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Occurrence of microplastics on beach sediment at Libong, a pristine island in Andaman Sea, Thailand

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ABSTRACT: Microplastic pollution is a global issue and a hot issue in Thailand. This is the first assessment of microplastics at Libong, a pristine island, located in Andaman Sea. The investigation was carried out by collecting the sediment from beach and mudflat areas of the island in May and July, 2019. Three class sizes of microplastics were determined: greater than 5 mm, 18 pieces; 1–5 mm, 28 pieces; and less than 1 mm, 129 pieces. The total number of microplastics from beach sediment was greater than that from the mudflat sediment. The discovered microplastics were mainly constituted of fibers (59%) and fragments (41%). A great variety of colors were found, and white (43% from beach, 41% from mudflat area) was the most common, followed by blue (9% from beach, 35% from mudflat) and red (12% from beach, 6% from mudflat). Polymers identified by Fourier Transform Infrared Spectrophotometer consisted of poly vinyl chloride (PVC), polypropylene (PP), Nylon, Polyethylene (PE), Polyester, Polyacrylate (PA) and polymer with a structure similar to EPDM rubber.

KEYWORDS: microplastic, FTIR, polymer, beach, mudflat, sediment

INTRODUCTION

Marine plastic waste has long been recognized as an environmental problem. As plastic pollution of marine ecosystems has become a widely acknowledged environmental problem, it has been placed on the agenda at the highest international levels [1]. Geyer et al [2] estimated that approximately 6300 million tons of plastic waste were generated between the years 1950 and 2015, and 4977 million tons of which were accumulated in landfills and the natural environment. The origin of microplastics is from a large piece of marine plastic waste under the influence of UV rays in sunlight [3, 4] and wave action breaking the plastic into small particles [4, 5]. A small piece of plastic is called microplastic. This includes small plastic product that is primarily made as a scrub for cosmetic use [3, 5]. Microplastics have been classified with different size ranges, varying from study to study, with diameters of < 10 mm [6], < 5 mm [7], < 2 mm [8] and < 1 mm [9, 10]. They easily spread to the environment, but it is difficult to handle or eliminate them. They are thus especially vulnerable for both land- and sea-based microplastic debris inputs, often exhibiting high numbers of microplastics [11]. Many researchers define microplastics as plastic particles that are smaller than 5 millimeters [3, 4].

Microplastics are both abundant and widespread within the marine environment, which are found in their highest concentrations along coastlines and within mid-ocean gyres [12]. These microplastic particles have already been detected in environments, ranging from beach sediment and surface waters all around the globe to more remote locations such as deep sea sediments and arctic waters [13, 14]. Among the above-mentioned environmental compartments studied, beach sediments represent the interface between the ocean and terrestrial habitats [15].

Plastics are synthetic organic polymers, which are derived from the polymerization of monomers extracted from oil or gas [16]. Primary source of microplastics includes Polyethylene (PE), polypropylene (PP) and polystyrene (PS) particles in cosmetic and medical products. Secondary microplastics originate from physical, chemical and biological processes, resulting in fragmentation of plastic debris [8, 17]. Using Fourier Transform Infrared Spectroscopy (FTIR), items of interest can then be confirmed as plastic by comparing spectra of the samples with those of known polymers [18, 19]. The most commonly used and abundant polymers are high density polyethylene (HDPE), low-density polyethylene (LDPE), poly vinyl chloride (PVC), polystyrene (PS), polypropylene (PP) and poly(ethylene terephthalate) (PET), which together account for approximately 90% of the total plastic production worldwide [20].

For Thailand, very few previous studies on marine waste and microplastics in the environment and living organisms have been published such as Azad et al [21] conducting the study of microbiological contamination in the stomachs of economic fishes from the lower Gulf of Thailand. It was found that the plastic ingested by aquatic animals was 79.52% microplastics (< 5 mm) and 20.48% mesoplastics (5–25 mm). According to the study result of Goh et al [22], the mean concentration of microplastic in these green mussel (*Perna viridis*) samples was 21.10 ± 0.15 items/g and 12.30 ± 0.20 items/individual. Microplastic studies in the beach ecosystem were still conducted in the limited areas usually in the beach with tourist attraction. Furthermore, the study results were not comprehensive and sufficient especially in areas that are islands which have the opportunity to be developed as a tourist destination in the future such as the Island of Libong, Thailand. Thus, this study result certainly provided the valuable information for fulfilling the background data of the aforementioned unique ecological system. Moreover, Libong Island is an important sea grass area of the Andaman coast with the water depth between 0.5–2.8 m of sea level [23]. This definitely makes it become important ecological area because it is the habitat of dugongs in Trang Province. Microlight surveying around Trang Province between 15–23 November 2006 found 84 dugongs and their 25 offspring [24]. Furthermore, the abundant sea grasses around the Libong and Muk Islands are important food sources for the largest herd of dugongs in Thailand. Therefore, if there are some quantities of marine wastes and microplastics around the beach system of Libong Island, they may affect aquatic animals, dugongs and humans who consume the aquatic fauna and sea grasses contaminated with microplastics. Thus, the objective of this study was to study the microplastic contamination and their types in sand and mud beach ecosystems.

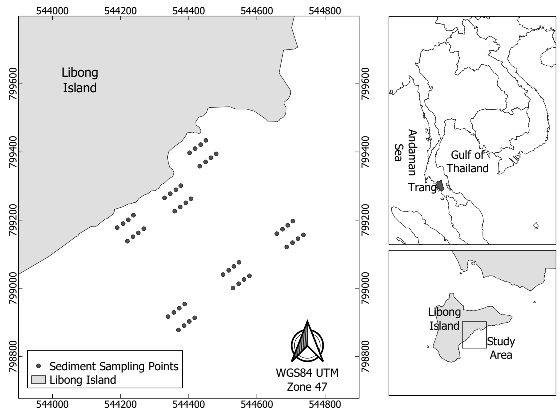

Fig. 1 Study area with the sampling sites at Libong Island, Thailand

MATERIALS AND METHODS

Study area

Libong Island was selected for this study. It is a pristine island located in Andaman sea at latitude 07°14′–07°17′ N and longitude 99°22′–09°27′ E on the western coastline of Kantang District, Trang Province (Fig. 1). Libong Island has a diverse ecosystem, including sandy beach, mudflat next to the sand beach, coral reefs, mangrove forests and an extensive seagrass bed. The study site is situated on the east coast of the island where the large seagrass bed can be found. Libong Island is affected by monsoon winds as follows: (1) Southwest monsoon (SW) blows from the ocean to the southwest direction of the shore of the island around May to October or early November and makes heavy rain and strong wave to the island; (2) Northeast monsoon (NE) blows from the South China Sea and the Gulf of Thailand into the southeast of the southern Thailand region and blows to the northeastern of the island around November to April, making light rain and light wind.

Collecting sediment samples

Sampling of sediment samples was carried out at sand and mud beaches located at the Eastern site of the island, and there were villagers' houses at their head beaches. The 48 sampling points were selected for collecting the samples 2 times in May and July 2019, which is a rainy season in this area. This study divided the found microplastics into 3 sizes including (1) larger than 5 mm, (2) 1–5 mm and (3) smaller than 1 mm.

Sediment samples were sampled along the coast by placing a 50 × 50 cm quadrant frame in a 100 × 100 m specimen block at the beachhead, the middle and the end of each beach with a distance of 100 m apart among the blocks; collecting sediment in the quadrant frame was carried out using a shovel by scooping about 10 cm depths and putting the samples in glass jars (5 replicates) per station before sending to laboratory for analysis.

Analysis of microplastics in sediment samples

The sediment samples were prepared for analysis by air drying and sieving through sieves with 1 mm and 5 mm apertures. The sediment that remained on the 5 mm sieve was weighed and sorted for the microplastics with the naked eye. Sediment between 1–5 mm was weighed and sorted for microplastics with the naked eye or collected for microscopic examination. The samples sieved through the 1 mm sieve were analyzed for microplastics using the modified method from NOAA Marine Debris Program [25]. The 400 mg sieved sample was transferred to a 500 ml beaker. About 100 mg subsediment sample was weighed and oven dried at 90 °C for 24 h. Then, the dried sample was placed in a 1000 ml beaker and stirred in NaCl solution to separate the debris or plastics by floating. After that, the sample was filtered through a 300 µm filter cloth. The sample left on a 300 µm filter cloth was taken to a 500 ml beaker. Then, 20 ml of ferrous sulfate and 20 ml of 20% hydrogen peroxide were added, and chemical reaction was proceeded at room temperature for 5 minutes. Then, the sample was heated and stirred at the temperature controlled (not higher than 75 °C) in the fume hood and kept in a tall cylinder for 1 night. After that, the sample was filtered through GF/C filter paper and oven dried at 60 °C for 3 h. Then, the sample was examined under a stereo microscope at different magnifications to find microplastics.

Table 1 Microplastic found in beach sediment and mudflat sediment at Libong Island.

Sediment	Size	1st: No. of pieces	2nd: No. of pieces	Occurrence (pieces/m^2)
Beach	>5 mm	–	18	
Beach	1–5 mm	13	7	
Beach	<1 mm	31	83	
Total		44	108	25
Mudflat	>5 mm	–	–	
Mudflat	1–5 mm	8	–	
Mudflat	<1 mm	–	15	
Total		8	15	4

Polymer identification

About 40% of the total number of microplastics was used in this study. Samples was analyzed to identify polymer types, color and shape. To characterize and identify polymer types, the spectra of the potential polymer particles less than 1 mm were obtained from Fourier transform infrared (FTIR) spectrometer, Frontier model, coupled with Spotlight 200i FTIR microscope (Perkin Elmer, USA) whereas the potential samples with larger than 1 mm dimension were identified by using Frontier FTIR spectrometer with attenuated total reflection (ATR) technique. The spectra were identified by comparing with referent polymer spectra in the spectral library obtained from the FTIR program.

RESULTS AND DISCUSSION

Microplastic contamination in the beach and mudflat area

The total area of sampling area in this study was 120 000 cm^2, including 60 000 cm^2 each of sandy beach and mudflat area. For the 1st microplastic contamination study in the sandy beach of Libong Island, Trang province in May 2019, 44 microplastics were found in the sandy beach ecosystem with 31 microplastics smaller than 1 mm (Table 1). There were 13 pieces of microplastics with 1–5 mm size. For the mudflat area 8 pieces were found with 1–5 mm size. In the 2nd time, in July 2019, the total of 108 microplastics found in the sandy beach ecosystem consisted of 83 pieces of the most abundant microplastics with smaller than 1 mm, followed by the microplastics larger than 5 mm and 1–5 mm which were 18 and 7 pieces, respectively, while in the mudflat area 15 pieces for size smaller than 1 mm were found.

The comparison of the number of microplastics

Table 2 Microplastic found in sediment

Location	Occurrence	Plastic type	Plastic size	Reference
UK	Max 8 items/kg	–	–	[19]
Hong Kong	Average abundance of 5595 items/m^2 and maximum 258 408 items/m^2	Microplastic	0.315 to >5 mm	[26]
Belgian Coast	Average 92.8 items/kg dry sediment	Microplastic	38 μm to 1 mm	[10]
Gulf of Thailand, Thailand	248 items/kg	Microplastic	315 lm–5 mm	[28]
West beach of Phuket, Thailand	265 pieces/m^2	Microplastic	–	[29]
Straits of Johor, Malaysia	300 items/kg	Microplastic	315 lm–5 mm	[28]
Libong Island, Thailand	25 pieces/m^2 (sandy beach) 4 pieces/m^2 (mudflat)	Microplastic	<1 mm, 1–5 mm, >5 mm	This study

found in sediment in this study with other areas worldwide (Table 2) revealed that the number of microplastic found in this study (25 pieces/m^2 (sandy beach) and 4 pieces/m^2 (mudflat) was less than that from other areas such as 258 408 items/m^2 found at Fan Lau Tung Wan, Hong Kong [26] and more than that of the Belgian Coast, 92.8 particles/kg dry sediment (assuming sediment sample in 1 m^2 possessing 1 kg dry weight). This is because of the tourist activities of the Fan Lau Tung Wan beach whereas Libong Island is still natural beach. Kaberi et al [27] sampled on 6 beaches of Kea Island in the Aegean Sea. They sampled for microplastics larger than 2 mm and smaller than 4 mm in diameter. The abundance that they found ranged from 0 to 1218 items/m^2. Most microplastics and plastic pellets were made from PE and have undergone degradation. They identified the open sea as a source of microplastics for this island. When the amounts of microplastics were compared within Thailand [28, 29] and in Straits of Johor, Malaysia [28], the abundance of microplastics from this study was less than those of the aforementioned studies by several times.

The reason that other regions had more amounts of microplastics than those of Libong Island was probably explained by tourist activities of those other areas. The mainland also receives microplastic waste from community sewage whereas the island of Libong is still natural and located in non-hunting area. The community characteristics of the islanders are agricultural communities and awareness of nature conservation as well as the dangers of marine waste and microplastics and therefore they produce less waste than those with urban way of life, and tourism of Libong Island is still in its infancy. In the mud beach area, the amounts of microplastics found were much less than those of sandy beaches. This was probably caused by the microplastic transportation with current. Sea water brought the microplastics to accumulate in the sandy beach during the high tide, and therefore a lot of microplastics were found around the sandy beach. Another possible explanation was that some microplastics in the mud beach were consumed by the marine life such as molluscs, crabs, shrimp or even dugongs that might accidentally eat microplastics adhered to the leaves of seagrass since they misunderstood microplastics as their food, resulting in the less amounts of microplastics found in the mud beach than those of the sandy beach. Further study of this issue should be conducted.

Plastic morphotypes, color and sizes

Discovered microplastics were mainly constituted of fibers (59%), followed by fragments (41%) (Fig. 2). A great variety of colors were found, and white (43% from beach, 41% from mudflat area) was the most common, followed by blue (9% from beach, 35% from mudflat) and red (12% from beach, 6% from mudflat) (Fig. 3). The sources of the fragments are difficult to be tracked, but fibers are commonly produced by the degradation of textiles [13]. A range of marine biota, including seabirds, crus-

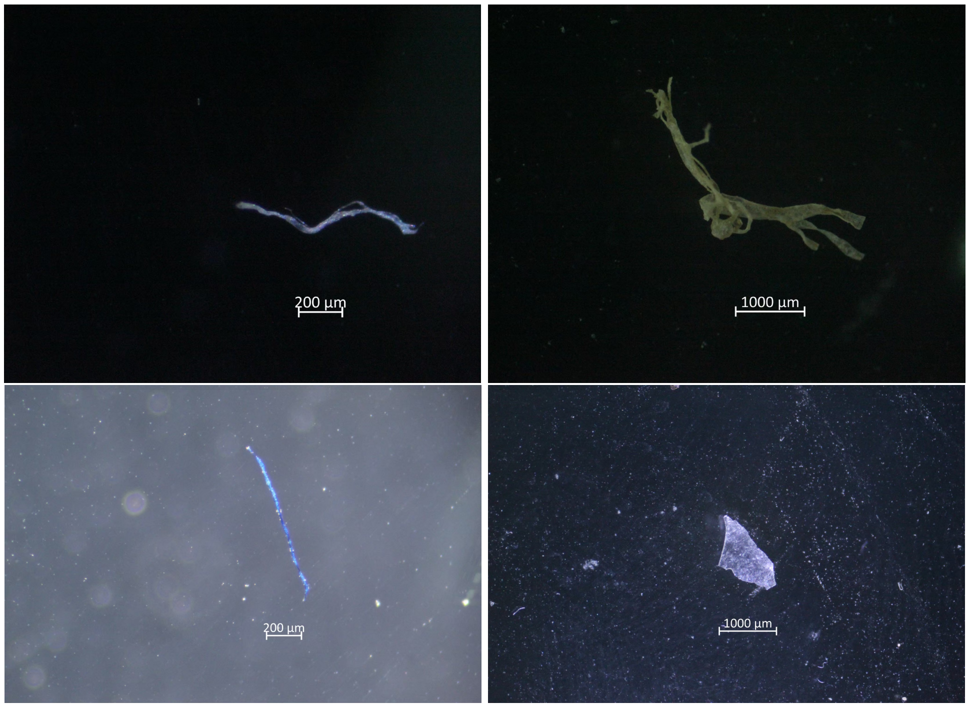

Fig. 2 Examples of microplastic found in sediment samples.

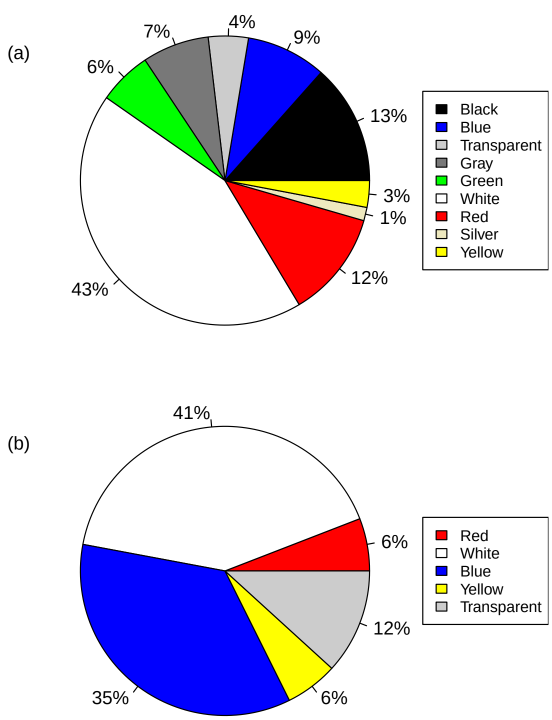

Fig. 3 Percentage of plastic color found from (a) sand beach sediment and (b) mudflat sediment.

taceans and fishes, can ingest microplastics [30]. Plastic fragments were first identified in the guts of sea birds in the 1960s when global plastic production was less than 25 million tonnes per annum [17, 29]. Plastic fibers were also found in the stomachs of mussels [22] and fishes [21] (pelagic fishes caught in the Gulf of Thailand). The colors of these particles are of importance since they could affect the likelihood of marine organisms ingesting them [31]. For instance, it was found that some fishes will consume more blue particles because they resemble the blue copepods that they usually feed on. Microplastic sizes found from this study were mainly smaller than 1 mm (61%), larger than 5 mm (18%) and 1–5 mm (13%). The sizes of particles also determine the likelihood of the sizes of marine organisms ingesting them. For example, the particles found in this study were relatively smaller than 1 mm and therefore may be available to small filter feeding organisms such as mussels and squids [21, 22], and particle larger than 1 mm may be gulped by bigger fishes.

Type of plastic

The study area at village no. 7 of Libong Island revealed the microplastics with the highest fiber content contaminated in sandy beach and mudflat beach. The microplastic types found were poly

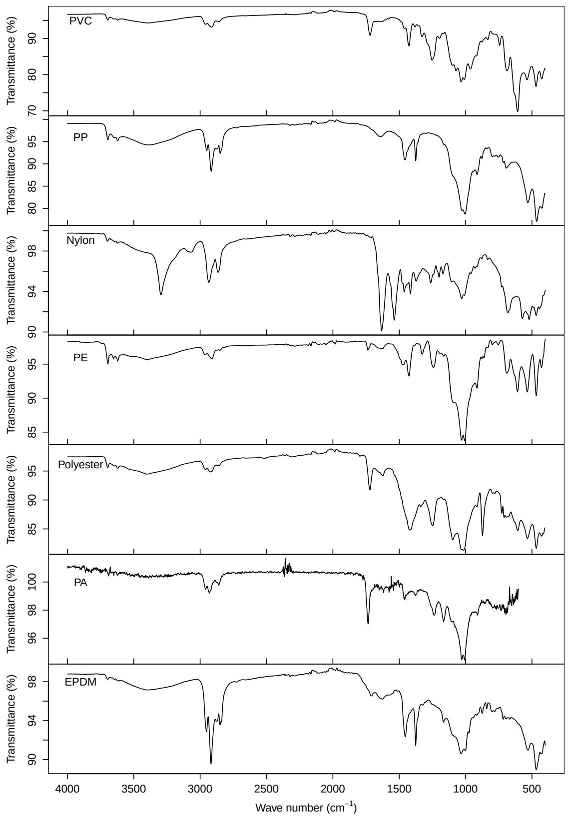

Fig. 4 Types of polymer detected in beach sediment at Libong Island: PVC, PP, Nylon, PE, Polyester, PA (polyacrylate) and EPDM.

vinyl chloride (PVC), polypropylene (PP), Nylon, Polyethylene (PE), Polyester, Polyacrylate (PA) and polymer with a structure similar to EPDM rubber (a blended polymer between ethylene and propylene), and another monomer was added to make a double bond in the polymer structure (Fig. 4).

In our result, 7 types of polymers were found by analyzing sediment samples whereas Thompson et al [19] found microplastics consisting of 9 different polymers in 23 samples out of 30 estuarine, beach and sub-tidal sediment samples taken around Plymouth, UK, including microscopic fibers and fragments typically derived from clothing, packaging and ropes. From this study, the result showed no polystyrene if compare our result with other beaches at Fah Lau Tung Wan, Hong Kong [26], from which over 90% of samples were classified as microplastics (< 5 mm) with 92% of the microplastic being polystyrene. It may be because of the lifestyle of the people in Hong Kong using insulated boxes for takeaway food or food transportation [26], but the lifestyle of people on Libong Island is still the traditional way. Our result found Nylon and polypropylene (PP), which is the same as the study of Claessens et al [10] which investigated beach sediment along the Belgian Coast and found microplastic with fibers over 88%. The polymers of the analyzed fibers were Nylon, poly vinyl alcohol and polypropylene (PP), which were mainly derived from fishing nets, carpets and ropes. Since the fishing is a common activity on the Libong Island and the fishing nets tend to become brittle, break down into small pieces and eventually degrade further when exposed to UV radiation either under direct sunlight or in seawater [32]. Apart from this, we found Polyester that was probably derived from textiles. The high abundance of PP can be explained by high production volumes and use, especially for packaging materials, and thus it has higher probability for becoming plastic litter. The study conducted by Lee et al [5] investigated the abundance of plastic in different seasons and found that the accumulation of plastic in beach sediment after the rainy season was higher than that before the rainy season. A great abundance of plastic items was observed on windward beaches as compared to leeward beaches [33].

From FTIR spectra in the Fig. 4, it was found that all the spectra show absorption peaks at wavenumber of 2800–3000 cm^{-1}, which are referred to vibration of —CH stretching from the backbone structure of each polymer. Moreover, these spectra show a strong peak at 1000–1100 cm^{-1}; it is possible that the absorption peak is affected by unremoved soil, sand or some other chemicals that are used in the polymers, but it cannot be identified by this technique. The spectrum of poly vinyl chloride (PVC) shows a strong absorption peak C—Cl stretching close to 600 cm^{-1}, methylene groups (—CH=C) wagging at 1420 cm^{-1} and —C—H stretching from CH—Cl structure at 1257 cm^{-1}. Moreover, it has a strong vibration peak at 1720 cm^{-1} that might be due to the characteristic of carbonyl band from phthalate plasticizer which is always used in PVC. For polypropylene (PP) spectrum, it is clearly seen the strong vibration peaks of $—CH_3$ and $—CH_2$ bending in the PP structure at 1450 cm^{-1} and 1376 cm^{-1}, respectively [34]. Nylon spectrum shows a strong absorption peak of —NH stretching and —NH bending from its structure at wavenumber of 3290 cm^{-1} and 1535 cm^{-1}, respectively. Furthermore, the absorption peak of C=O stretching at 1630 cm^{-1} is a good evidence to prove the structure of Nylon. Basically Polyethylene (PE) has a simple structure because it is synthesized from only ethylene monomer ($CH_2{=}CH_2$). From the FTIR spectra, PE structure has been confirmed by the presence of −CH bending at 1460 cm^{-1}. The FTIR spectrum of Polyester clearly shows the absorption peak of C═O at 1720 cm^{-1} and the vibration of O═C─O─C at 965 cm^{-1} [35]. These are the characteristic peaks of Polyester. The structure of Polyacrylate (PA) is proved by the FTIR spectrum as the presence of carbonyl group vibration (C═O) at 1740 cm^{-1} and strong stretching bands of ester group from acrylate structure in the region of 1100–1300 cm^{-1} [36]. Ethylene-propylene-diene rubber (EPDM) is a synthetic rubber which has a chemical structure closed to PP structure. PP is a copolymer of propylene as a major phase and ethylene. It is observed that the FTIR structures of PP and EPMD are similar. However, EPDM spectrum shows some absorption peak of carbonyl group (C═C) at 1620 cm^{-1} from diene groups in EPDM structure [37]. Due to the fact that the FTIR of PP and EPDM are quite similar, it is not clearly confirmed by only FTIR technique. According to the sample appearance, the EPDM is softer and more elastic than PP sample. This helps to confirm the characteristic of EPDM.

Several broad classes of plastics are used in packaging: Polyethylene (PE), polypropylene (PP), polystyrene (PS), poly (ethylene terephthalate) (PET) and poly vinyl chloride (PVC); polyolefins (PE and PP) and Nylons are primarily used in fishing gear applications [38].

CONCLUSION

This is a first report of the study of polymer types present in beach sediment at Libong Island, which is a significant habitat of the endangered dugongs. Microplastics found in this study were composed of a variety of polymers including poly vinyl chloride (PVC), polypropylene (PP), Nylon, Polyethylene (PE), Polyester and Polyacrylate (PA). The size of microplastics was mainly smaller than 1 mm which might be consumed by small benthic organisms and dugongs living on the beach sediment. Therefore, they can contaminate the food chain and finally reach to humans and dugongs, as already happened to the death of the young dugong named Mariam caused by consuming some fragments of plastic bags in August 17th, 2019 at Libong Island. Hence, further studies should focus on investigating microplastic contamination in the marine organisms, sediment, sea grasses (dugong food) and also the current direction since it is currently a serious global problem waiting to be solved immediately.

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