App. Envi. Res. 41(2) (2019): 54-62

Applied Environmental Research

Journal homepage : http://www.tci-thaijo.org/index.php/aer

Preliminary Study of Distribution and Quantity of Plastic-debris on Beaches Along the Coast at Phuket Province

Pensiri Akkajit*, Sudarat Thongnonghin, Siriporn Sriraksa, Supissara Pumsri

Faculty of Technology and Environment, Prince of Songkla University, Phuket Campus, Phuket, Thailand
* Corresponding author: Email: pensiri.a@phuket.psu.ac.th

Article History
Submitted: 21 January 2019/ Revision received: 4 April 2019/ Accepted: 7 May 2019/ Published online: 11 July 2019

Abstract

The beach sediment samples from Kalim, Tri Trang, and Patong Beaches, Phuket Province, southern of Thailand were collected for preliminary investigation on coastal debris. A total of 9 samples were taken from a 1 x 1 m quadrat at the depth of 5 cm, parallel with the shore during the period of maximum low tides in November, 2018. Microplastics (particles size < 5 mm) were extracted using sodium chloride (1.15 g mL^{-1}) and their characteristics- including abundance (items m^{-2}), weight (g), density (items m^{-2}), color and shape- were determined using a stereo microscope. The results showed that microplastic debris varied in abundance from 1 to 35 items m^{-2} at the three selected beaches, depending on sampling location. In comparison, abundance of macroplastic (> 2.5 cm) and mesoplastic debris (5 mm to 2.5 cm) varied from 1 item m^{-2} quadrat (Kalim Beach) to 38 items (Patong Beach), 9 items (Tri Trang Beach) and 68 items (Patong Beach) m^{-2}. Blue fibers were predominant among microplastic debris found at Kalim Beach; these are likely to have originated from pieces of rope, safeguard lines and fishing materials. In contrast, microplastic debris found in Patong and Tri Trang Beaches were predominantly green in color. The results of this study provide an overview of the sources of microplastics in coastal environments, which provides a basis for developing long term plastic management plans for these highly popular beaches in Phuket Province.

Keywords: Beaches; Microplastics; Patong; Plastic-debris; Phuket; Sediment

Introduction

Plastics represent a major source of marine pollution around the world. Pollution of coastal areas, especially by micro-plastic debris is a growing concern as it carries major impacts for marine life. The U.S. National Oceanic and Atmospheric Administration (NOAA) defines microplastics as particles smaller than 5 mm in diameter [1]. The majority of marine-plastic debris is derived from land-based sources such as urbanization, shipping and industrial development, with the majority transported from these upstream sources to the sea via rivers and estuaries [2]. Plastics are the most commonly found component of marine debris [2-5] due to its wide range of applications and its long-term persistence in the environment. Moreover, microplastics can act as carriers of contaminants such as chemical additives or organic contaminants. Ingestion and accumulation of microplastics in the bodies of many organisms can result in severe adverse impacts on the marine environment [6]. Microplastics may have physical effects on organisms (e.g. blocking of digestive tracts), act as vectors for hydrophobic pollutants and as substrates for organisms, or affect sediment properties [7]. Ingestion of microplastics has been recorded in a wide variety of marine organisms resulting in diverse physiological disorders [8]. Once ingested, microplastics can reduce feeding capacity, energy reserves and reproductive output as well as cause detrimental changes to intestinal function [9]. In addition to the environmental impacts of microplastics, mesoplastic (5 to 25 mm) and macroplastic (> 25 mm) debris are also considered significant as macroplastic debris can be fragmented due to UV radiation, wind, currents, waves, and tides into mesoplastic debris, which can then further break down into microplastic and nanoplastic debris [10]. For this reason, the study of composition, abundance, and distribution of microplastic-debris along beaches and the marine environment is essential to enhance our understanding of the microplastic contamination situation in beaches, water, and marine sediments.

Accumulation of plastic debris in Thailand's coastal ecosystems has been studied at numerous locations [11]. However, relatively little is known about the abundance and distribution of microplastics in sediments, especially in Phuket Province, a major global tourism destination. Microplastic contamination in intertidal invertebrates (*Saccostrea forskalii*, *Balanus amphitrite*, and *Littoraria* sp.) in Angsila, Bangsaen and Samaesarn in Chonburi Province on Thailand's eastern coast showed significant accumulation of microplastics (0.2 to 0.6 counts g^{-1}), indicating higher pollution levels along the coastline [11]. Phuket, Thailand's largest island in Thailand, is located in the south of the country and is well known as a global tourism hub. However, the accompanying economic boom is a major source of pollution, especially in coastal areas. The vast majority of plastic debris is produced onshore and reaches the coastal environment as the main sink for plastic debris.

An understanding of the extent of microplastic pollution in coastal environments will be essential as a basis for environmental impact assessment and development of sustainable management plans for marine waste. Data on sources, distribution and composition of microplastic debris are crucial in order to assess and predict the toxicity of plastic wastes in coastal environments, and to determine the depositional behavior of microplastics within sediments [12].

Therefore, the objectives of this study are 1) to investigate the composition, abundance, and distribution of microplastic debris in the coastal areas at Phuket Province; and 2) to examine the relationship between the occurrence of microplastic debris and intensive human activity in coastal areas. Results from this research may contribute to development of long-term plastic management plans in coastal areas, especially in the very popular beaches of Phuket Province.

Materials and methods

1) Study area

The three beaches selected for the study were Patong (7°53′24″N, 98°17′24″E) designated as P (P1 to P3), Kalim (7°54′45.3096″N, 98°17′37.6722″E) designated as K (K1 to K3), and Tri Trang (7°53′14″N, 98°16′35″E) designated as T (T1 to T3). The selected beaches for this study were some of Phuket's most popular tourist destinations, located on the western coast of Phuket Island, Thailand (Figure 1). Patong Beach is located on the central west coast, an important and intensive tourist destination. Kalim Beach is situated north of Patong Beach directly on the shore road where tourism pressure is less intensive than at Patong Beach. With a rocky shore, Kalim is considered the best surfing destination in Phuket. Tri Trang Beach is located at the southern end of the coastline, with some maritime activities, but the quietest bay of the three sample locations.

2) Sample collection and preparation

Sampling was conducted during the period of maximum low tides in November, 2018. Sediment samples were taken from 1 x 1 m quadrats in the intertidal zone using a clean stainless steel spatula [12]. Quadrats were located 20 m apart in parallel with the shore, with 3 samples per location. Plastic debris in the beach sediments was collected at a depth of 5 cm; each sample thus represented a volume of 0.05 m^3. The sampling points (P1 to P3, K1 to K3, and T1 to T3) were recorded using GPS to identify the sampling coordinates for further study. Subsequently, the 9 samples (3 locations x 3 samples per site) were transferred into metal buckets, packed, and shipped to the laboratory at the Faculty of Technology and Environment, Prince of Songkla University Phuket Campus for processing and analysis. At the laboratory, the plastic debris was separated into 3 sizes: 1) less than 5 mm (micro); 2) between 5 mm to 2.5 cm (meso); and 3) more than 2.5 cm (macro). No plastic tools or containers were used during sampling.

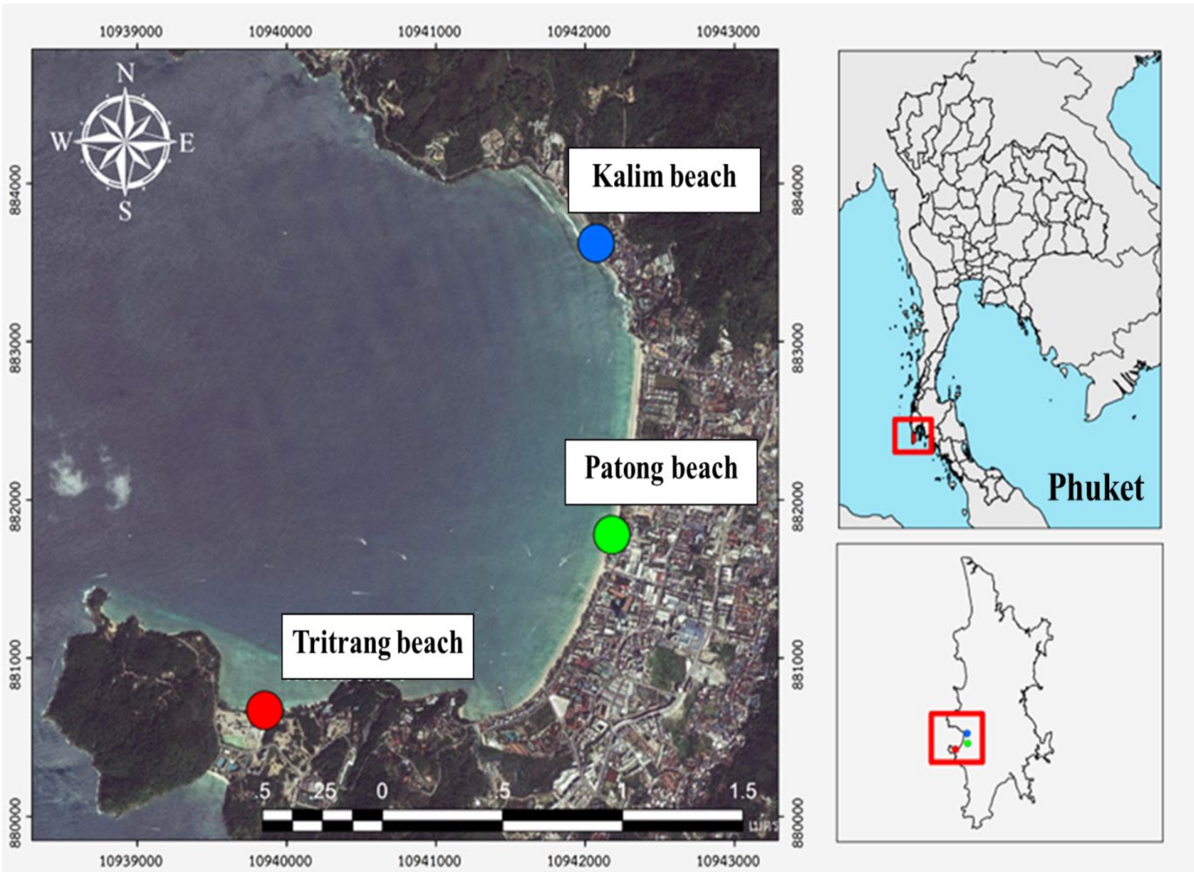

Figure 1 Study areas: Patong, Kalim, and Tri Trang Beaches, Phuket Province, Thailand.

Then, each category of waste was weighed using a TANITA scale (0.1 g) then air-dried at room temperature for 72 h or until constant weight was reached. Weights were recorded. For each quadrat, abundance (items m^{-2}), weight (g), and density (items m^{-2}) were determined, with the microplastic debris identified visually under a stereo-microscope for color (white/ transparent, yellow/orange, pink/red, green, blue, purple, black/brown/grey) [13] and shape (hard plastics, soft plastics (e.g., foams), films, line, fibers, sheet and other) [1]. The amount of meso and micro plastic-debris were visually counted and recorded.

3) Sample analysis

Dried sediment samples (400 g) were mixed with 300 mL of a concentrated saline solution of NaCl (density = 1.15 g mL^{-1}) for density separation in order to separate micro plastic-debris in the sediments prior to counting, weighing and identification. The solution was shaken for 3 min and allowed to settle for at least 2 h, depending on observed clearing of the sediment from suspension. All residual solids were transferred to a sieve and sieving was repeated until all floating debris was collected. The supernatant was then digested to remove organic components from the sediment. Then, 20 mL of aqueous 0.05 M Fe(II) solution ($FeSO_4 \cdot 7H_2O$) was added to the beaker containing micro plastic-debris, followed by 20 mL of 30% H_2O_2 for 5 min at room temperature for wet peroxide oxidation.

The process was continued on a hot plate at 75ºC until no natural organic material was visible [1]. Then, the solution was filtered using filter paper no. 4 (Millipore) (20 µm) with a filtration unit and vacuum pump. The particles retained on the filter paper were then used for color and shape analysis. This density separation method [1] using saline solution (NaCl) is sited to separate low-density plastics such as polyethylene (0.91-0.97 g mL^{-1}), polypropylene (0.94 g mL^{-1}), and polystyrene (1.05 g mL^{-1}) from higher-density non-plastic particles, but unsuitable for high density plastic polymers (polyvinyl chloride and polyethylene terephthalate) [4].

For visual analysis of micro plastic-debris, an Olympus CX 31 stereomicroscope at 40x magnification was used to count and identify the shape and color of microplastic objects. All objects visually identified were counted and categorized into different types: hard plastics, soft plastics (e.g., foams), films, lines, fibers, sheets and other. Precautions were taken to minimize sample contamination. In this study, the abundance of microplastics is expressed as mass concentration (number or items per sediment area, items m^{-2}).

4) Statistical analysis

All data were analyzed using ANOVA and a two-way ANOVA was conducted with the plastic sizes (micro, meso, and macro plastic-debris) and sampling locations as fixed effects and replication as a random effect at $p \leq 0.05$ for all statistical tests.

Results and discussion

1) Abundance and density of plastic-debris

The abundance of macro, meso and micro plastic-debris in the three selected beaches is summarized in Figure 2. The results indicate that Patong Beach had the highest concentration (items m^{-2} quadrat) for all plastic-debris sizes (macro, meso and micro) as compared to Kalim and Tri Trang Beaches. Microplastic debris abundance (items m^{-2} areas of quadrate) in Patong Beach was widespread and spatially variable with the range of 7 to 35 items m^{-2} quadrat. In contrast, microplastic debris abundances in Kalim and Tri Trang Beaches ranged from 2-13 and 1-14 items m^{-2} areas of quadrat, respectively. The abundance of microplastics on the beaches of Guanabara Bay, Brazil was studied by Carvalho and Neto (2016).

They reported microplastic concentrations ranging from 12-1,300 items m^{-2} on the beaches [2] where Martinhoa et al. (2017) found that the concentration of micro-plastics in beach sediments of the Southern Baltic Sea varied from 25-53 items kg^{-1} at highly urbanized beaches [14].

In comparison, mesoplastic and macroplastic-debris concentrations 1 m^{-2} area in Patong Beach varied from 28-68 and 17-38 items m^{-2}, respectively. Concentrations of all plastic sizes were higher than at other locations due to the high intensity of tourist activity at this central tourist destination. Discarded plastic debris from tourist activity were a major source, as shown in Figure 2. Mesoplastic and macroplastic-debris in Kalim (K1 to K3) and Tri Trang (T1 to T3) Beaches ranged in abundance from 9-27 and 9-22 items m^{-2}; and 1-20 and 12-22 items m^{-2}, respectively. Macro- and meso-plastic items were more frequently seen as compared with microplastics, especially in Patong Beach (Figure 2). Given that land-based sources are was frequently reported as the major contributor [15], the distribution observed in this study may be liked to the close proximity of the Patong sampling site to major entertainment areas, including a high density of hotels, restaurants and bars. This proximity could explain the high contribution of large plastic items as compared to micro-plastics found at the sampling site.

2) Categorization of microplastic debris

Examples of different types of microplastics collected from the three selected sampling locations are illustrated in Figure 3. The samples may be divided into 7 types according to the categorization framework of the NOAA Marine Debris Program (2015): hard plastics, soft plastics (e.g., foams), films, lines, fibers, sheets and other [1]. In this study, three main types of microplastics were identified: fibers, other, and sheets. Fibers were predominant within the micro-plastic components of the samples, especially in Tri Trang (5-15 items) Patong (1-15 items), and Kalim (6-11 items). The highest numbers of all three types were found at Patong Beach, which coincided with the highest intensity of tourist activity. Fibers are derived mainly from broken safeguard lines, plastic ropes and personal care products [3]. Browne et al. (2011) suggested that a large proportion of microplastic fibers found in the marine environment may originate sewage, as a consequence of washing of clothes made from synthetic materials such as polyester or nylon [3]. Fibers have also been identified in microplastics samples found on the beaches of Guanabara Bay, southeastern Brazil, accounting for 7.2% of the total [2], and was also predominant as a component of microplastics found in marine bottom and beach sediments in the brackish Baltic Sea, Poland [16].

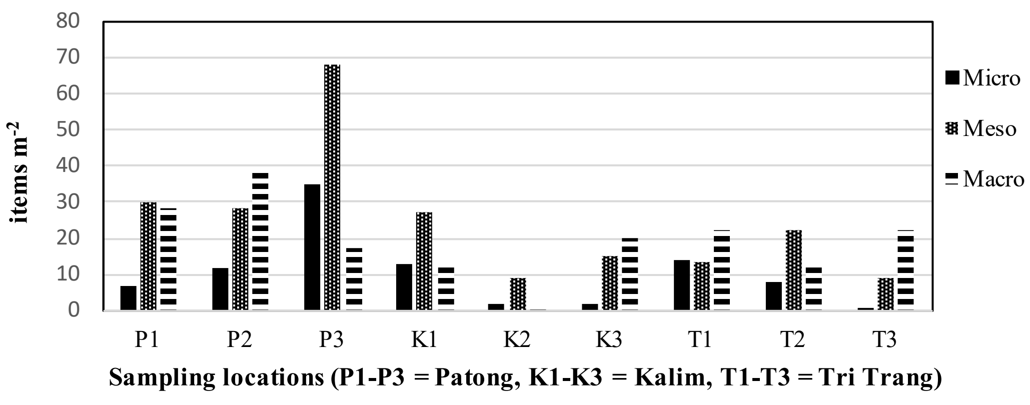

Figure 2 Abundance (items m^{-2} quadrat) of macro-, meso- and micro-plastic debris found in beach sediments.

a) Other b) Sheet c) Fiber

Figure 3 Examples of plastic debris retrieved from the samples.

The result of this study is consistent with previous work such as Lee et al. (2015) who reported that fibers represent the dominant component of macro-plastics found in plastic marine debris (54.7%) at 12 beaches in South Korea, collected during 2013 and 2014 [17]. However, the study of Kazmiruk et al. (2018) reported smaller numbers of microfibers (100-300 kg^{-1} dry sediment) as compared to microbeads, which were found in higher amounts (up to 25,000 kg^{-1} dry sediment) at 16 sites used as growing areas for the Pacific oyster (Crassostrea gigas) within Lambert Channel and Baynes Sound, British Columbia in Canada [12].

Such microbeads may derive from physical breakdown of primary plastics and fragments, films and plastic bags into smaller fragments [2]. The current study found that the microplastic-debris shape classified as 'other' was the second most dominant category on Patong Beach (2-6 items) followed by Tri Trang Beach (0-3 pieces). As with fibers, these microplastics are likely to originate from land-based human activity [12]. Plastic debris found in the sediments of Rameswaram Island, Gulf of Mannar, India- a densely populated coral island, also exhibited a dominance of white-colored and irregular-shaped (other) plastic debris due to tourist activities and fishing [18].

The third most frequent type of micro-plastic found in this study were 'sheets', which are widely used in manufacturing of plastic products, and are readily dispersed via waterways to the sea.

3) Color of microplastic debris

Microplastic debris was seen in a wide variety of colors. This is significant because color represents an important factor affecting food selection among aquatic organisms. Microplastics are ingested by a variety of aquatic organisms either through accidental consumption or by active selection due to misidentification as food [9]. It is possible that color may play a part in this misidentification [19]. In this study, the microplastic debris was divided into 7 color categories: white/transparent, yellow/orange, pink/red, green, blue, purple, and black/brown/grey. The results indicate that green, pink/red and blue were the predominant colors of microplastic debris found in the studied beaches (Figure 4). However, this differed among the three sites. At Patong Beach, 33% of micro-plastics found were green in color, with white/transparent and pink/red contributing 30% and 23%, respectively (Figure 4a). Tri Trang Beach exhibited the same trend, with green micro-plastics representing 29% of the total, followed by white/transparent

(23%) and pink/red (22%) (Figure 4c). In contrast, at Kalim Beach, blue was predominant (52%), followed by pink/red (18%) and green (17%) (Figure 4b). Young and Elliott (2016) found that most common plastic color of sediment samples from Hawaiian beaches (Kahuku Beach and Kamilo Beach) were white/transparent (71.8%) followed by blue (8.5%), green (7.5%), black/grey (7.3%), and red/pink (2.6%) [20]. In order to identify the sources and the types of microplastic, qualitative analysis of the structures of the polymers would be required using methods such as attenuated total reflectance-Fourier transform infrared spectro-scopy (ATR-FTIR).

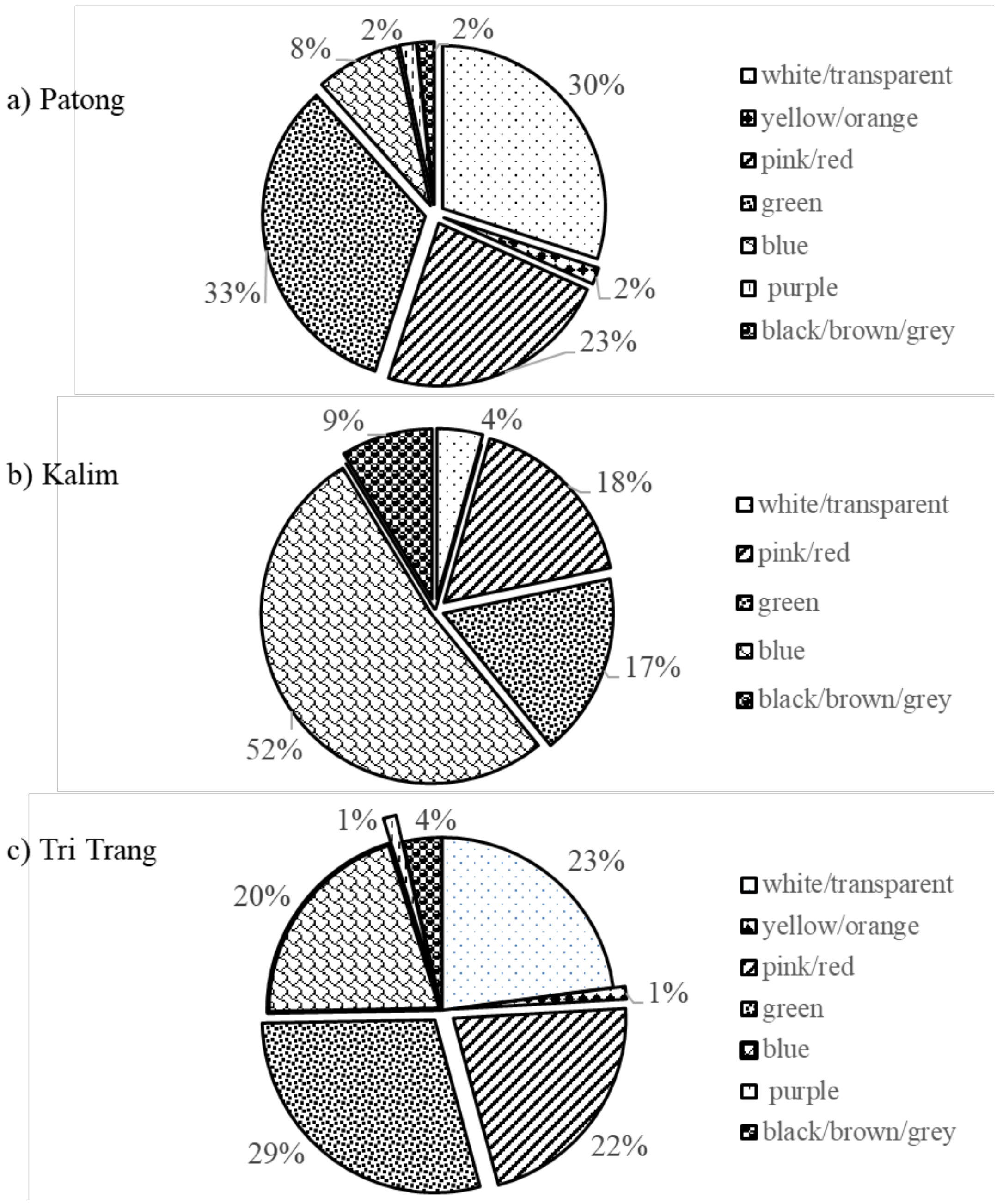

Figure 4 Colors of microplastic debris found on the beaches of a) Patong, b) Kalim, and c) Tri Trang Beach.

Conclusion

Plastics debris are widely distributed globally and are now ubiquitous in the world's marine environment. Concentrations and composition varied considerably among sampling locations at three beaches in Phuket Province. This study found that Patong Beach had higher levels of plastic debris than Kalim and Tri Trang Beaches due to heavy tourism pressure and recreational activities. The sampling location at Patong Beach was also close to point sources of plastic pollution, pointing to a relationship between population density and concentration of microplastic debris. The majority of microplastic debris found in the samples was comprised of fiber, especially at Kalim Beach; these are likely to have originated primarily from ropes, safeguard lines, personal care products and fishing materials. The predominant color of microplastic debris found in Patong and Tri Trang Beaches was green, whiles blue was predominant at Kalim Beach. Advanced identification techniques, especially for very small plastic pieces, should be conducted to improve accuracy of estimation and cast further light on the provenance of microplastics found in marine environments. This can then provide a basis for development of long-term management plans to minimize this long-term threat to our oceans.

Acknowledgements

The author would like to express sincere thanks to the Faculty of Technology and Environment, Prince of Songkla University, Phuket Campus in terms of facilities and scientific equipment.

References

[1] NOAA Marine Debris Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Laboratory methods for the analysis of microplastics in the marine environment: Recommendations for quantifying synthetic particles in waters and sediments, 2015.

[2] Carvalho, D.G., Neto, J.A. Microplastic pollution of the beaches of Guanabara Bay, Southeast Brazil. Ocean & Coastal Management, 2016, 128, 10-17.

[3] Browne, M.A., Dissanayake, A., Galloway, T.S., Lowe, D.M., Thompson, C.R. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). Environmental Science & Technology, 2008, 42(13), 5026-5031.

[4] Jang, Y.C., Lee, J., Hong, S., Lee, J.S., Shim, W.J., Song, Y.K. Sources of plastic marine debris on beaches of Korea: More from the ocean than the land. Ocean Science Journal, 2014, 49(2), 151-162.

[5] McDermid, K.J., McMullen, T.L. Quantitative analysis of small-plastic debris on beaches in the Hawaiian Archipelago. Marine Pollution Bulletin, 2004, 48(7-8), 790-794.

[6] Wright, S.L., Thompson, R.C., Galloway, T.S. The physical impacts of microplastics on marine organisms: A review. Environmental Pollution, 2013, 178, 483-492.

[7] Duis, K., Coors, A. Microplastics in the aquatic and terrestrial environment: Sources (with a specific focus on personal care products), fate and effects. Environmental Sciences Europe, 2016, 28(1), 1-25.

[8] Ogunola, O.S., Palanisami, T. Microplastics in the marine environment: Current status, assessment methodologies, impacts and solutions. Journal of Pollution Effects & Control, 2016, 4(2), 1-13.

[9] Nelms, S.E., Galloway, T.S., Godley, B.J., Penelop, D.S.J., Lindeque, K. Investigating microplastic trophic transfer in marine top predators. Environmental Pollution, 2018, 238, 999-1007.

[10] 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. Marine Pollution Bulletin, 2017, 23(1-2), 92-96.

[11] Thushari, G.G.N., Senevirathna, J.D.M., Yakupitiyage, A., Chavanich, S. Effects of microplastics on sessile invertebrates in the eastern coast of Thailand: An approach to coastal zone conservation. Marine Pollution Bulletin, 2017, 124(1), 349-355.

[12] Kazmiruk, T.N., Kazmiruk, V.D., Bendell, L.I. Abundance and distribution of microplastics within surface sediments of a key shellfish growing region of Canada. PloS One, 2018, 13(5), e0196005.

[13] Marine and Coastal Resources Research and Development Institute and Faculty of Marine Technology, Burapha University. Complete report, survey and classification of micro-plastic wastes, 2014. [Online] Available from: https://www.dmcr.go.th/upload/dt/file/file-3095-201705161494905397559.pdf. (in Thai)

[14] Martinhoa, G., Balaia, N., Piresab, A. The Portuguese plastic carrier bag tax: The effects on consumers' behavior. Waste Management, 61, 2017, 3-12.

[15] Gomiero, A., Strafella, P., Fabi G. From macroplastic to microplastic litter: Occurrence, composition, source identification and interaction with aquatic organisms. experiences from the Adriatic Sea. http://dx.doi.org/10.5772/intechopen.81534

[16] Graca, B., Szewc, K., Zakrzewska D., Dołęga, A., Szczerbowska-Boruchowska, M. Sources and fate of microplastics in marine and beach sediments of the Southern Baltic Sea-a preliminary study. Environmental Science and Pollution Research, 2017, 24(8), 7650-7661.

[17] Lee, J., Lee, J.S., Jang, Y.C., Hong, S.Y., Shim, W.J., Song, Y.K., …, Hong, S. Distribution and size relationships of plastic marine debris on beaches in South Korea. Archives of Environmental Contamination and Toxicology, 2015, 69, 288-298.

[18] Vidyasakar, A. Neelavannan, K., Krishnakumar, S., Prabaharan, G., Sathiyabama A.P.T., Magesh, N.S., …, Srinivasalu, S. Macrodebris and microplastic distribution in the beaches of Rameswaram Coral Island, Gulf of Mannar, Southeast coast of India: A first report. Marine Pollution Bulletin, 2018, 137, 610-616.

[19] Wright, S.L., Thompson, R.C., Galloway, T.S. The physical impacts of microplastics on marine organisms: A review. Environmental Pollution, 2013, 178, 483-492.

[20] Young, A., Elliott, J. Characterization of microplastic and mesoplastic debris in sediments from Kamilo Beach and Kahuku Beach, Hawai'i. Marine Pollution Bulletin, 2016, 113, 477-482.