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A REVIEW ON THE IMPACTS OF MICROPLASTIC BEADS USED IN COSMETICS

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ABSTRACT

Microplastic beads used in cosmetics are responsible for significant proportion of the human-made solid waste in aquatic environments. Globally concerns about the impacts of these microplastics on marine and freshwater ecosystems have been raised. Microplastics once released into the environment, persist for long before becoming fully decomposed and reentering normal biogeochemical cycles. Microplastic beads are utilized for manufacturing of soap, shampoo, deodorant, toothpaste, wrinkle creams, moisturizers, shaving cream, sunscreen lotion, facial masks, lipstick, eye shadow, children's bubble bath, etc. The actual level of impacts of microplastics cannot be estimated as the volumes of plastic ingredients used worldwide in cosmetics and personal care product formulations are publically unavailable. Microplastics have been shown to induce negative impacts on the health of various marine organisms. The possibilities of transfer in food chain as well as biomagnification of toxins present in microplastic beads are also predicted which may directly induce toxicity in human beings through seafood. The present review summarizes the sources, fate and behavior, toxicity and impacts, proposed alternatives and current regulations on banning the use of microplastic beads.

INTRODUCTION

Richard Thompson, a renowned professor of Marine Science and Engineering at Plymouth University, England had coined the term 'microplastics' in 2004 [1,2]. Microplastic beads having sizes <5 mm [3,4] are responsible for significant proportion of the human-made solid waste in aquatic environments. They are sourced from the abrasives used in cosmetics and are of rapidly growing environmental concern [1,5-8]. The upper size limit of microplastic beads as 5 mm is mostly used among researchers, although some prefer a definition of <1 mm and in that case any cosmetic formulation containing particles >1 mm in size is said to contain 'meso- or macroplastic', which are also indicators for marine litter under the Marine Strategy Framework Directive [9].

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The screening operation in the wastewater treatment plants fails to trap these tiny plastic particles [10]. Globally concerns about the impacts of these microplastics on marine [5,11-14] as well as freshwater ecosystems [15-19] have been raised by many investigations. This is because of the small size of microplastic beads which makes them bioavailable to organisms throughout the aquatic food web [20-22]. The physical and chemical characteristics of many of these particles are similar to those of microbeads from household consumer products, which are apparently not degraded or completely removed by treatment facilities. Microplastic beads have also been reported as a pollutant in the Great Lakes [23]; moreover, this report had established the three major pathways to microplastic pollution: (1) effluent discharge from wastewater treatment plants; (2) overflow from sewage treatment plants during heavy downpour; and (3) runoff from sewage-based fertilizer deposited on agricultural or public lands.

Current researches are focused mainly to identify the various potential sources of microplastic pollution in order to maneuver decision-making on preventing actions and abatement measures. Emission prevention is cited as the key mitigation strategy [24]. Six years of research by the 5 Gyres Institute estimated that 5.25 trillion plastic particles weighing some 269,000 tons are floating on the surface of the sea [25].

Microplastic beads usage in personal care and cosmetic products has been established as one of the prime sources and routes through which persistent, potentially harmful plastic materials can be emitted to the marine environment [1,5,26]. Everyday use of personal care and cosmetic products releases these plastic particles directly into wastewater as the products are for the most part washed off or rinsed down the drain during or after use. A typical facial scrub contains approximately 350,000 microbeads [27]. Celmo and Addison [28] reported that over half of women use four or more beauty products a day (estimated global spending by women: $426 billion a year), and a large portion of those cosmetics consists of products containing microplastic beads.

Sources of Microplastic Beads

Microplastic beads of type thermoplastics and thermoset plastics including silicones are utilized in the cosmetic and personal care industries for manufacturing of a wide range of products like soap, shampoo, deodorant, toothpaste, wrinkle creams, moisturizers, shaving cream, sunscreen lotion, facial masks, lipstick, eye shadow, children's bubble bath, etc [9]. They are useful for film formation, viscosity regulation, skin conditioning, emulsion stabilizing, etc purposes.

The microplastics responsible for the marine pollution have the following properties in common with other microplastic litter: (1) they are synthetic polymers and/or copolymers (2) they are solid phase materials i.e. particulates, and not liquids, (3) they are insoluble in water, (4) they are non biodegradable, and (4) they have small size [26]. There are although a variety of microplastics in the environment those come from sources other than cosmetics. For example, one load of laundry is estimated to contain more than 1,900 fibers of microplastics, with fleeces releasing the highest percentage of fibers [7]. Moreover, these clothing fibers adhere very easily to various other chemicals in the ambient environment and transform themselves into more toxic forms [29]. Microplastics can be derived from physical, biological and chemical breakdown of larger plastic debris, both at sea and on land, and are called the 'Secondary microplastics'. Ship movements, coastal tourism, recreational and commercial fishing, natural calamities, dumping of sewage sludge and marine industries are also sources of plastic wastes in the aquatic environment; on long-term degradation they induce secondary microplastics in the aquatic ecosystem.

Fate and Behavior of Microplastic Beads

A large portion of rinse off cosmetic and personal care products that contain microplastic beads moves from household drains to surface water bodies or sewage treatment plants, if available. Screening of wastewater in the treatment facilities is unable to remove these tiny plastic particles [10]. Passing through riverine system they get ultimately discharged into seas and oceans. In the marine environment microplastics can then travel vast distances by floating in seawater or sediment to the seabed [26]. Once released into the environment, microplastic beads of cosmetics are expected to persist for centuries before becoming fully decomposed and reentering normal biogeochemical cycles [9]. Sewage sludge is another important receptacle of microplastics from cosmetics and personal care products [26]. The contaminated sewage sludge sometimes incinerated or used for land filling or even applied in the agricultural fields as manures. These all result into the release of harmful microplastics in the different spheres of the environment [30,31]. In the aquatic environment microplastic particulates are consumed by various organisms like lugworms, amphipods and barnacles [1], blue mussels [32], sea cucumbers [33], and others, and thus can potentially enter the food chain [22]. Presence of microplastics has been detected, for example in Northern Fulmar seabirds [34], Norwegian lobsters, oysters, mussels, common periwinkles and amphipods [35] and various species of fish [11,36,37].

Toxicity and Impacts of Microplastic Beads

As the volumes of plastic ingredients used worldwide in cosmetics and personal care product formulations are not publically available their true impacts cannot be estimated. In various studies primary producers to marine invertebrates or mammalian systems to human tissue systems when exposed to sufficiently high concentrations of microplastic beads are reported to show various symptoms of toxicity [9]. According to this report sufficient exposure to microplastics can lead to oxidative stress and inflammatory responses in various parts of the body. It was also found that the fine particulates can translocate to bloodstream, brain and other organs of biota. Furthermore, inhalation of these tiny particulates has been related to allergic reactions, asthma, cancer and heart disease among subjects. Microplastics have been shown to induce negative impacts on the health of marine organisms, affecting the energy availability required for important life sustaining processes, affecting the filtration behavior as well as physiological parameters in the blue mussel, impacting the immunological system of mammals, algal photosynthesis, granuloma formation (inflammatory response), decreased lysosome stability, increase in haemocytes, etc [9,38,39]. Particle toxicity has been established to be size and shape-dependent but according to Leslie [40] it may also be dependent on the specific chemical make-up of the microplastic particles i.e.

monomer, polymer, additives, possible absorbed contaminants, etc. In human beings the microplastics can be transported through gastrointestinal tracts to lymph and circulatory systems, through placentas to unborn fetuses, absorbed in lungs when inhaled, causing a variety of biological responses from the immune system and negatively impacting health of body cells [26,41-43]. Reduction in algal feeding by copepods was seen when they were acutely exposed to high concentrations of microplastics [44]. Von Moos et al. [39] demonstrated that microplastics taken up by mussels resulted in a strong inflammatory response. Plastic particles can induce immunotoxicological responses, alter gene expression and cause cell death, among other adverse effects [2].

Characteristics, accumulation zones and transport pathways of microplastics still remain poorly assessed. In their study on water bodies around Australia, Reisser et al. [12] concluded that marine plastics were predominantly microplastics with the potential to affect organisms ranging from zooplankton and small fish to mega fauna. Moreover, the authors also predicted the possibility of biomagnification of toxins present in microplastic beads in marine ecosystem. Similarly plastic accumulation in the guts of myctophid fish was shown to be biomagnified in the seal scat and Southern Bluefin tuna species of Tasmania [45]. Plastic pollution derived from liquid hand-cleansers was first recognized in the 1990s although it was then considered as a minor source of plastic pollution due to their rare uses by the average consumer. However, Fendall and Sewell [5] reported that the millions of consumer of today's world were likely to be using microplastic-containing hand-cleanser and other cosmetic products on a daily or at least weekly basis. Thus, the report suggested that polyethylene microplastics, raw material of most of facial cleansers would definitely pollute the marine ecosystem as wastewater treatment plants were unable to screen them. These microplastic beads are predicted to have both immediate as well as long-term impacts on plankton and filter-feeding organisms at the base of marine food chains. Moreover, the persistent nature of microplastics in the environment would consequently lead to more toxic responses over time [5]. The authors also assumed that microplastics when ingested by organisms of the lowest trophic tier in the food chain would transfer in different species of pelagic fish that may directly induce toxicity in dietary intake by human beings. Experts are especially concerned about the enormous amounts of plastic particles that are smaller than grains of sand and may enter the food chain [46]. This assumption was further reinforced by different studies on the consumption of microplastics by various marine invertebrates [44], fish [36], sea birds [21] and mammals [45]. Microplastic ingestion by these species has reported to cause negative health impacts like reduced feeding, depleted energy reserves and decreased ecophysiological function as a result of physical injury, physiological stress and false satiation [19,22,39,44]. Investigations till date although unable to correctly quantify the amount of plastic in the ocean do appear to contribute to persistent, bioaccumulative and toxic substances in the human diet [47]. The aim of an ongoing NOAA study is to demonstrate for the first time the biomagnification in marine organisms of chemicals introduced via plastics. The experiment involves feeding contaminated plastic pellets to mussels, feeding the mussels to sturgeon, and then testing levels of PCBs within the bodies of the sturgeon. Results are still awaiting analysis and publication.

Alternatives of Microplastic Beads

Uses of microplastics in cosmetics have emerged as a major environmental concern. At the same time the popularity and worldwide prominent sale of these cosmetic products containing microplastics make it difficult to eliminate those products from use. Hence a safer substitute is required to replace these environmentally hazardous constituents. World plastics production has experienced almost constant growth for more than half a century, rising from approximately 1.9 tons in 1950 to approximately 330 million tons in 2013 [48]. A recent study had revealed that 5.25 trillion plastic particles weighing some 269,000 tons are floating on the surface of the sea [25]. The option to remove the accumulated plastic load from the ocean is time consuming, costly as well as non viable on some aspects. Moreover, this operation will simultaneously remove the normally abundant microscopic yet significant planktons and other flora and fauna from the food chain which may disrupt the entire marine ecosystem [46]. Thus, the only option is to minimize and if possible cease the entrance of more plastic in the lakes, rivers, seas and ocean. Ocean Conservancy, Plastic Pollution Coalition, 5 Gyres, etc organizations are working with the scientists, politicians and industries to aware the public about the problems related with the use and discharge of microplastic beads [2]. As part of the overarching contribution in providing sustainable solutions, representatives of plastics organizations from around the globe have announced a 'Declaration for Solutions on Marine Litter' at the 5th International Marine Debris Conference in Honolulu. The declaration describes steps that the industries will take and suggest approaches and platforms for global cooperation and future partnerships. As of 2015, 60 world plastic organizations from 34 countries signed the pledge. Different multinational companies like Avon, Beiersdorf, Colgate-Palmolive, Henkel, L' Oréal, Oral B, Procter and Gamble, Unilever, etc had announced that they would phase out the use of microplastics in their cosmetics products. Many other personal care product companies are voluntarily phasing out the use of microplastics in their products. Chinese plastic industry associations are the conglomerate of major plastic producers of the world. They have recently joined the global effort to prevent used plastics from entering the environment. New legislations

are thus required to chalk-out strategies in manufacturing sustainable and biodegradable plastics, handling plastic products more responsibly after utilizing them during their life cycle through proper recycling, safe disposal and extended responsibility from the producers' end.

A possible alternative to traditional microbeads for cosmetics and personal health care products was suggested to be the biodegradable polyhydroxyalkanoate (PHA) microbeads [28]. Being soluble PHAs minimize the potential threats of microplastic beads in the environment. PHAs can biodegrade in either aerobic or anaerobic environments. The authors have also demonstrated the faster biodegradation rate of PHAs in comparison with other traditional synthetic polymers. Havens et al. [49] have applied for a patent on the method for reducing marine pollution using PHA microbeads. They have claimed that the described method by incorporating PHA microbeads into personal care formulations such as exfoliants, cosmetics and toothpaste would reduce aquatic pollution significantly.

Regulations on Banning the Use of Microplastic Beads

Illinois was the first US state to enact legislation banning the manufacture and sale of products containing microbeads in 2014. The ban was a resultant on the reports of microplastic pollution in the Great Lakes [23] and North Shore Channel, Chicago [50]. The two-part ban will be effective from 2018 and 2019, respectively. Other US states, including New Jersey and Maine had passed similar legislation. These legislative efforts have broad support from the American Chemistry Council's Plastics Division, consumer product manufacturers and environmental groups. The Netherlands, Austria, Luxembourg, Belgium and Sweden expressed the situations as of utmost priority and issued a joint call to ban the microplastics used in personal care products. The joint call was aimed to take measure that would protect marine ecosystems and seafood such as mussels from contamination. One of the most prominent campaigns is the 'Beat the Microbead' movement, which focuses on removing microplastics from cosmetics and personal care products.

CONCLUSION

As there are no reliable data regarding how much plastic disposed off into the environment and on what timescale it decays to microplastics [46] educating the public by creating necessary awareness on the risks of using microplastic containing products that present immediate as well as long-term direct and indirect threats to the aquatic ecosystems and on the human health through food is to be done in an urgent basis. The permanent solution of this new-age pollution will necessarily require a combination of more scientific research to determine where to best put effort and resources, technological innovations and public/policy initiatives to refuse, reduce, reuse, recycle and rethink so that the flow of plastic to the environment is stemmed [46].

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CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

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