. Pollut.* 2017, 220, 407–412. [CrossRef] [PubMed]
35. Jayasiri, H.B.; Purushothaman, C.S.; Vennila, A. Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. *Environ. Monit. Assess.* 2013, 185, 7709–7719. [CrossRef]
36. Moreira, F.T.; Balthazar-Silva, D.; Barbosa, L.; Turra, A. Revealing accumulation zones of plastic pellets in sandy beaches. *Environ. Pollut.* 2016, 218, 313–321. [CrossRef]
37. Wang, M.; He, Y.; Sen, B. Research and management of plastic pollution in coastal environments of China. *Environ. Pollut.* 2019, 248, 898–905. [CrossRef] [PubMed]
38. Wessel, C.C.; Lockridge, G.R.; Battiste, D.; Cebrian, J. Abundance and characteristics of microplastics in beach sediments: Insights into microplastic accumulation in northern Gulf of Mexico estuaries. *Mar. Pollut. Bull.* 2016, 109, 178–183. [CrossRef] [PubMed]
39. Zhao, S.; Zhu, L.; Li, D. Characterization of small plastic debris on tourism beaches around the South China Sea. *Reg. Stud. Mar. Sci.* 2015, 1, 55–62. [CrossRef]
40. Paler, M.K.O.; Malenab, M.C.T.; Maralit, J.R.; Nacorda, H.M. Plastic waste occurrence on a beach off southwestern Luzon, Philippines. *Mar. Pollut. Bull.* 2019, 141, 416–419. [CrossRef]
41. Shim, W.J.; Thomposon, R.C. Microplastics in the ocean. *Arch. Environ. Con. Tox.* 2015, 69, 265–268. [CrossRef]
42. Graca, B.; Szewc, K.; Zakrzewska, D.; Dołęga, A.; Szczepowska-Boruchowska, M. Sources and fate of microplastics in marine and beach sediments of the Southern Baltic Sea—A preliminary study. *Environ. Sci. Pollut. Res.* 2017, 24, 7650–7661. [CrossRef]
43. Van Cauwenberghe, L.; Devriese, L.; Galgani, F.; Robbens, J.; Janssen, C.R. Microplastics in sediments: A review of techniques, occurrence and effects. *Mar. Environ. Res.* 2015, 111, 5–17.
44. Waldschläger, K.; Lechthaler, S.; Stauch, G.; Schütttrumpf, H. The way of microplastic through the environment—Application of the source-pathway-receptor model. *Sci. Total Environ.* 2020, 713, 136584. [CrossRef] [PubMed]
45. Kühn, S.; Bravo Rebolloedo, E.L.; van Franeker, J.A. Deleterious Effects of Litter on Marine Life. In *Marine Anthropogenic Litter*; Bergmann, M., Gutow, L., Klages, M., Eds.; Springer International Publishing: Cham, Switzerland, 2015; p. 89.

46. Shim, W.J.; Hong, S.H.; Eo, S.; Zeng, E.Y. (Eds.) *Microplastic Contamination in Aquatic Environments*; Marine Microplastics: Abundance, Distribution, and Composition; Elsevier Inc.: Amsterdam, The Netherlands, 2018; Chapter 1; pp. 8–16.

47. Jeong, C.B.; Won, E.J.; Kang, H.M.; Lee, M.C.; Hwang, D.S.; Hwang, U.K.; Zhou, B.; Souissi, S.; Lee, S.J.; Lee, J.S. Microplastic size-dependent toxicity, oxidative stress induction, and p-JNK and p-p38 activation in the monogonont rotifer (Brachionus koreanus). *Environ. Sci. Technol.* 2016, 50, 8849–8857. [CrossRef] [PubMed]

48. Zhang, P.; Wei, L.R.; Jin, Y.L.; Dai, P.D.; Chen, Y.; Zhang, J.B. Concentration, composition and fluxes of land-based nitrogen and phosphorus source pollutants input into Zhanjiang Bay in summer. *J. GDOU* 2019, 39, 46–55.

49. Zhang, P.; Peng, C.H.; Zhang, J.B.; Zou, Z.B.; Shi, Y.Z.; Zhao, L.R.; Zhao, H. Spatiotemporal urea distribution, sources, and indication of DON bioavailability in Zhanjiang Bay, China. *Water* 2020, 12, 633. [CrossRef] [PubMed]

50. Lavers, J.L.; Oppel, S.; Bond, A.L. Factors influencing the detection of beach plastic debris. *Mar. Environ. Res.* 2016, 119, 245–251. [CrossRef] [PubMed]
65. Portz, L.; Manzolli, R.P.; Garzon, N. Management priorities in San Andres Island beaches, Colombia: Associated risks. *J. Coastal Res.* 2018, 85, 1421–1425. [CrossRef]

66. Wu, W.M.; Yang, J.; Criddle, C.S. Microplastics pollution and reduction strategies. *Front. Environ. Sci. Eng.* 2017, 11, 6. [CrossRef]

67. Horton, A.A.; Svendsen, C.; Williams, R.J.; Spurgeon, D.J.; Lahive, E. Large microplastic particles in sediments of tributaries of the River Thames, UK—Abundance, sources and methods for effective quantification. *Mar. Pollut. Bull.* 2017, 114, 218–226. [CrossRef]

68. Peng, G.; Zhu, B.; Yang, D.; Su, L.; Shi, H.; Li, D. Microplastics in sediments of the Changjiang Estuary, China. *Environ. Pollut.* 2017, 225, 283–290. [CrossRef]

69. Tsang, Y.Y.; Mak, C.W.; Liebich, C.; Lam, S.W.; Sze, E.T.; Chan, K.M. Microplastic pollution in the marine waters and sediments of Hong Kong. *Mar. Pollut. Bull.* 2017, 115, 20–28. [CrossRef] [PubMed]

70. Black, J.E.; Kopke, K.; O’Mahony, C. A trip upstream to mitigate marine plastic pollution—a perspective focused on the MSFD and WFD. *Front. Mar. Sci.* 2019, 6, 689. [CrossRef]

71. Ramos, J.A.A.; Pessoa, W.V.N. Fishing marine debris in a northeast Brazilian beach: Composition, abundance and tidal changes. *Mar. Pollut. Bull.* 2019, 142, 428–432. [CrossRef] [PubMed]

72. Xue, B.M.; Zhang, L.L.; Li, R.L.; Wang, Y.H.; Guo, J.; Yu, K.F.; Wang, S.P. Underestimated Microplastic Pollution Derived from Fishery Activities and “Hidden” in Deep Sediment. *Environ. Sci. Technol.* 2020, 54, 2210–2217. [CrossRef]

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).