Microplastics: Origin, Environmental impact, Food and Beverage contamination and Management methods

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Abstract

Since the production of in the early 1900s to present, there have been ongoing reports on the problems of plastic and microplastic waste contaminated in the environment. Moreover, within the last 10-15 years, the number of reports on microplastics contamination and impact on living organisms have increased in almost every country around the world. This article is a review, report and analysis of the literature on microplastics and with the objectives focusing on 1) Origins and routs of microplastics contamination 2) Potential impact of microplastics on organisms 3) Microplastics in organisms, foods and beverages 4) The situation of micro-plastics in Thailand 5) The process of dealing with microplastics in the environment

Keywords: plastics, microplastics, microbead

Introduction

The first plastic material "Celluloid" was developed in the 1860s by John Wesley Hyatt who discovered the process of melting cellulose nitrate and reacting with camphor under heat, resulting in a tough, flexible, water resistant and moldable plastic material. Celluloid was used to replace natural materials such as ivory, tortoiseshell, and horn for the manufacture of variety products, such as combs, eyeglass frames, piano keys, and billiard balls. However, celluloid tends to soft under heat and is not suitability for the molding method such as injection molding.

In 1907 the first synthetic plastic "Bakelite" or phenol formaldehyde resin was developed by the Belgian-American chemist Leo Hendrik Baekeland. Bakelite is a thermosetting plastic that was not only durable, heat resistant, chemically resistant but also electrical nonconductivity. Due to the properties as mentioned above, Bakelite is used to make handles for kitchen utensils, appliances for various electrical appliances and electrical insulation. Moreover, Bakelite is especially suitable for mass production because it could be shaped or molded into diverse products such as lamps, desk sets, clocks, radios, telephones, kitchenware, tableware, and children's toys. The discovery of Bakelite by Leo Hendrik Baekeland encouraged the search for new synthetic plastics ie: polystyrene in 1929, polyester in 1930, polyvinylchloride (PVC) and polythene in 1933, nylon in 1935.

Plastics are increasingly replacing traditional materials like metal, wood, glass, and paper because of their versatility and their excellent mechanical properties, and their chemical and weather resistance. These attractive characteristics have led to an ever increasing amount of plastic waste, and the serious problem of plastic litter must now be tackled (Punyauppa-path & Pattanapipitpaisal, 2017). Since plastic has been produce and entered everyday life, the world is facing on the problem of increasing plastic wastes. Over the past decade, there has been more and more reports of environmental contamination and impact by microplastics in almost every country around the world. The environmental contamination is caused by discarding the primary microplastics into the environment and also caused by the secondary microplastics which occurred by deterioration and size reduction of plastic waste to a size of 5 millimeters or fewer. At present, distribution of both types of microplastic is found in nature, especially water sources around the world. Moreover, it also can be found in organisms such as plankton, insects, plants and animals.

1. Origins and routs of microplastic contamination in the environment

Microplastics are generally considered to be plastic particles smaller than 5 millimetres in diameter that can be classified according to their origin into primary microplastics and secondary microplastics. Primary microplastics are plastic resins that manufacture from the beginning to be of a microscopic size (smaller than 5 mm). These plastics are typical use for various scrubbing, polishing, cleaning, which can be found in consumer skin care products such as body cleansing, liquid soap, facial cleanser and toothpaste (Figure 1). These resins have been patented since 1980, with the trade name Microbeads, Micro-exfoliates or scrub. These microbeads are manufactured from many different types of plastics such as PE, PP, PET polymethyl methacrylate (PMMA) and nylon in different shape and sizes depending on the usage characteristics. (Gouin, Roche, Lohmann, & Hodges, 2011; Eriksen et al., 2013; UNEP, 2015) In addition, the industry is also uses small plastic resins (plastic grit) made form acrylic, melamine and polyester for scrubbing, cleaning surfaces, rusting or polishing off metal surfaces by using a tool called Air blasting machine. (Derraik, 2002; Cole, Lindeque, Halsband, & Galloway, 2011)

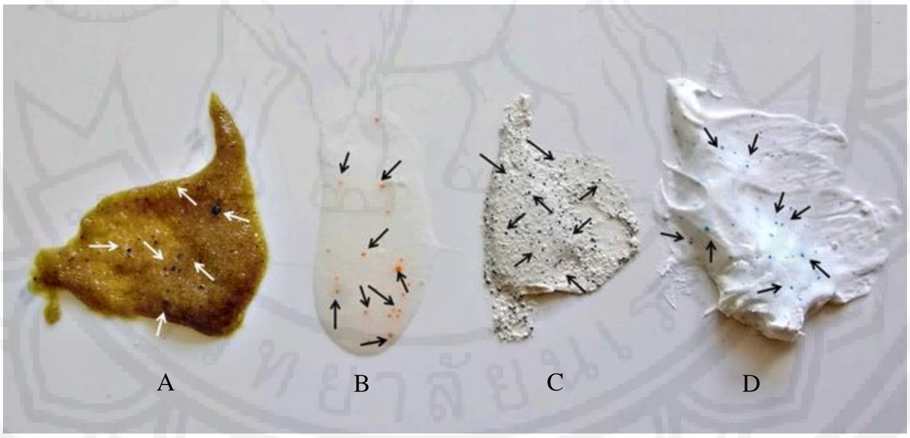

Figure 1 Primary microplastics (arrows) in skin care products and toothpaste A and C = body cleansing, B = facial cleansing and D = toothpaste

While the secondary microplastics caused by the size reducing of plastic wastes in the environment through physical processes, biological processes and chemical processes. These degradation processes make a large plastic items (macroplastics) fracture or tear to a microscopic size (smaller than 5 mm). It also involves broken fiber from the textile manufacturing process, cleaning clothes and discarding plastic fibers used in daily life and fishing gear (Napper, Bakir, Rowland, & Thompson, 2015). Origins of primary and secondary microplastics are shown in figure 2.

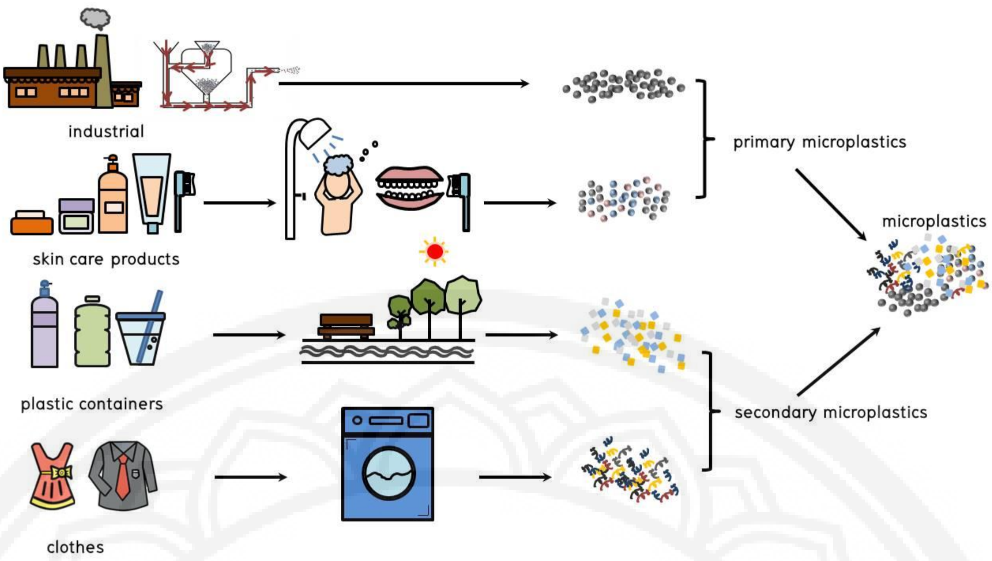

Figure 2 Origins of primary and secondary microplastics

The natural contamination path of primary microplastics can be caused by the use of products containing microplastics and the direct use of microplasticd granules for different purposes including cleaning, polishing rust or dirt from the surface before disposal into wastewater treatment system. Because of their microscopic size, these particles can pass through filtration systems and enter aquatic environments before dispersing to soil and air respectively.

However, the nature contamination route of secondary microplastics differs from primary microplastic. Secondary microplastics cause by fragmentation and size reduction of macroplastics (plastic debris) in nature via physical, biological and chemical processes resulting in plenty of small pieces or particles of plastic. These small pieces or particles of plastic can be transported between environmental compartments (e.g. from land to freshwater and from freshwater to marine environments) and may be ingested by living things in nature. Although, the source and process of contamination of primary and secondary microplastics in nature are different, however these two kinds of microplastics will then gather in natural fresh water resources (rivers or canals) before being transferred to the sea and ocean (as shown in Figure 3)

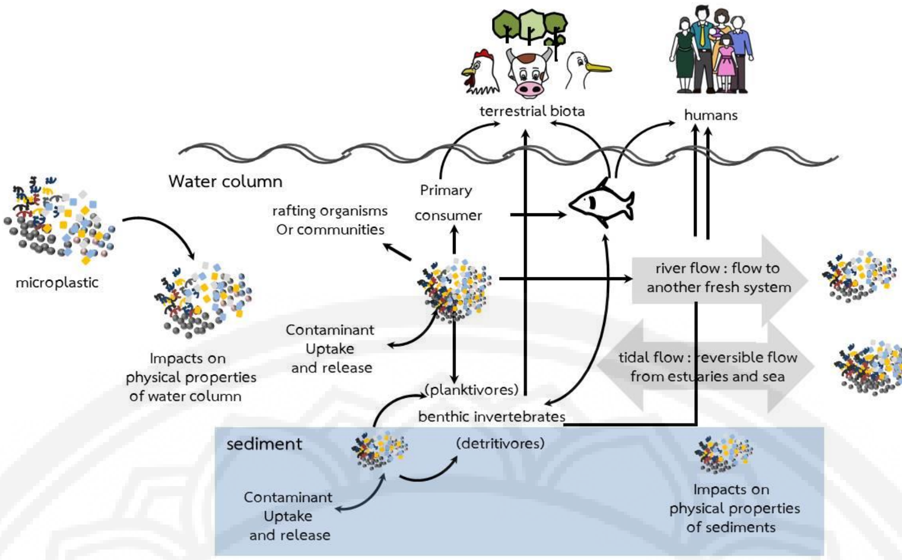

Figure 3 The microplastics contamination routes in water, plants, animals and humans

2. Potential impact of microplastics on organisms

Microplastics contaminated in fresh water resources can be spread to soil by using of fresh water for agriculture purposes. Hence, it is within terrestrial systems that microplastics might first interact with biota eliciting ecologically relevant impacts. Living organisms in the environment may engulf or absorb these microplastics into their bodies and cause adverse effects. Adverse effects of microplatics are consequence from the physical and chemical properties that are presented in microplastics. For potential physical effects, in plant, seaweed and phytoplankton microplastics can accumulate and block the food and water transport systems. In addition, microplastics can affect on the photosynthesis by obscuring the light from reaching the photosynthesis area. (Bhattacharya, Lin, Turner, & Ke, 2010; Cole et al., 2013). In animals, the small particles can be ingested or inhaled, which is causing an accumulation and obstruction of the digestive or respiratory tract and even enter into the circulatory system of the organisms. Moreover these particles not only cause an abrasion, irritation and inflammation of the mucous membranes but also block the digestive tract, reduce feeding stimulus, reduce growth rates, embedment in tissues, and even affect reproduction. (Rehse, Kloas, & Zarfl, 2016; Machado, Kloas, Zarfl, Hempel, & Rillig, 2017; Jin et al., 2018)

For the potential chemical effects, toxic substances contained in microplastics granules such as additives plastic additives, plasticizers, inorganic fillers, stabilizers and pigments in microplastics will be released and absorbed when the microplastics are ingested by living organisms. These toxic substances can cause many adverse effects such as inflammation, alterations in membrane permeability, oxidative stress, endocrine disruption, damages the genetic information within a cell, inhibited locomotion, affecting reproduction and development, mutagenesis, carcinogenesis in the organisms. Moreover, ingestion of microplastics may therefore be introducing toxins to the base of the food chain, from where there is potential for bioaccumulation, biomagnify and transfer to higher-trophic organisms. (Mato et al., 2001; Teuten, Rowland, Galloway, & Thompson, 2007; Cole et al., 2013)

3. Microplastics in living things, foods and beverages

As we already know that plastics have a high degradation resistant properties which microplastics still retain all the properties like macroplastics. In adding, having a smaller size resulted in more broadly contamination in water, soil and organisms than ever before. Microplastics contamination is currently reported in terrestrial and aquatic ecosystems around the world. Furthermore, there is a growing body of evidence indicating that microplastics interact with terrestrial and aquatic organisms such as earthworm, sea bird, fish, shell, seaweed and sea turtle (Torre et al., 2014; Setälä, Norkko, & Lehtiniemi, 2016; Duncan et al., 2019; Alshawafi, Analla, Alwashali, Ahechti, & Aksissou, 2018).

Rillig, Ziersch, and Hempel (2017) and Lwanga et al., 2019 reported about the distribution of microplastics (in both horizontal and vertical directions) in soil by earthworm and discovery of microplastics in the stomach of earthworms. Furthermore, Lwanga et al. (2017) also found an evidence of microplastics transfer from soil to chickens.

Holland, Mallory, and Shutler (2016); Zhao, Zhu, and Li (2016) and Gil-Delgado et al. (2019) reported the discovery of microplastics in the stomach of freshwater birds and seabird in China Canada and Spain. All of these reports indicated that the microprocessor found in the bird came from plastic debris in water resources parts from agricultural tools and fishing gear.

Microplastics can be detected in many water sources around the world, and also be detected in aquatic animals and plant such as sea turtles (Duncan et al., 2019), fish (Alshawafi et al., 2018), shells (Torre et al., 2014; Setälä et al., 2016) plankton (Setälä, Fleming-Lehtinen, & Lehtiniemi, 2014; Möhlenkamp, Purser, & Thomsen, 2018), seaweed (Besseling, Wang, Lürling, & Koelmans, 2014; Sjollema, Redondo-Hasselerharm, & Leslie, 2016; Zhang, Chen, Wang, & Tan, 2017). In addition, microplastics effects have been reported on many aquatic organisms i.e. algae and phytoplankton by affecting the photosynthesis. In aquatic animals and phytoplankton: microplastics can accumulate in tissues and affect the respiratory system, digestive system, reproductive system, embryo development and growth rate in aquatic animals. Cole et al., (2013) reported about the effect of micropolystyrenes accumulation in the tissues of zooplanktons, *Centropages typicus* and *Calanus helgolandicus*, caused lower reproductive rate, smaller eggs, low hatching rate and a high mortality rate.

Microplastics not only found in terrestrial and aquatic organisms but also found in foods and beverages. There have been reports of microplastics in various types, sizes and shape contaminated in canned fish, honey, salt, sugar, beer, drinking water, mineral water and tap water of many countries including countries in Europe, America, Asia, and Oceania.(Liebezeit & Liebezeit, 2013, 2014; Yang et al., 2015; Karami et al., 2017; 2018; Kosuth, Mason, & Wattenberg, 2018; Schymanski, Goldbeck, Humpf, & Fürst, 2018). Furthermore, Orb media, a large non-profit organization, environmental and health work, has examined and reported microplastics contamination of 11 drinking water brands in 12 countries including Thailand, China, India, Indonesia, Kenya, Lebanon, Germany, France, Italy. United States, Mexico and Brazil (Chris & Dan, 2019)

4. The situation of microplastic in Thailand

Thailand has no studies, no calculations, and no concrete reports on the amount of primary microplastics in the environment. According to a research report about the estimation of the number of microbeads contained in products used for facial cleaning and many body types enter water sources in nature such as Gouin et al. (2011) estimated the weight of contaminated microplastic beads when using the face and body cleansing products consisting of microplastic beads per person/ day is 2. 4 grams, or approximately 0. 876 kilograms/year/person. When calculating this figure with the Thai population in the year 2019, which has a total of approximately 70 million people, by requiring the use of products about 50% or 35 million people will find that the microplastic beads contaminated into water 30,660 tons per year. When estimates the duration of the use of various products containing microplastic beads in Thailand for 10 to 15 years, which means that currently the amount of primary microplastic in water of Thailand is very high.

In addition, Plastic Waste Management Subcommittee (2018) reported that Thailand produced and used more than 45 billion plastic bags and also had a large amount of plastic wastes, which included plastic shopping bags and other items (517,054 tons), single use plastic cup (241,233 tons), plastic straw (3,873 tons), foam food containers (29,248 tons) within the year 2017. Therefore, the amount of secondary microplastics in Thailand should be high according to the amount of waste discarded into the natural environment. For example, if we estimate the amount of secondary microplastics from plastic waste is 5-10% of the total plastic waste in 2017, the amount of secondary microplastics is approximately 39.570.4 - 79,140.8 tons per year that enter the environment of Thailand.

Thailand has many researches regarding microplastics in the environment, most of which are conducted at sea, for example Microplastics contamination in bivalve mollusk at Chao Lao beach and Kung Wiman beach Chanthaburi Province (Tharamon, Praisanklul, & Leadprathom, 2016), Effects of Microplastics on Invertebrates in the East Coast of Thailand: Coastal Conservation Guidelines (Thushari, Senevirathna, Yakupitiyage, & Chavanich, 2017), First evidence of the existence of microplastics in stomach of some commercial fishes in the lower Gulf of Thailand (Azad et al., 2018; Azad, Towatana, Pradit, Patricia, & Hue, 2018), Microplastics Waste at West Coast Beaches Phuket, Ekchit & Ruamkaew (2019), in which the results of the survey report found microplastics of various shapes in sediment and in various sea creatures of Thailand, with the high number of microplastics are fibrous and irregular shape.

5. The process of dealing with microplastics in the environment

Method of dealing with microplastic problems can be achieved by reducing the amount of microplastics that enter the environment from the beginning. Therefore, many countries enact the law regarding on the ban on the use of primary microplastics in skincare products and body cleansing products, including with oxo-plastic. Moreover, method “reuse-reduce-recycle” of plastic are being used in order to reduce the plastic waste. Thailand one of the countries, that has declared prohibiting the use of microplastics in skin care products, liquid soap, facial cleanser and toothpaste and also ban oxo-plastic plastic in the year according to the roadmap for plastic waste management, 2018-2030.

Currently, microplastics that contaminated in the environment is not easily to be removed. There are concepts regarding the removal of microplastics in the environment using biological methods such as microbial degradation or the use of small organisms e.g., plankton to trap, engulf and digest the microplastics (Dawson et al., 2018). However, the biological methods do not seem to be successful because of the excellent chemical and biological degradation resistance of mircoplatics. Morover, the microplastics still remain in the small organisms, accumulate and pass along the food chain if the organisms are consumed by larger organisms. European Union research team in the GoJelly project (GoJelly.eu) had an idea of removing microplastics in the environment by using the mucus of jellyfish. The EU research team had produced TRL 5-6 prototype microplastics filter or GoJelly from 3 species of jellyfish; *Cotylorhiza, tuberculata* (fried egg jellyfish), *Rhizostoma pulmo* (barrel jellyfish) and *Mnemiopsis leidy* (warty comb jellyfish). These filters will be tested for trapping microplastics in the sea of three EU countries, Norwegian, Baltic and Mediterranean, details about this project can be found at https://gojelly.eu/. (Javidpour & Rotter, 2018)

Conclusion and Suggestions

Microplastic is an environmental problem occurs in every country around the world and is still a problem that needs to find out the way to reduce the amount of microplastics entry into the environment and the ways to eliminate them from the environment. Additionally, more research is required in the accumulation, transmission of microplastics in the food chain and the effect of microplastics on organisms. In Thailand, it is found that there are a few research on microplastics and all of the research focuses on exploring the contamination of microplastics in the environment. Therefore, research in various areas should be done urgently in order to manage and mitigate the impacts of microplastics appropriately and to cover all aspects.

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