Ramkhamhaeng International Journal of Science and Technology (2020) 3(3): 1-12

ORIGINAL PAPER

Accumulation of microplastics in zooplankton from Chonburi Province, the Upper Gulf of Thailand

Darika Buathong*[,a], Pronsiri Sriwisait[a], Sittiporn Pnengsakun, Charernmee Chamchoy[a], Orathep Mue-suae[a], Supphakarn Phoaduang[a], Montaphat Thummasan[b], Duangkamon Sangiamdee[c], Thamasak Yeemin[a], Makamas Sutthacheep[a,*]

[a]Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok, Thailand
[b]Green Biology Research Division, Research Institute of Green Science and Technology, Shizuoka University, Shizuoka 422-8529, Japan
[c]Department of Chemistry, Faculty of Science, Ramkhamhaeng University, Bangkok, Thailand 10240

*Corresponding author: *smakamas@hotmail.com*

Received: 18 August 2020 / Revised: 2 September 2020 / Accepted: 9 September 2020

Abstract : Microplastics particles cannot be digested by marine organisms, causing physiological problems to different animals worldwide. Zooplankton can ingest microplastic and introduce it into the food web, causing bioaccumulation from basic to top levels, which can later reach humans consumers. We investigated the characteristics and abundance of microplastics ingested by different groups of zooplankton. The samples were collected by using 120 μm mesh plankton net with a mouth diameter 30 cm, by horizontal hauls. Later analyzed under a stereomicroscope and identified by using Fourier transform infrared spectroscopy (FTIR). Microplastics were detected at all dominant zooplankton groups here: chaetognaths, shrimp larvae, cyclopoid copepods, calanoid copepods, and cirripedia nauplius, except for harpacticoid copepods. The highest abundance of microplastics was found in cirripedia nauplius with 1.15 particles per individual, followed by cyclopoid copepods with 0.5 particles per individual. All microplastics found were fibrous, ranging from 0.1 to 0.5 mm in length. The majority (87.7%) were blue. A total of 63.9% of the microplastics come from polyethylene terephthalate, while 27.9% come from polyurethane, and only 8.2% are rayon. We found evidence that zooplankton ingests microplastic in the Upper Gulf of Thailand, potentially introducing it into the local food web. A higher abundance of particles from PET origin evidence a high level of domestic trash and land bourne microplastics, possibly carried by the rivers to ocean waters. worldwide, this study indicates its presence in zooplankton of the Upper Gulf of Thailand, and urgent measures are needed to prevent human consumption and related health problems.

Keywords: Gulf of Thailand, ingestion, microplastics, zooplankton

1. Introduction

Plastic is considered the wonder product of the last century due to its cheap manufacturing cost, durability, and flexibility. Currently, the annual global production of plastics has increased from 1.5 million tons in the 1950s to>335 million tons in 2016 (PlasticsEurope, 2018). Plastic bags, fishing gear, food containers, and drinks are the most common waste ingredients that are transported to the oceans by rivers, coastal town sewers, floods, and winds and contaminate beaches and resorts (Zhou et al., 2018). The inadequate disposal plan, accidental loss, and fragmentation of larger plastics have contributed to the increasing accumulation of tiny plastic particles and fibers (<5 mm) in the environment (Cole et al., 2011; UNEP, 2016), with plastic now contributing up to 80% of all marine debris (Barnes et al., 2009). Microplastics primarily originate from manufactured items of microscopic size (e.g., exfoliates in cosmetics products) or secondary items derived from the biological and mechanical breakdown of microplastics.

Plastic pollution is a global level environmental issue (Thompson et al., 2004; Cole et al., 2011; Rochman, 2018; Botterell et al., 2019). Plastics debris are widely found in marine environments, including coastal zones, estuaries, open ocean, the deep sea, and polar marine environments (Van Cauwenberghe et al., 2013; Cozar et al., 2014; Turra et al., 2014; Lusher et al., 2015; Tang et al., 2018). Being similar in size to natural food items and suspended organic particles, microplastics can be ingested by a variety of marine organisms such as zooplankton, sea cucumber, decapods, mussels, lugworms (Graham and Thompson, 2009; Murray and Cowie, 2011; Cole et al., 2013; Farrell and Nelson, 2013; Setälä et al., 2014; Van Cauwenberghe et al., 2015; Sun et al., 2017, 2018a, 2018b;) and fishes (Lusher et al., 2013; Rochman et al., 2013). In addition, Gall and Thompson (2015) reported encounters between organisms and marine debris for a total of 693 species; of this debris, 92% were plastics. Marine organisms can unintentionally ingest microplastics, whether capturing them while filter- or deposit-feeding, mistaking them for preys when foraging, or even by ingesting organisms of lower trophic levels contaminated with these particles, i.e., trophic transfer (GESAMP, 2015). As a consequence, plastics are now considered as the most common and persistent pollutants, which ultimately end up in the coastal and oceanic environment through numerous pathways, including riverine and atmospheric transport, beach littering, via aquaculture, shipping, and fishing activities (Lebreton et al., 2017; Villarrubia-Gomez et al., 2017). Given the exponentially increasing demand and insufficient waste management, coupled with the resistance of synthetic polymers to environmental degradation, it is expected that the marine plastic inventory will continue to increase for a few more decades (Jambeck et al., 2015). However, few studies reported ingestion of microplastics by zooplankton in Thailand and the presence of microplastics in coral reefs adjacencies. This study aims to investigate the characteristics and abundance of microplastics ingested by different groups of zooplankton on a beach in the Upper Gulf of Thailand.

2. Materials and Methods

2.1 Study site and samples collection

This study was carried out at Ao Bang Lamung, a beach near an industrial complex on Chonburi Province, the Upper Gulf of Thailand, in 2019 (Figure .1). The zooplankton samples were collected by horizontal tows using a standard 120 μm mesh plankton net with a mouth diameter of 30 cm with 5 meters depth. Zooplankton samples were preserved in formaldehyde for cell counts. Zooplanktons were identified group and counted the number of cells by using a stereomicroscope. The form and density of microplastics were assessed in at least 20 individuals of each zooplankton group.

2.2 Extraction of MPs from zooplankton

The zooplankton samples were cleaned with distilled water two to three times to ensure no plastic was attached to their body surface. Then, rinsed zooplankton of each group was transferred to a 20-ml scintillation vial for storage. The zooplankton samples were treated with 30% hydrogen peroxide (H_2O_2) and heated up to 55-65 ºC until they were completely digested. Microplastics particles were separated from the digested samples by flotation in saturated sodium chloride solution (250 g/ml) (Mathalon and Hill, 2014). After 24h of floatation at room temperature, the overlying water was vacuum filtered through a 20 μm pore size filter. Several blanks containing only H_2O_2 in an empty vial were run to correct for potential air-borne particle deposition in the laboratory. No contamination of blanks was observed during the experiments. Each filter was placed into a clean glass petri dish for observation under a stereoscopic microscope and photographed with a digital camera.

2.3 Microplastics Identification and Qualification

The microplastics samples on the membrane were observed under a stereomicroscope.

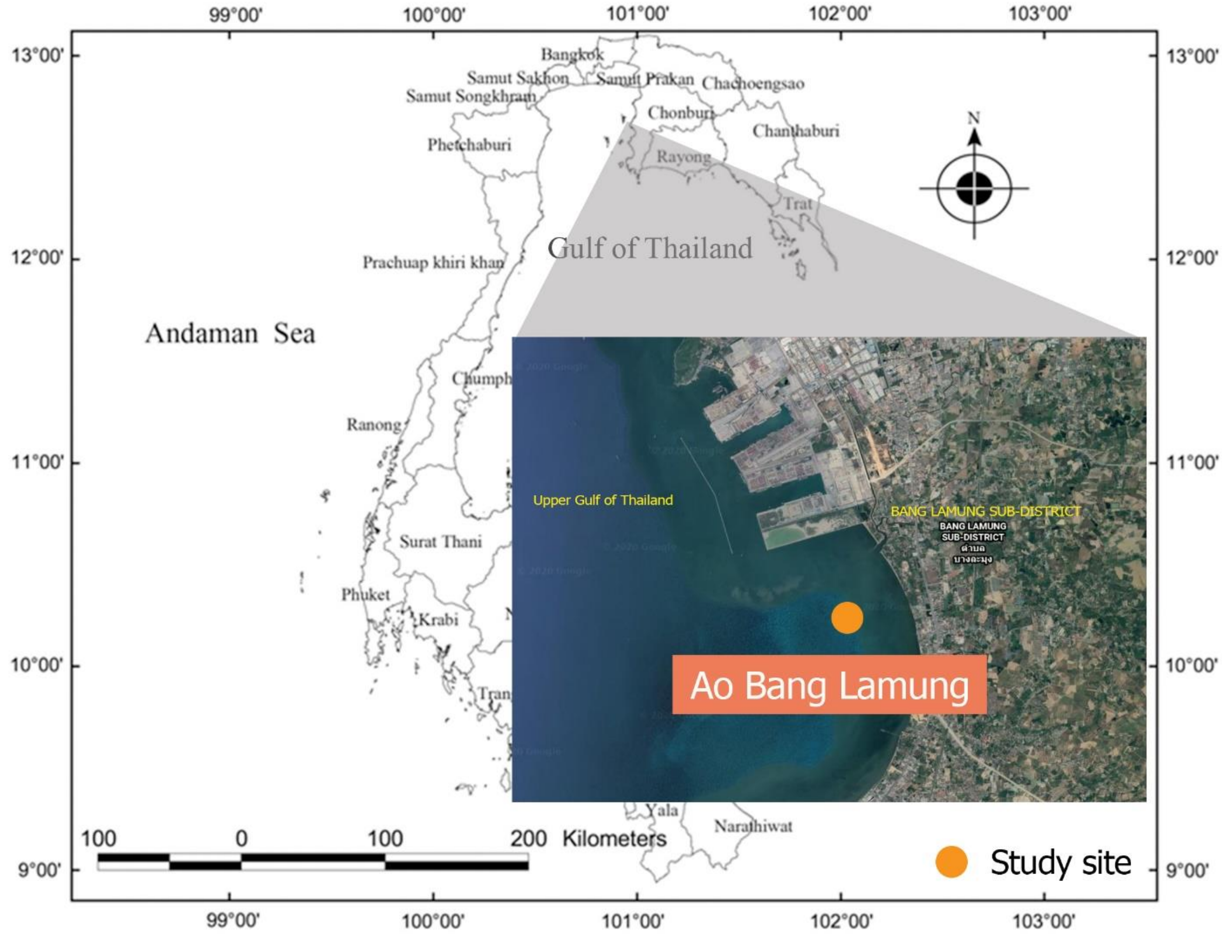

Figure 1 Map of Ao Bang Lamung, the Upper Gulf of Thailand showing the locations of the study

All plastic particles were used to record the microplastic's quantity, color, shape, and size. Microplastic particles were further identified by using Fourier transform infrared spectroscopy (FTIR). The polymer types were identified by comparing the sample spectra with FTIR spectral libraries.

2.3 Data Analysis

Due to the high amount of zeros in samples, differences of microplastics abundance among zooplankton groups were examined by Kruskal-Wallis Rank Sum test in R, package "stats" version 3.6.1, and the post-hoc Dunn's Multiple Comparisons test, package "FSA" version 0.8.30, was used to analyze differences between groups.

3. Results

The density of zooplankton ranged between 42 and 6,166 individual m^{-3}, while size of zooplankton were ranged 0.8 to 5.2 mm (Table 1) Six dominant zooplankton groups were selected for microplastics analysis under a stereomicroscope, i.e. chaetognaths, shrimp larvae, harpacticoid copepods, cyclopoid copepods, calanoid copepods and cirripedia nauplius. These six major groups accounted for over 84% of total zooplankton abundance. Microplastics were detected in all zooplankton groups examined except for harpacticoid copepods. The abundance of microplastics significantly varied across zooplankton groups (Figure 2) and the highest abundance of microplastics were found in cirripedia nauplius (1.15 ±0.05 particles/ind.) followed by cyclopoid copepods (0.50 ±0.03 particles/ind.), calanoid copepods (0.45 ±0.04 particles/ind.), shrimp larvae (0.45 ±0.03 particles/ind.) and chaetognaths (0.30 ±0.02 particles/ind.) while no microplastic was detected in harpacticoid copepod. (Figure .2).

The shape of all microplastics in zooplankton consisted of fibers. Mostly, the length of the microplastic particles ranged from 100 μm to 500 μm. Across all zooplankton groups, approximately 87.7% of the microplastics were blue, followed by red (8.7%), brown and red (1.8%) plastics also well represented (Figure .4 and 5).

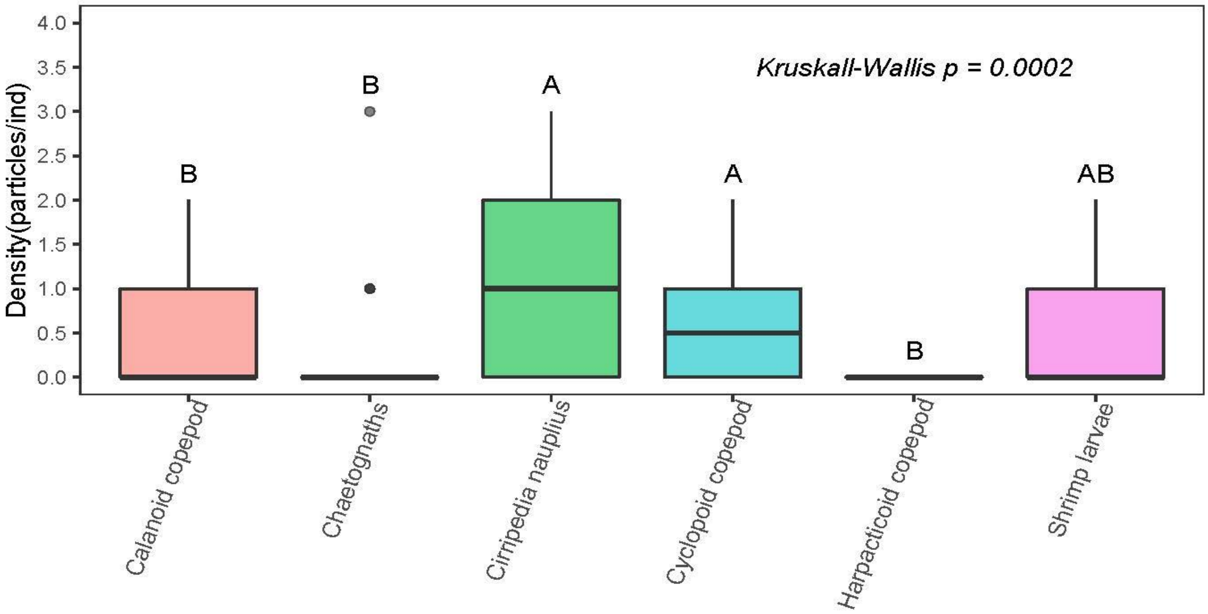

Figure .2 The number of microplastics in different zooplankton groups

Chaetognath Shrimp larva Harpacticoid copepod

Cyclopoid copepod Calanoid copepod Cirripedia nauplius

Figure .3 Dominant zooplankton in the study site

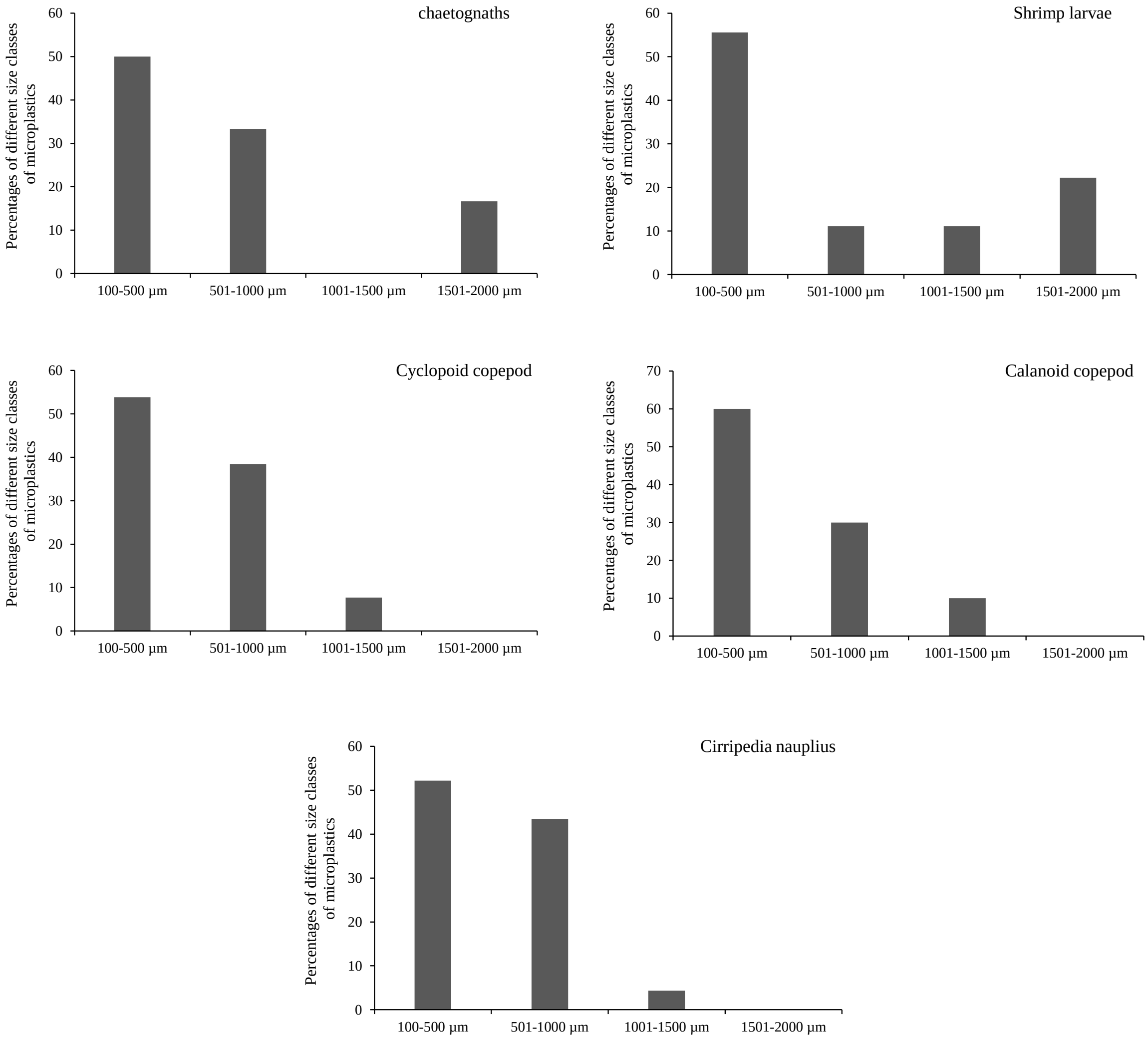

Figure .4 Size composition of microplastics in zooplankton

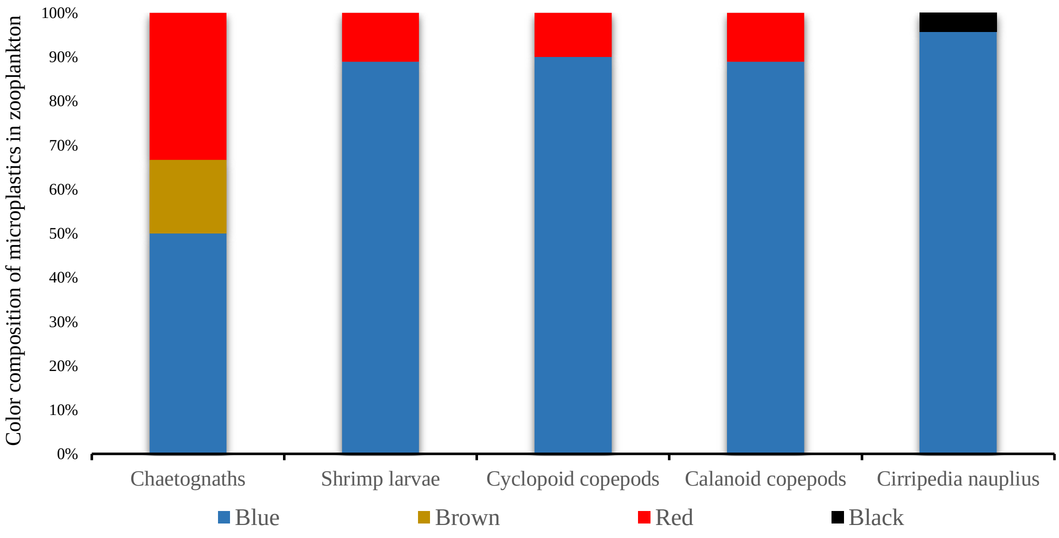

Figure .5 Color composition of microplastics in zooplankton at Ao Bang Lamung

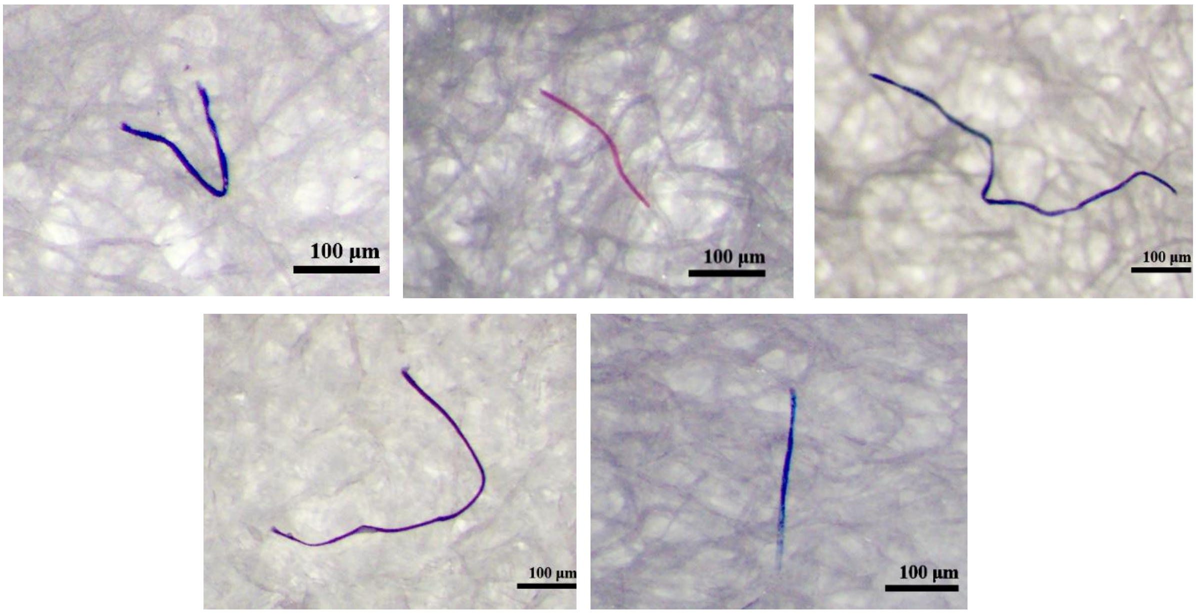

Figure .6 Type and size of microplastics found in zooplankton at Ao Bang Lamung

Table 1 Characteristic of plastic ingested by zooplankton collected from all zooplankton groups.

Zooplankton group	Density of zooplankton (individual m^{-3})	Average size of zooplankton (mm)	Average size of microplastics (µm)	Frequency of occurrence (%)
Chaetognaths	42.7±5.1	3.3±0.5	656.7±617.9	20
Shrimp larvae	153.3±18.3	2.6±0.5	327.7±319.4	35
Harpacticoid copepod	625.6±74.9	0.9±0.1	Not found	Not found
Cyclopoid copepod	2163.7±257.5	0.8±0.5	517.9±319.9	30
Calanoid copepod	6166.7±740.8	1.1 ± 0.1	458.6±311.3	50
Cirripedia nauplius	4300.7±516.6	0.8 ± 0.2	526.3±360.49	45

Characteristic and size particles of microplastics in zooplankton were shown in Figure .6. The FTIR microscope analysis of the 61 representative microplastics (6 particles from chaetognaths, 9 particles from shrimp larvae, 13 particles from cyclopoid copepod, 10 particles from calanoid copepod, and 23 particles from cirripedia nauplius) was identified and classified into three polymer categories: polyethylene terephthalate, polypropylene, and rayon. The dominant polymers in the zooplankton group were polyethylene terephthalate (63.9%), followed by polyurethane (27.9%) and rayon (8.2%) (Figure .7).

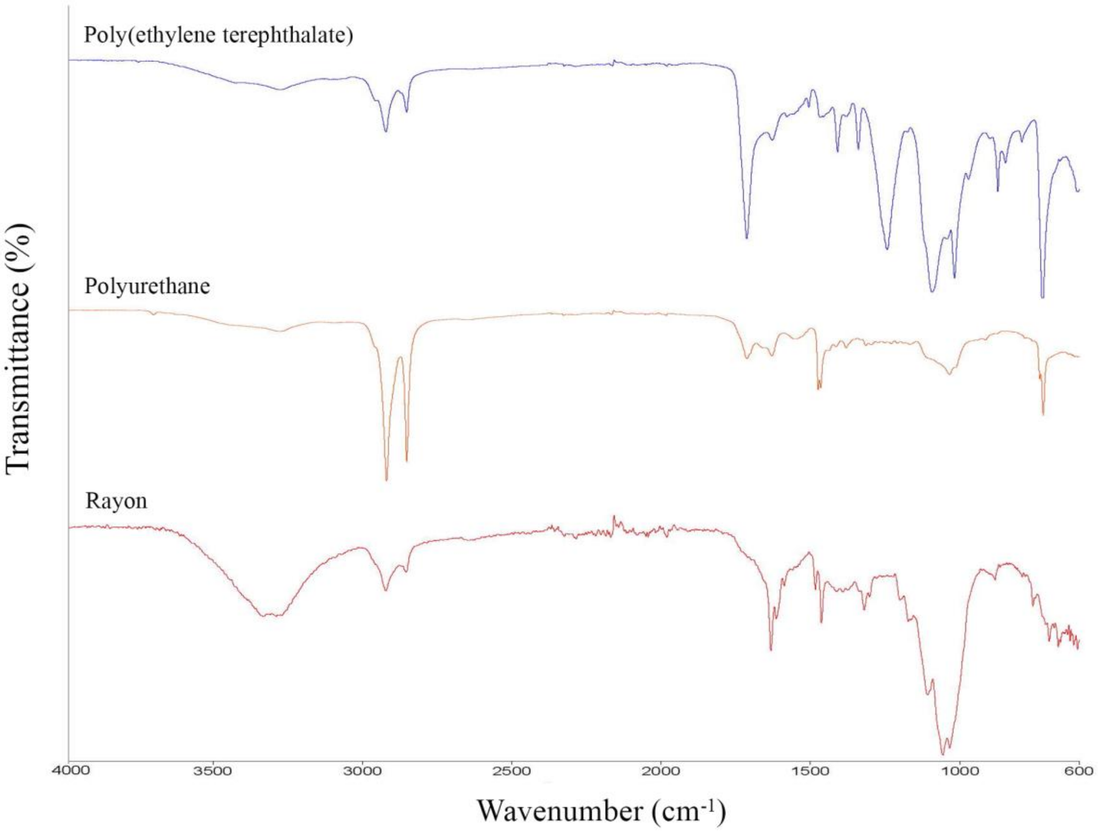

Figure .7 FTIR spectra of the selected microplastic particles

4. Discussion

Detection of microplastics in most zooplankton groups depicts its bioavailability within this community. Given that zooplanktons are the primary consumers in the marine food chain, they are susceptible to the hazardous effects of microplastics litters due to accidental ingestion (Botterell et al., 2019). In this study, microplastics were detected in zooplankton around Ao Bang Lamung, Chonburi Province, the Upper Gulf of Thailand, indicating microplastic contamination in these areas. The microplastic abundance in zooplankton are in accordance with previous studies reported in the Yellow Sea (0.07-1.17 particles/ind; Sun et al., 2018a), but slightly higher than that in the Northeast Pacific Ocean (0.03-0.06 particles/ind; Desforges et al., 2015), Portuguese coastal waters (0.04-0.14; Frias et al., 2014), Kenya's marine environment (0.16-0.46; Kosore et al., 2018) and Terengganu coastal waters (0.003-0.14; Amin et al., 2020). Significant differences were observed in the number of microplastic among the different zooplankton groups. Zooplankton lifestyle/feeding habits can influence microplastic ingestion. It has been reported that omnivorous and carnivorous zooplankton are more susceptible to accidental microplastic ingestion or accumulation via contaminated prey species than herbivores (Sun et al., 2017, 2018b). In a planktonic food web, fish larvae are positioned above copepod and chaetognath, and they predominantly feed on smaller zooplankton, thereby increasing their chances of microplastic ingestion.

Microplastic ingestion by marine organisms occurs accidentally and mainly depends on the abundance and debris size (Rodríguez-Seijo and Pereira, 2017). The present results showed microplastics ingested have a similar size range from those reported in the Northeast Pacific; 555.5-816.1 (Desforges et al., 2015); the Northern South China Sea; 125-167 μm (Sun et al., 2017) and Terengganu coastal waters 49.5-1135 μm (Amin et al., 2020). Further, many planktons lack the prey selectivity and feed on anything of its palatable size (Moore, 2008). Sun et al. (2017) recorded a 30 fold higher microplastic ingestion by smaller-sized zooplankton (collected with the net of 160 μm mesh) than the larger-sized group (collected with the net of 505 μm mesh size). On the other hand, Christaki et al. (1998) found that the size of microplastic fibers played a crucial role in the clearance rate in ciliate Strombidium and plastic microsphere (0.75 μm) were indistinguishable from fluorescently labeled algae cells. Some zooplankton like calanoids, shrimps, and fish larvae can feed on prey items that can reach lengths of up to 1.54 mm (Baier and Purcell, 1997).

The composition of microplastic particles in zooplankton at Ao Bang Lamung indicated that the zooplankton tended to ingest relatively small fibers. These results showed a similar report in coastal areas of China (Sun et al., 2017, 2018a, 2018b) and the Bohai Sea (Zheng et al., 2020). The microplastics particles were mainly composed of blue color, which was consistent with the color composition of microplastics in the seawater. Blue has also been reported as the most dominant fiber color in marine areas such as the Swedish west coast, the Northeast Atlantic Ocean, and the South African coast (Norén, 2007; Lusher et al., 2014; Nel and Froneman, 2015). The color and shape of microplastics may affect the ingestion choices of marine organisms (Boerger et al., 2010; Wright et al., 2013). According to the review of Gago et al. (2018), blue is the most common microplastics color in seawater and sediments because blue plastic products are very common and are often used in fishing nets, ropes, and other fishing gear.

Three different types of microplastics were detected in the present study, of which polyethylene terephthalate (PET) showed the highest ingestion in the zooplankton. PET is one of the most widely used and commonly identified plastic polymers in various marine habitats globally, and our results are consistent with earlier reports (Murray and Cowie, 2011; Patterson et al., 2019). For instance, polyethylene terephthalate is widely used in fibers for clothing, containers for liquids and foods, thermoforming for manufacturing, combination with glass fiber for engineering resins, and most of the nets used in marine fisheries.

Knowledge on the mechanism of microplastic transfer across the food web and implications on their health remains unclear. Setälä et al. (2014) reported that microplastics could be transferred via planktonic organisms to higher trophic levels; in addition, the transfer of microplastics between trophic levels has also been demonstrated among adult marine invertebrates (Spear et al., 1995; Graham and Thompson, 2009; Murray and Cowie, 2011; Rochman et al., 2013; Sun et al., 2018b). This indicates the bioaccumulation potential of these contaminants, as predatory fish have also been found to contain microplastic (Avio et al., 2015; Zhang et al., 2016; Murphy et al., 2017). This study further justifies the importance of following studies on microplastic ingestion by plankton, extending the sample collection both spatially and temporally, as zooplankton abundance and distribution may vary based on locality and season. To conclude, the results from this study have successfully shown that zooplankton sampled at Ao Bang Lamung in the Upper Gulf of Thailand was able to ingest microplastics.

Acknowledgements

We are most grateful to the staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University, for their fieldwork assistance. This research was funded by a budget for research promotion from the Thai Government to Ramkhamhaeng University and partly supported by the Coral & Coastal Conservation Foundation.

References

Amin RM, Sohaimi ES Anuar, ST Bachok Z (2020) Microplastic ingestion by zooplankton in Terengganu coastal waters, southern South China Sea. Marine Pollution Bulletin 150:110616

Avio, C. G., Gorbi, S., & Regoli, F. (2015) Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. Marine environmental research 111:18-26

Baier CT, Purcell JE (1997) Trophic interactions of chaetognaths, larval fish, and zooplankton in the South Atlantic Bight. Marine Ecology Progress Series 146:45-53

Barnes DKA, Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of The Royal Society B: Biological Sciences Biological Sciences 364(1526):1985-1998

Boerger CM, Lattin GL, Moore SL, Moore CJ (2010) Plastic ingestion by planktivorous fishes in the North Pacific central gyre. Marine Pollution Bulletin 60:2275-2278

Botterell ZLR, Beaumont N, Dorrington T, Steinke M, Thompson RC, Lindeque PK (2019) Bioavailability and effects of microplastics on marine zooplankton: A review. Environmental Pollution 245:98-110

Christaki U, Dolan JR, Pelegri S, Rassoulzadegan F (1998) Consumption of picoplankton- size particles by marine ciliates: effects of physiological state of the ciliate and particle quality. Limnology and Oceanography 43(3):458-464

Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J, Galloway TS (2013) Microplastic ingestion by zooplankton. Environmental Science & Technology 47(12):646-6655

Cole M, Lindeque P, Halsband C, Galloway TS (2011) Microplastics as contaminants in the marine environment: a review. Marine Pollution Bulletin 62:2588-2597

Cozar A, Echevarria F, Gonzalez-Gordillo JI, Irigoien X, Ubeda B, Hernandez-Leon S, Palma AT, Navarro S, Garcia-de-Lomas J, Ruiz A, Fernandez-de-Puelles ML, Duarte CM (2014) Plastic debris in the open ocean. Proceedings National Academy of Sciences, USA, pp 10239-10244

Desforges JPW, Galbraith M, Ross PS (2015) Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. Archives of Environmental Contamination and Toxicology 69 (3):320-330

Farrell P, Nelson K (2013) Trophic level transfer of microplastic: Mytilus edulis (L.) to Carcinus maenas (L.). Environmental Pollution 177:1-3

Frias JP, Otero V, Sobral P (2014) Evidence of microplastics in samples of zooplankton from Portuguese coastal waters. Marine Environmental Research 95:89-95

Gago J, Carretero O, Filgueiras AV, Vinas L (2018) Synthetic microfibers in the marine environment: A review on their occurrence in seawater and sediments. Marine Pollution Bulletin 127:365-376

Gall SC, Thompson RC (2015) The impact of debris on marine life. Marine Pollution Bulletin 92:170-179

GESAMP (2015) Sources, fate and effects of microplastics in the marine environment: a global assessment. In: Kershaw PJ (eds) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Report Study, GESAMP, No.90, p 96

Graham ER, Thompson JT (2009) Deposit and suspension feeding sea cucumbers (Echinodermata) ingest plastic fragments. Journal of Experimental Marine Biology and Ecology 368:22-29

Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Narayan R, Law KL (2015) Plastic waste inputs from land into the ocean. Science 347(6223):768-771

Kosore C, Ojwang L, Maghanga J, Kamau J, Kimeli A, Omukoto J, Ndirui E (2018) Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: first documented evidence. African Journal of Marine Science 40(3):225-34

Lebreton LCM, Van Der Zwet J, Damsteeg JW, Slat B, Andrady A, Reisser J (2017) River plastic emissions to the world's oceans. Nature Communications 8(1):1-10

Lusher AL, Burke A, O’Connor I, Officer R (2014) Microplastic pollution in the Northeast Atlantic Ocean: validated and opportunistic sampling. Marine Pollution Bulletin 88(1-2):325-333

Lusher AL, McHugh M, Thompson RC (2013) Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin 67:94-99

Lusher AL, Tirelli V, O’Connor I, Officer R (2015) Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. Scientific Report 5(1):1-9

Mathalon A, Hill P (2014) Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Marine Pollution Bulletin 81(1):69-79

Moore CJ (2008) Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Environmental Research 108(2):131-139

Murphy F, Russell M, Ewins C, Quinn B (2017) The uptake of macroplastic & microplastic by demersal & pelagic fish in the Northeast Atlantic around Scotland. Marine Pollution Bulletin 122(1-2):353-359

Murray F, Cowie PR (2011) Plastic contamination in the decapod crustacean Nephrops norvegicus (Linnaeus, 1758). Marine Pollution Bulletin 62(6):1207-1217

Nel HA, Froneman PW (2015) A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa. Marine Pollution Bulletin 101:274-279

Norén F (2007) Small plastic particles in coastal Swedish waters. KIMO Sweden Report 1-11

Patterson J, Jeyasanta KI, Sathish N, Booth AM, Edward JKP (2019) Profiling microplastics in the Indian edible oyster, Magallana bilineata collected from the Tuticorin coast, Gulf of Mannar, Southeastern India. Science of the Total Environment 691:727-735

PlasticsEurope **(**2018**)** Plastics - The Facts 2017**,** an Analysis of European Plastics Production, Demand and Waste Data, p 16

Rochman CM **(**2018**)** Microplastics research-from sink to source. Science 360(6384):28-29

Rochman CM, Hoh E, Kurobe T, Teh SJ (2013) Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Report 3(1):1-7

Rodríguez-Seijo A, Pereira R (2017) Morphological and physical characterization of microplastics. In Comprehensive Analytical Chemistry 75:49-66

Setälä O, Fleming-Lehtinen V, Lehtiniemi M (2014) Ingestion and transfer of microplastics in the planktonic food web. Environmental Pollution 185:77-83

Spear LB, Ainley DG, Ribic CA (1995) Incidence of plastic in seabirds from the tropical pacific, 1984-91: relation with distribution of species, sex, age, season, year and bodyweight. Marine Environmental Research 40:123-46

Sun X, Li Q, Zhu M, Liang J, Zheng S, Zhao Y (2017) Ingestion of microplastics by natural zooplankton groups in the northern South China Sea. Marine Pollution Bulletin 115(1-2):217-224

Sun X, Liang J, Zhu M, Zhao Y, Zhang B (2018a) Microplastics in seawater and zooplankton from the Yellow Sea. Environmental Pollution 242:585-595

Sun X, Liu T, Zhu M, Liang J, Zhao Y, Zhang B (2018b) Retention and characteristics of microplastics in natural zooplankton taxa from the East China Sea. Science of the Total Environment 640:232-242

Tang GW, Liu MY, Zhou Q, He HX, Chen K, Zhang H, Hu JH, Huang QH, Luo YM, Ke HW (2018) Microplastics and polycyclic aromatic hydrocarbons (PAHs) in Xiamen coastal areas: Implications for anthropogenic impacts. Science of the Total Environment 634:811-820

Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AWG, McGonigle D, Russell A.E (2004) Lost at sea: where is all the plastic? Science 304:838-838

Turra A, Manzano AB, Dias RJS, Mahiques MM, Barbosa L, Balthazar-Silva D, Moreira FT (2014) Three-dimensional distribution of plastic pellets in sandy beaches: shifting paradigms. Scientific reports 4(1):1-7

UNEP (2016) Marine Plastic Debris and Microplastic Technical Report. United Nations Environmental Programme, Nairobi

Van Cauwenberghe L, Devriese L, Galgani F, Robbens J, Janssen CR (2015) Microplastics in sediments: a review of techniques, occurrence and effects. Marine Environmental Research 111:5-17

Van Cauwenberghe L, Vanreusel A, Mees J, Janssen CR (2013) Microplastic pollution in deep-sea sediments. Environmental Pollution 182:495-499

Van Sebille E, Wilcox C, Lebreton L, Maximenko N, Hardesty BD, van Franeker JA, Law KL (2015) A global inventory of small floating plastic debris. Environmental Research Letters 10(12):124006

Villarrubia-Gomez P, Cornell SE, Fabres J (2017) Marine plastic pollution as a planetary boundary threat-the drifting piece in the sustainability puzzle. Marine Policy 96:213-220

Wright SL, Thompson RC, Galloway TS (2013) The physical impacts of microplastics on marine organisms: A review. Environmental Pollution 178:483-492

Zhang K, Su J, Xiong X, Wu X, Wu CX, Liu JT (2016) Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. Environmental Pollution 219:450-455

Zheng S, Zhao Y, Liangwei W, Liang J, Liu T, Zhu M, Li Q, Sun X (2020) Characteristics of microplastics ingested by zooplankton from the Bohai Sea, China. Science of The Total Environment 713:136357

Zhou Q, Zhang H, Fu C, Zhou Y, Dai Z, Li Y, Tu C, Luo Y (2018) The distribution and morphology of microplastics in coastal soils adjacent to the Bohai Sea and the Yellow Sea. Geoderma 322:201-208