Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

Tiny Microbeads - Threat to Human Life, Threat to Environment

Shrabana Ghosh
School of Bioengineering and Biosciences
Lovely Professional University
Phagwara, Punjab, India

***Abstract*—Microbeads are small, solid, manufactured plastic particles that are less than five millimeter in diameter and do not degrade or dissolve in water. They are often added to act as an exfoliant or application enhancer in personal hygiene products such as rinse-off cosmetics, personal care and cleaning products. The overuse of plastic results in accumulation of plastic waste in our ecosystems. Microbeads are not captured by most of the wastewater treatment systems. If they are washed down the drains after use, they can end up in rivers, lakes and oceans. The Netherlands was the first country to ban cosmetic microbeads in followed by Austria, Luxembourg, Belgium and Sweden. The United States enacted a legislative ban in December one year later. Although ban of microbeads in some developed countries has proven effective, but many countries do not take any legal actions. They are very small but collectively have a huge surface area. In the marine environment microbeads can both release and absorb toxins, which can then move throughout the food chain. In human beings plastic ingested causes internal bleeding, abrasion, ulcers and blockage of digestive tract. A recent review highlighted the bioaccumulation of microbeads via the food chain and its adverse effect on environment.**

Keywords*—*Microbeads; food chain; bioaccumulation; legislative ban; personal care products

I. INTRODUCTION

This Pollution has served a great purpose towards making our environment ugly. There are not one source of pollution, but lot many, each having its own effect on environment health. Most of these are a result of urbanization and indiscriminate use of natural resources [1]. Plastic pollution leads to accumulation in the environment of synthetic plastic products to the point where they create problems for wild life and their habitats as well as for human populations. Decades ago, the menace of plastic was revealed and after great deal of effort and debates from scientists and stake holders the threat seemed to go dormant. Microplastics now imposes a greater threat, though small in size but with a larger scope of long-term consequences to our ecosystem [2]. Microbeads are small particles that are less than 5mm in size, added to a wide range of products such as soaps, face washes, cosmetics and toothpaste as an application enhancer. They were first introduced in 1972 and are currently used in more than 100 consumer products. Consumers using these products often wash the product down the bathroom drains in their homes, which drain into the sewer system making their way to wastewater treatment plants. The majority of the wastewater treatment equipment used nowadays is unable to filter or remove microbeads, which ultimately gets deposited into waterways as a pollutant [3]. Microbeads are used as a bulking agent, for controlled time release of active ingredients and to prolong the shelf life. Furthermore, they are also a relatively cheap ingredient, which have been used to replace natural exfoliating materials like oatmeal, apricots or walnut husks in cosmetics. Colored microbeads in cosmetics not only inert visual appeal to people but are also used as visible markers in different techniques of microscopy and biotechnology [4]. The increasing amount of microplastics in our environment imposes unconfirmed eco-toxicological consequences. The term ‘microbeads’ is used to describe plastic particles present as ingredients in different personal care products; they may also be called as microspheres, nanospheres, plastic particulates or mermaid tears [5]. These are mostly made up of polyethylene or petrochemical plastics like polypropylene or polystyrene, having low melting temperatures and fast phase transitions which make them suitable for creating porous structures in products [6]. There’s mounting evidence that these beads, while being great at scraping dead dermis, are equally adept at killing marine life and bringing harmful chemicals into the food chain. Since 2012, when researchers searched the Great Lakes for small pieces of plastic and found high concentrations of microbeads, environmentalists have campaigned to ban them.

Fig.1. A plankton sample collected in Libyan waters by Greenpeace vessel also contained significant quantities of microplastics (source: Greenpeace/Gravin Parsons)

Plastics used in microbeads readily absorb pollutants. And to a hungry aquatic organism, little pieces of plastic look pretty tasty. The smallest microbeads can even become snacks for plankton as seen in **Fig.1**, and travel all the way up the food chain. When a fish gobbles up contaminated microbeads, or some plankton that have been noshing on contaminated microbeads, this doesn’t just put the animal at risk—it also increases the odds that pollution-laden plastic will make its way to your dinner plate. Some of the pollutants that microbeads pick up have been linked to birth defects, cancer, and developmental problems in humans. Microbeads don't just contain pollutants; the plastic can also release BPA and other chemical additives [3].

The purpose of this review is to include the updated information on the microplastic based particles which has caused an environmental threat to our ecosystems. Due to human activities the threat has emerged out more prominently. Use of cosmetics and products containing microbeads suddenly increased manifold, hence there is an urgent requirement of awareness among people from the toxicological point of view. Assessing the gaps between consumers and the hazardous effects of such chemicals is a critical priority. So, effective communication with people regarding use of microplastics and their detrimental effects on public heath is highly important [7]. Furthermore, microbeads are claimed as a complex problem not only due to its harmful effects but also to devise ways to combat them. A further research is recommended to assess real time impacts of microplastics on environmental health.

II. SUBJECT BACKGROUND

The findings of a research program lead by Professor Richard Thompson of University of Plymouth, published in Science in the year 2004, portrayed detailed explanation of microplastic pollution. The article was the first to allude to the spread of microplastics throughout the marine environment and suggested that though these are minute particles, but are not biodegradable, which leads to mass accumulation [8]. Upon getting exposed to the UV radiation, plastics degrade due to abrasive wave action, however concentration of marine microplastics are increasing rapidly [9, 4].

During the last decade it was realized that plastics in the form of small particles 'microplastics' pollutes a large amount of marine environment through natural runoffs. These microplastics occur in our environment due to the release of manufactured (primary) microplastics in products and the breakdown of larger plastics (secondary plastics). Primary microplastics are generally found in personal care products like soap, tooth pastes, shampoos or from vectors of drug delivery. Secondary microplastics come from the breakdown of larger plastic litter in the environment or its separation from fibrous synthetic material due to rigorous washing [10]. Ingestion of microplastics was reported in a vast range of microorganisms like fish, marine mammals and seabirds [11, 12, 13]. However, to which extent chemicals are absorbed onto the plastics, causing harm to marine life on ingestion are yet to be discovered. Traces of microplastics in different water bodies have been reported in various parts of the world. Their small size makes them bioavailable to all species in all the trophic levels. Microplastics are mainly used as an exfoliating agent and thus mostly result in contaminating water bodies. There have been no such reviewed publications confirming the type of microplastics used in different products. Fendall and Sewell in 2009 reported that microbeads used in cosmetic products may impose a potential risk to the environment [14].

About 93% of the microbeads used in personal care products and cosmetics are made up of polyethylene, polypropylene, polymethyl methacrylate, polyethylene terephthalate and nylon [15] as stated in **Table 1**.

TABLE I. Polymer compositions and corresponding functional properties for typical particulates found in products

Sr. no	*Polymer Name*	*Functions in Product Formulations*
1	Nylon-12 (polyamide-12)	Bulking, viscosity controlling, opacifying (e.g. wrinkle creams)
2	Poly(butylene terephthalate)	Film formation, viscosity controlling
3	Poly(ethylene isoterephthalate)	Bulking agent
4	Poly(ethylene terephthalate)	Adhesive, film formation, hair fixative; viscosity controlling, aesthetic agent, (e.g. glitters in bubble bath, makeup)
5	Polyethylene	Abrasive, film forming, viscosity controlling, binder for powders
6	Polystyrene	Film formation
7	Polypropylene	Bulking agent, viscosity increasing agent

Microbeads are transported from the houses to the water treatment plants and are detained in oxidation ponds and sewage sludge [5]. But due to their small size they surpass all the filtration systems and finally end up in water bodies, ultimately polluting them [16]. Plastics once released into the environment can also accumulate as persistent organic pollutants (POPs) [17]. Research into the extent and consequences of microplastics have thrown considerable light on the growing evidences that confirm the harmful effects that microbeads are causing to the environment. There is a great need to address the source of the microplastic pollution and its harmful effects. Due to the enormity of the challenge scientists, environmentalists and researchers have come to the solution, that the source of the microplastic pollution should be reduced [18, 19].

III. MICROBEADS: WHAT ARE THESE?

According to a report [20], high abundances of plastic pellets less than 1mm ware found in many water bodies, which has lead to a major concern on the effects of microbeads on the environment. Microbeads which are flushed down our drains find their way into the natural ecosystem, to come back at us in a monstrous way as stated in **Fig.2**. At present, waste water plants do not need to monitor microbeads in the influent and effluent stream, as per the regulations. In order to remove microplastics more advanced filtration techniques are required such as microfiltration, microscreens, sand filtration, or mixed media filtration [21]. This can only be done by implementing regulations and uniform policies sincerely.

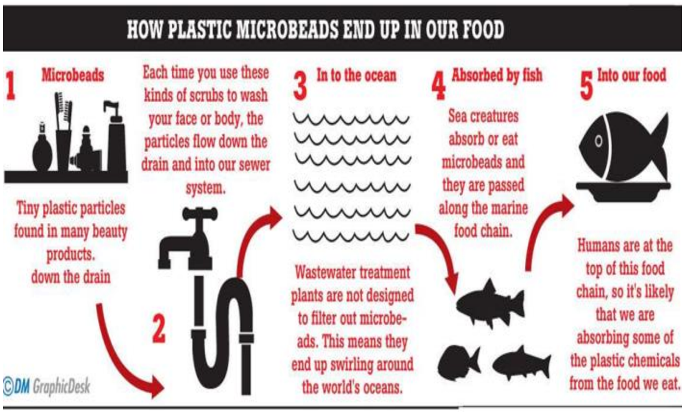

Fig.2. Process by which microplastics pollute our environment

Microplastic debris has been the focus of environmental concern for quite some time. It is only since the last decade that the tiny particles collectively known as 'microplastics' have been regarded as pollutants [22]. Microplastics have been categorized into different size ranges, with diameter of <10mm, <5mm, 2-6mm, <2mm and <1mm [23, 24, 25, 22, 27]. The term 'microplastics' was coined by Andrady [28] to differentiate the plastics seen by naked eye and the plastics only visible under the microscope. Recently another scientist Kniggendorf [28] added another type of microplastic which can only be detected by spectroscopic methods such as Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy, thus making their detection more complicated in future unless strict laws are implemented.

IV. PRIMARY AND SECONDARY MICROPLASTICS

Plastics which are of microscopic size are defined as primary microplastics. These are typically found in cosmetics and personal products, while their use in medicines as vectors have also been reported [29]. Under broader definition of microplastic, virgin plastic production pellet can also be considered as primary microplastics although they have already been categorized [30]. Primary microplastics have also been used in air blasting technology [31]. In processes like blasting of acrylic, melamine, or polyester microplastic scrubbers at machinery, engines and boats have been done to remove rust and paint [32]. Due to the repeated use of these scrubbers, they loose their cutting power and often get contaminated with heavy metals like cadmium, nickel, lead and chromium [25]. Whereas tiny plastic particles derived from the breakdown of larger plastic debris, both at land and sea are considered as 'secondary plastics'. Over the time physical, chemical and biological processes reduce the structural integrity of plastic debris and results in fragmentation [32]. The increase in biodegradable plastics is often seen as a perfect replacement for ordinary traditional plastics. Nevertheless, they too may be the source of microplastics as they do not degrade in the ocean, leading to accumulation and increase in marine plastic litter [7, 33].

V. PROPERTIES OF MICROPLASTICS

Microbeads can vary in shape, size and density based on both chemical composition and method of synthesis. Polymer particles can range in polymer densities from 0.9-2.10 g/cm^3 , while density of water at 25ºC is approximately 1 g/cm^3 [34]. Apart from the polymer density, the chemical such as additives and fillers added to it during its manufacture also plays a role in its total density. The variation in densities causes some microbeads to float in water while, others may be present in the water column or settle to the sediments. Once out in the environment, this behavior may change depending on the aggregation or dis-aggregation and agglomeration or dis-agglomeration. Some microbeads may be fouled by microorganisms and as a consequence may eventually sink to the sea bed. Depending on the properties of the microbeads as observed in **Figure 3**, they can either be physically or chemically stable or unstable. Stable microbeads are most likely to persist in the environment. In western Mediterranean [35] it was reported that dominance of fragments (77%), thin films (13%), foams (7%), lines (2%) and pellets (2%). Around 96% of polyester and nylon was reported to be found in the Celtic sea, whereas no resin pellets were found [36].

Additives are the hazardous substances added to plastics as reported by the Norwegian Environment Agency in 2013. Plasticizers, fillers, stabilizers, colorant, curing agents, coupling agents are types of additives that are added to plastics. Two types of plasticizers, internal plasticizers and external plasticizers are used. Internal plasticizers are added to plastics while its polymerization while external plasticizers are added to plastics after polymerization. The plasticizers are mostly used as a softening agent and most of the plasticizers are used in conjunction with PVC [37, 38, 39].

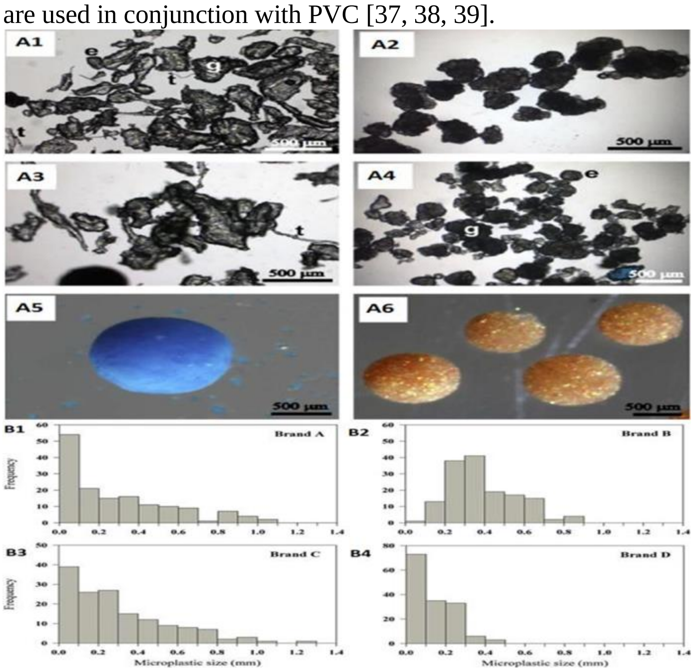

Fig.3. Shapes of polyethylene microbeads from four different facial cleansers available in New Zealand (A1- A4) Two of the four cleansers contained additional spherical microbeads (shown in A5 and A6, respectively) with unknown chemical composition; (graphs- B1-B4) the size distribution of mmmimicrobeads in the tested cleansers (*source: Fendall, L.S., Sewell, M,A. (2009). Contributing to marine pollution by washing your face: Microplastics in facial cleansers. Marine Pollution Bulletin, 58(8), 1225-1228)*

VI. BIODEGRADABILITY OF MICROBEADS

Biodegradability is the process of degrading any material using microbial technology, which has innovatively solve the problem of degrading plastic waste from the standpoint of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

development of new materials. The challenge for some countries and provincial bills is that, they have to deal with the biodegradability issues, either they do not define the term 'biodegradable' or allow the use of microbeads. Ontario has defined microbeads as 'non-biodegradable solid particles measuring>1 mm in diameter which are used in soaps, cosmetics and other similar products' in the bill 75. Such definitions allow manufacturers to produce more 'biodegradable plastic' as a substitute of synthetic plastic microbeads. This imposes a challenge, as studies states that biodegradable microbeads are as harmful to the environment as the conventional synthetic microplastics [40, 41, 42].

Biodegradable plastics are mainly composed of synthetic polymers and vegetable oils, starch or other special chemicals designed to accelerate the degradation process. If they are disposed they will degrade in composting plants under aerobic conditions. Exposure to direct sunlight for prolonged period of time may lead to photo-degradation of plastics, while ultraviolet radiation caused oxidation of polymer matrix results in bond cleavage. But such degradation may result to leaching out of additives which add to the durability of the plastic and makes it corrosion resistant [43, 44, 27].

Both the U.S. microbead-free water Act of 2015 and the proposed Canadian regulation remove the conflict over biodegradability. The U.S. Act defines microbeads as 'a solid particle with length of less than 5 mm', while the Canadian regulation proposed similar prohibition of biodegradable plastics as a substitute of conventional products. The US Federal Act will overtake the state bills, which include the 'biodegradable loophole' resulting in a strong ban of microbeads, while Canadian government will pass a plan by the end of 2019, which will close the loophole in Canada as well [45].

VII. TOXICOLOGY OF MICROBEADS

Plastics when ingested by living organisms, causes abrasion, ulcers, internal bleeding and blockage of digestive tract. Plastic particles also serve as a vector for other potential pollutants such as persistent organic pollutants (POP) and heavy metals [46, 47]. Plastic absorption decreases the biodegradation of other contaminants, resulting in increasing persistence in the environment. Plastic debris can transport several pathogenic species along with them. Thus, plastic debris has devastating effect on environment [24, 48, 49]. GESAMP reported in an assessment the fate, source and effects of microplastics in the ocean. Though they have an improved understanding, but certain uncertainties require some further investigation. So, two sets of policies were recommended by them. First is the action oriented recommendations addressing marine microplastics and second is recommendations to improve future assessments (GESAMP reports and studies No. 90).

One of the major ingredient of microbeads is polyacrylamide (a polymer of acrylamide), used in over 110 of cosmetic formulations, at concentrations ranging from 0.05 to 2.8%, and has been the main cause of toxicity in animals. Polyacrylamide may not be directly absorbed through skin, but has neurotoxic effects on both the central and peripheral nervous system, possibly via microtubule disruption, which has been the probable mechanism of genotoxic effects in mammals [50]. Effects of 0.05, 0.5 and 6 micrometer diameter of polystyrene microbeads on the growth and fecundity of the copepod, *Trigiopus japonicas* using acute and chronic toxicity tests. All the three sizes of the microbeads were egested by *T. japonicas* and when the phytoplankton were added, they exhibited no selective feeding. Their results suggested that polystyrene microbeads may have negative effect on marine copepods [51].

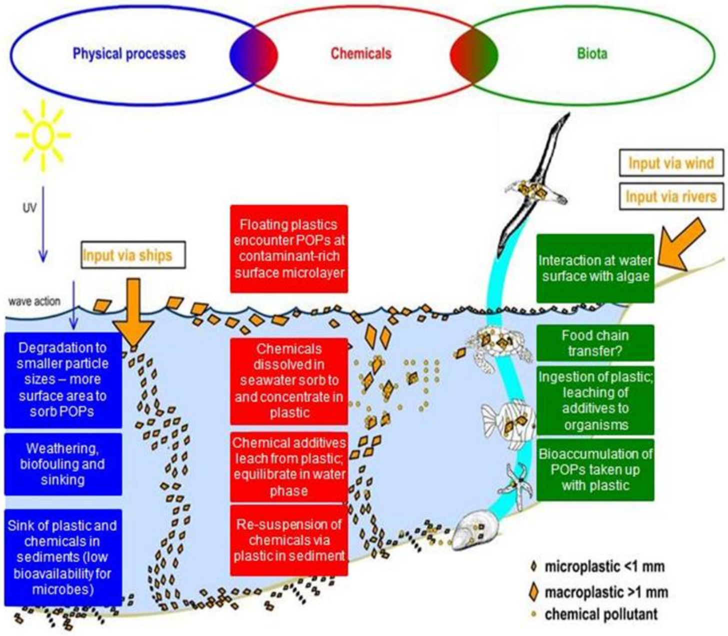

Fig. 4. Environmental fate and behavior of plastic particles after release to the aquatic environment. While the figure focuses on secondary microplastics, the behavior applies to microbeads as well. Note that microbeads can float due to the lower relative density and/or interact with dissolved/dispersed chemicals and eventually partition to sediments. Microbeads can come into contact with organisms at any stage (source: Leslie HA. 2014. Review of microplatics in cosmetics. IVM Institute of environmental studies. Report R14/29)

The effect of microbeads in organisms as shown in **Fig.4.**

Uptake: Microbeads are readily taken up by a variety of organisms including fish, mussels and several types of zooplankton [52]. In this study, microbeads were found in the gut of the tested organisms such as *Daphnia magna*, *Lumbriculus variegatus*, *Notodromas monacha* and most organisms removed microbeads overtime through faeces upto 96% microbeads found in faeces with no measurable effects.

Translocation: Microbeads translocation from gastrointestinal tract into the organism has been confirmed in a study done by Rosenkranz and colleagues in 2009 [53], where they found rapid uptake and disruption of microbeads in *Daphnia magna*, they also found the presence of microbeads in the *Daphnia* lipid storage droplets. In addition to this Von Moos and his colleagues in 2012 [54] found that microbeads can also be internalized from tissues into the cells by measuring the presence of microbeads in the intestine, lumina of the digestive tract and digestive epithelial cells of blue mussels.

Food-wed transfer: Setala and his coworkers in 2014 [55] had shown that microbeads can transfer across food-webs by feeding microbead-containing zooplankton to mysid shrimp

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

and confirming the presence of the beads after three hours of incubation.

Long-term impacts: There is a paucity of information on the long term effects of microbeads. A multigenerational study in corepods conducted in 2013 [56] found that 0.5 micrometer polysterene microbeads caused mortality of nauplii and copepodites in the first generation at a concentration of 12.5 microgram per milliliter and in the second generation at 1.25 microgram per milliliter. In the same study, developmental delay was measured at 25 microgram per milliliter for 0.5 micrometer microbeads.

Direct effects: Nobre in 2015 [57] had noted direct effects in a 24 hour study on the embryonic development from the residual chemicals in the microbead during production of sea urchins exposed to as produced and beach-sourced microbeads (20% by volume). In a 9 day study done by Cole and his co-workers in 2015 in copepods [58], impedance of feeding behavior led to devreased reproductive output. Similar findings have been shown recently in *Hyalella Azteca* with decreased body growth and reproduction due to feeding impedance. In a study done by scientists in 2015 calculated 10-day-LC50 of 4.64 x 10^4 microbeads/ml for spherical polyethylene microbeads and 71.43 microbeads/ml for fiber microbeads [59]. Another study done by Carlos in 2015 [60] indicated a color-specific uptake where red and black microbeads significantly impeded feeding behavior relative to white microbeads.

Celluler and sub-cellular effects: In year 2013 [61] the scientist named Rochman and his colleagues found that microbeads either with or without pollutant absorption causes stress in the liver which is determined by glycogen depletion, fatty vacuolation and single cell necrosis in Japanese medaka. In a follow up study by the same group of scientists in the year 2014 [62], on the same organisms and following a two month exposure from plain and pollutant modified microbeads, it was observed that there was altered gene expression in the male fish (from the pollutant-modified microbeads) and the female fish (from both the modified and unmodified microbeads). They found that there was significant down regulation of chiriogenin gene expression in males and significant downregulation of vitellogenin, choriogenin and estrogen receptor alpha in females. These findings stated that both modified and unmodified microbeads have the capability of inducing an endocrine-disrupting effect. However, it was still unclear whether the effects on the fishes were from only the particle or from the residual chemicals from manufacturing. In another study done by the scientist Avio and his colleagues in 2015 [63] with both unmodified and pyrene-modified microbeads, DNA damage in mussels was observed, suggesting possible genotoxicity.

Transport of pollutants: various studies have stated that microbeads have the capability to absorb pollutants from the environment and desorb them in other organisms. For example it was seen in the experiment done by the scientist Rochman and his colleagues in 2013 [61], where they exposed Japanese medaka to microbeads modified with polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and flame retardants (PBDEs) and found that in all the cases an increase of pollutants was found inside the fish relative to the concentrations in the test media. In another study done by the scientist Brown in 2013 [64] in lugworms, it was found that although microbeads absorb and desorb pollutants, higher concentration of silica was found in the gut tissue of the fish suggesting more study to be done on this matter. A recent study done in 2015 [65], has shown that microbeads extracted from cosmetics have similar potential to absorb and hence transport chemicals similar to conventional microbeads and secondary microplastics.

There are still number of key questions that remain to be answered, at what degree do plastics transport chemical additives and pollutants to the organisms after ingestion? What is the role of plastic in making contaminant burden in organisms upon exposure through food, water or sediments? And, ultimately what part of human exposure to microplastics and other pollutants occurs through food chain? Researchers from all around the world are constantly running experiments and studies to answer these important questions.

VIII. PRESENT SCENARIO OF MICROBEADS IN DIFFERENT PARTS OF THE WORLD

Countries in different parts of the world as shown in **Table 2** are yet to understand the complex industrial use of microplastics and microbeads in the products, which are used extensively under the mask of natural and herbal ingredients, which needs to be further evaluated toxicologically as shown in **Fig.5**.

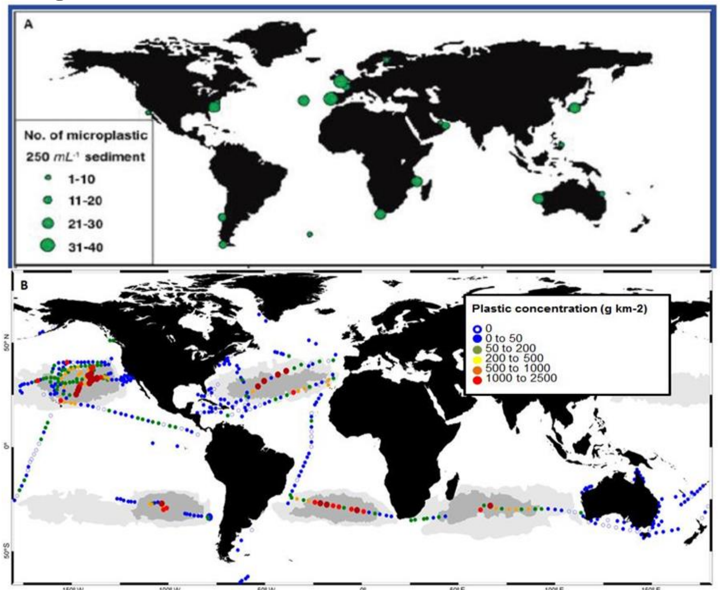

Fig. 5. (A) Global distribution of microplastics in sediments from 18 sandy shores from around the world (source: Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, Thompson R. 2011. Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ Sci Technol. 45(21):9175–9179. doi:10.1021/es201811s) and (B) average concentrations of plastics (primarily microplastics) in surface waters (source: http;//www.ec.gc.ca/ese-ees/default.asp?lang=En&n=adda4c5f-1)

Southern India: A study presented by scientists Surthy and Ramasamy in [66], on the sediments of Vembanad Lake and recorded the mean density of microplastics in the water column to be 252.80 +/- 25.76 items/m^2, with low density polyethylene dominating 26%-91% of the plastic items. This value is comparable to 263 items/m^2 reported in Papua New Guinea mangrove sediment study done in 2012 [67].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

Australia: Inland waters in Australia have a high potential to be polluted by microplastics. Studies conducted on fresh water ecosystems in Australia in [68] reported an average of 0.28, 0.48 and 1.54 items/liter mean density of microplastics in the water column of final effluent in tertiary, secondary and primary treated effluent respectively. The dominant polymer type was polyethylene terephthalate fibers and irregular shaped polyethylene, which normally originate from synthetic clothing and personal care products.

Europe: Samples from different water bodies across Europe was collected and studied. The abundance of microplastics in Italy showed greater concentrations towards landward sites due to human caused pollution and industries. Human density, activity, urban development and environmental pressure were found to be directly proportionate with the concentrations of microplastics [69, 70, 71, 72, 73]. Specifically, high human settlements, with more than 95% of the total population may result in higher concentrations of microplastics in the aquatic systems [74].

Africa: In South Africa, plastic items within range of 340.7-4757 items/m^2 were found in the sediments collected from the beaches [75], while offshore sediments of Namibia had around 8.5 items/m^2 [76]. An abundance of microplastics in the Bloukrans River system was examined based on temporal differences in river flow [77].

North America: North America is bound by Atlantic Ocean on the east while Pacific Ocean on the west. Both oceans have dynamic nature due to ocean currents, tides and wave action. The mean water density of microplastics in the water column of Greenland increased from 0.99 items/m^2 to 2.38 items/m^2 in 2005-2014 [78].

Antarctica: Offshore and nearshore samples of Ross Sea, Antarctica were taken and study was done and it was found to contain lower concentrations of microplastics than other parts of the world [79, 89, 81]. Microplastic range was 0.0032-1,18 items/m^3, mostly dominated by polyethylene and polypropylene [82].

Saudi Arabia: an extensive study [83] provides an assessment of three classes of contaminants including Polycyclic Aromatic Hydrocarbons (PAH), metals and microplastics in coastal sediments of the Red Sea. It was found that the concentration of microplastics were more than the other two contaminants as per the international guidelines. A recent study [84] found microplastic litter found in the gastrointestinal tract of 26 commercial and non-commercial fish species of the Red Sea, which imposed a threat to their food web and human consumers. Some awareness programs conducted by different organizations, portraying the impact of plastic on environment initiate saving of animal and human lives by reducing plastic waste [85].

TABLE II. OCCURRENCE OF MICROPLASTICS IN VARIOUS SAMPLES COLLECTED FROM DIFFERENT AREAS OF SOME ASIAN COUNTRIES

Country where the study has undertaken	*Site of study*	*Sample studied*	*Type of polymer found*	*References*
Bangladesh	Northern bay of Bengal	Brown shrimps and Tiger shrimps	Polyamide-6 and rayon	[96]
China	Changjiang estuary	Marine sediments	Polyethylene, polypropylene, polystyrene	[97]
China	Small scale estuaries, Shanghai	Surface water	Polyethylene, polypropylene	[98]
China	Yong Xing island of South China	Marine birds	Polypropylene-polyethylene copolymer	[99]
India	New Delhi	Cosmetic products	Polyethylene, polystyrene	[88]
India	Indian Ocean	Sea salt	Polyethylene, polystyrene, polyamide	[89]
India	Kasimedu fishing harbor	Asian green mussels	Polystyrene	[100]
India	Three different location of Indian Ocean	Sand	Polyethylene, polypropylene, polystyrene, polyethylene terephthalate, polyvinyl chloride	
Iran	Coastline of Bandar Abbas city, Hormozgan province	Marine sediments	Polyethylene, polystyrene, polyethylene terephthalate	[101]
Japan and Russia		Human stool	Polypropylene, polyethylene terephthalate	[102]
Saudi Arabia	Eight different areas along Saudi Arabian Red sea coast	Marine sediments	polyethylene	[103]
Saudi Arabia	Saudi Arabian Red sea coast	Commercial and non commercial fishes	Polypropylene, polyethylene	[104]
Taiwan	Four beaches along the Northern coast of Taiwan	Sand	Polyethylene, polypropylene, polystyrene, polyethylene terephthalate	[105]
Turkey	Coastline of Datca Peninsula	Marine sediments	Styrene-Butadiene-styrene copolymer, polystyrene	[106]

United Arab Emirates: The cosmetic market in United Arab Emirates has always been booming as compared to other parts of the world. Tiny balls of microplastics in soaps and other personal care products are flushed everyday through sinks and showers. Different environmentalists and researchers considers microplastics as a threat to the environment as no research is being done regarding this issue. Also there is no legislativeaction is taken by the government for banning the use of microplastics in cosmetics [86].

India: National Green Tribunal (NGT) issued a directive to the Government of India for getting the cosmetics analyzed for the presence of microbeads. The Bureau of Indian Standards in May 2017 has classified microbeads as 'unsafe for use in cosmetics' but it is still in use as no action has been taken (as in a report published in Times of India) [87]. An non-governmental organization (NGO) Toxics Link from New-Delhi India, had confirmed the presence of microbeads in cosmetics for the first time. The researchers, during the study tested different products both national and international brands including the herbal ones. Their study concluded that 50% of the face washes and 67% of the face scrubs contained microplastics, while 38% of all the tested products contained microplastics. Still, there has been no notification from the government on banning the use of microplastics in India. As a result, microbead containing products are still sold in Indian markets [88]. Another study stated that Indian sea salts are contaminated with microplastics [89]. 80% of the contaminants extracted from the salts were plastic fragments smaller than 2-0.5mm, of which majority was poltsterene, polyethylene and polyamide. Some more studies were done at the same time stating contamination of sea coast along India with the presence of microplastics [90, 91, 92]. Recently another study [93] stated occurance of microplastic particles along the sea coast through analytical techniques like Fluorescence microscopy, SEM-EDS and FITR, the particles were categorized into polyethylene (43%), polyethylene terephthalate (17.3%), polysterene (17%), polypropylene (12.3%), polyvinylchloride (1.33%)and others (11%). This data gave alarming notation of the increasing impact of microplastics on the environment. Central Pollution Board of India reported that 6 million tons of plastic waste is produced in India per year. Delhi alone produces 690 tons of plastic per year. Chennai produces 429 tons of plastic per year while Kolkata and Mumbai produces 426 tons and 408 tons of plastic per year respectively. The political system of India should also come forward and support ban of use of plastic, as it is most important to free India of plastics [94] as plastic is putting the environment in danger. If urgent action is not taken locally as well as globally people might be dying of cancer and other environmental diseases [95].

IX. IMPACT ON OUR HEALTH

Several environmentalists, researchers and agencies are working on the long term risk assessment and environmental safety programs to answer the concerning questions regarding the hazards of microplastics towards environmental health. Many researchers like Mark Browne of the University of California studied on the effect of microplastics on human body after it gets inside the system as described in **Fig.6**. In 2008 he showed the microplastics of size 3.0 and 9.6 micrometer in diameter travel beyond the mussels gut and into the circulatory system and hemocytes, where they can remain for more than 48 days [107, 54, 108].

The long term implications of these particles on human body are yet to be understood. Mark Browne also stated that his team was working to develop a method of testing human tissues for presence of microplastics, which could give a better dimension to the efforts in protecting the human health. Another scientist Heather Leslie of the VU University in Amsterdam, herself is concerned about the toxicity of these microplastics. She even said that plastics can induce immune toxicological responses by altering gene expression and causing cell death. She explained even more by saying that exposed organisms then not only deals with chemical stress through multiple routes but also particle stress. She was also a part of the Europe's multinational CleanSea project and studied different toxicological effects of microplastics on the marine environment.

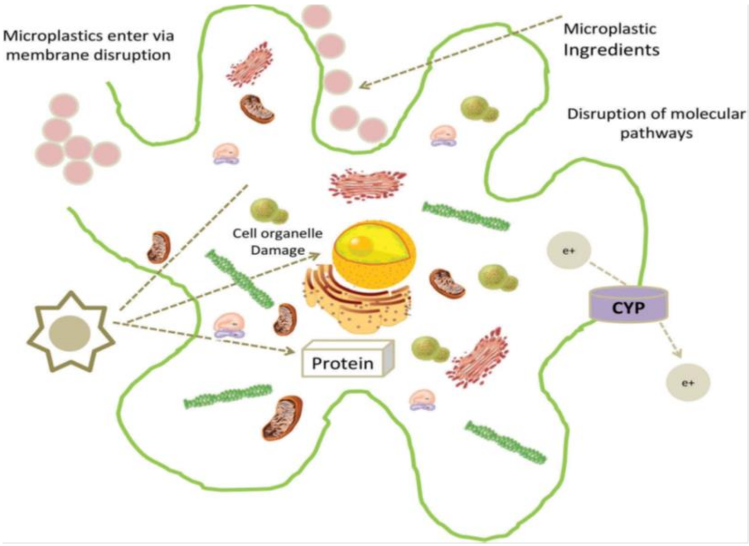

Fig.6. The schematic drawing of microplastics entering a cell through the cell membrane and the damage caused to cell organelles by micro pollutants (source: Shaima S. Miraj, Maima Parveen & Haya S. Zedan (2019) Plastic microbeads: small yet mighty concerning, International Journal of Environmental Health Research, DOI: 10.1080/09603123.2019.168923)

She even says that the effects of microplastics on the human body is concerning, they can pass through the placenta and the blood-brain barrier and can be taken up in the gastrointestinal tract and even the lungs, causing potential harm to the body. There is a lot to learn about microplastics from the field of particle toxicity and drug delivery technologies that apply to polymeric nanoparticles [109].

Recently a study [110] found that microplastics can even effect biophysical properties of the soil and thus affect plant performance. Significant changes were observed in plant biomass, elemental composition of tissue, soil microbial activities of spring onion (*Allium fistulosum*). Their findings gives close indication that microplastics has consequent effect on plant performance and thus can effect agroecosystem and humans as well as other organisms who consumed the affected plants.

X. STEPS TOWARDS BETTER FUTURE

Growing public support for banning microbeads has prompted action from multinational companies, NGOs and policy makers as shown in **Figure 7**. For instance, big multinational companies like Unilever, The Body Shop, IKEA, L'Oreal, Procter & Gample and Johnson & Johnson have pledged to stop using microbeads in their 'rinse-off' personal products. More than 70 NGOs are working in more than 30 countries are working on or helped pass legislative action to ban microbeads from personal care products. For example, several US states including Illinois, Colorado, Connecticut, New Jersey, Maine, Maryland and Wisconsin and the province of Ontario in Canada have regulated or banned microbeads.

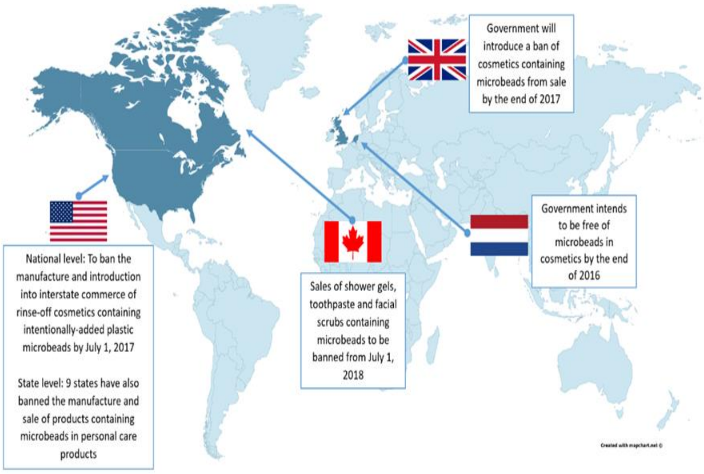

Fig.7. Microbead legislation around the world (source: https://www.the-ies.org/analysis/banning-bead-what-likely)

While laudable, the agreements and legislations enacted so far do not remove all sources of microbeads from the aquatic environment because of the wording of these documents. There are products that are application based such as deodorants, nail polish and cleaners, while ban are for microbeads that go down the drain in the products classified as "rinse-off products". Other issues include how the legislation defines terms "plastic" and "biodegradable". For example, the legislation passed in Illinois defines "plastic" as something that retains its "defined shape during life cycle and after disposal". This allows microbeads to be made from plastucs that biodegrade slightly, thus changing their defined shape in an unspecified time period. The major concern is that how the term "biodegradable" is defined, which leads us to a question that Is ban the only way to reduce the menace causing microbeads?

Several companies and legislation promise to remove "non-biodegradable" microbeads from personal products. When the terms are not quite well defined, it becomes easier not to abide by the laws. International standards do not mandate full degradation in aquatic environments, it allows for materials to be used in products that only degrade slightly during a 1-year period. New wording should be included to ensure better clarity and regulation, so that material that is persistent, bioaccumulative or toxic is not added to products.

Preventing microbeads from becoming the part of pollution will take time. In several debates, the argument have been raised that there is not enough scientific evidence to support banning microbeads. Though there are gaps in our understanding the precise the impact of microbeads on the environment. Several extant questions regarding the persistence, fate and hazards of microbeads can be addressed through more studies and research. The probability of risk from microbead pollution is high while the solution to this problem is simple. Spreading awareness among people through proper scientific evidences and proofs and then devising laws will ultimately protect the environment from microplastic pollution [111].

XI. CONCLUSION

The rapid advances in science and technological understanding of toxicology will surely be able to combat the explosive growth of the manufacturing and use of plastic materials, which causes major harm to the environment. Plastic has caused adverse effects in both human and environmental health by causing several diseases including digestive tract blockage in both humans and marine life upon its ingestion. Plastic is incredibly toxic even to plants, affecting their growth. Thus it is important to carry out more studies and research to overcome the challenges. Without quantitative measures of both exposure and effects, ecological risk assessment cannot be conducted and regulators will not have proper tools to adequate manage the toxic implications of microbeads. Our current understanding is limited in the area of understanding the level of toxicity produced by microplastics while it's persistent availability in the environment. Awareness in this regard plays a crucial role in this regard. Schools, colleges, institutions and moreover individuals have to play a larger role to make this happen.

XII. CONFLICT OF INTEREST

It is declared that the author has no conflict of interest.

REFERENCES

[1] Hunter P. 2007. The human impact on biological diversity. How species adapt to urban challenges sheds light on evolution and provides clues about conservation. EMBO Rep. 8(4):316–318. doi:10.1038/sj.embor.7400951.
[2] Kettner MT, Oberbeckmann S, Labrenz M, Grossart HP. 2019. The eukaryotic life on microplastics in brackish ecosystems. Front Microbiol. 10:538. doi:10.3389/fmicb.2019.00538.
[3] Department Of Agriculture, Water And The Environment. [online] Available at: https://www.environment.gov.au/protection/waste/plastics-and-packaging/plastic-microbeads#:~:text=Once%20in%20the%20water%2C%20microbeads,are%20almost%20impossible%20to%20remove.
[4] Goldstein MC, Rosenberg M, Cheng L. 2012. Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect. Biol Lett. 8(5):817–820. doi:10.1098/rsbl.2012.0298.
[5] UNEP. 2015. Plastic in cosmetics. ISBN: 978-92-807-3466-9.p. 33.
[6] Hardesty BD, Polidoro B, Compa M, Shim WJ, Widianarko B, Wilcox C. 2019. Multiple approaches to assessing the risk posed by anthropogenic plastic debris. Mar Pollut Bull. 141:188–193. doi:10.1016/j.marpolbul.2019.02.017.
[7] Shaima S. Miraj, Naima Parveen & Haya S. Zedan (2019) Plastic microbeads: small yet mighty concerning, International Journal of Environmental Health Research, DOI: 10.1080/09603123.2019.1689233
[8] Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AWG, McGonigle D, Russell AE. 2004. Lost at sea: where is all the plastic? Science. 304:838. doi:10.1126/science.1094559.
[9] Roy PK, Hakkarainen M, Varma IK, Albertsson AC. 2012. Degradable polyethylene fantasy or reality. Environ Sci Technol. 45(10): 4217–4227
[10] Teuten EL, Rowland SJ, Galloway TS, Thompson RC. 2007. Potential for plastics to transport hydrophobic contaminants. Environ Sci Technol. 41(22):7759–7764. doi:10.1021/es071737s.
[11] Boerger CM, Lattin GL, Moore SL, Moore CJ. 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre.

Mar Pollut Bull. 60:2275–2278. doi:10.1016/j.marpolbul.2010.08.007.

[12] Denuncio P, Bastida R, Dassis M, Giardino G, Gerpe M, Rodríguez D. 2011. Plastic ingestion in Franciscana dolphins, Pontoporia blainvillei (Gervais andd'Orbigny, 1844), from Argentina. Mar Pollut Bull. 62:1836–1841. doi:10.1016/j. marpolbul.2011.05.003.

[13] Avery-Gomm S, O'Hara PD, Kleine L, Bowes V,Wilson LK, Barry KL. 2012. Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific. Mar Pollut Bull. 64:1776–1781. doi:10.1016/j. marpolbul.2012.04.017.

[14] Fendall LS, Sewell MA. 2009. Contributing to marine pollution by washing your face: microplastics in facial cleansers. Mar Pollut Bull. 58:1225–1228. doi:10.1016/j.marpolbul.2009.04.025.

[15] Eriksen M, Mason S, Wilson S, Box C, Zellers A, Edwards W, Farley H, Amato S. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Pollut Bull. 77:177–182. doi:10.1016/j.marpolbul.2013.10.007.

[16] Wang J, Zheng L, Li J. 2018. A critical review on the sources and instruments of marine 545 microplastics and prospects on the relevant management in China. Waste Manag Res. 36:898–911. doi:10.1177/0734242X18793504.

[17] Lau MH, Leung KM, Wong SW, Wang H, Yan ZG. 2012. Environmental policy, legislation and management of persistent organic pollutants (POPs) in China. Environ Pollut. 165:182–192. doi:10.1016/j.envpol.2012.01.002.

[18] Xanthos D, Walker TR. 2017. International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. Mar Pollut Bull. 118(1–2):17–26. doi:10.1016/j.marpolbul.2017.02.048.

[19] Schnurr REJ, Alboiu V, Chaudhary M, Corbett RA, Quanz ME, Sankar K, Srain HS, Thavarajah V, Xanthos D, Walker TR. 2018. Reducing marine pollution from single-use plastics (SUPs): A review. Mar Pollut Bull. 137:157–171. doi:10.1016/j.marpolbul.2018.10.001.

[20] Eriksen M, Mason S, Wilson S, Box C, Zellers A, Edwards W, Farley H, Amato S. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Pollut Bull. 77:177–182. doi:10.1016/j.marpolbul.2013.10.007.

[21] Nalbone J. 2014. Unseen threat: how microbeads harm New York waters, wildlife, health and environment, environmental protection Bureau of the New York State Attorney General's Office. Albany (NY). http://ag.ny. gov/pdfs/Microbeads_Report_5_14_14.pdf).

[22] Ryan PG, Moore CJ, van Franeker JA, Moloney CL. 2009. Monitoring the abundance of plastic debris in the marine environment. Philos Trans R Soc Lond B Biol Sci. 364:1999–2012. doi:10.1098/rstb.2008.0207.

[23] Graham ER, Thompson JT. 2009. Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. J Exp Mar Biol Ecol. 368:22–29. doi:10.1016/j.jembe.2008.09.007.

[24] Barnes DKA, Galgani F, Thompson RC, Barlaz M. 2009. Accumulation and fragmentation of plastic debris in global environments. Philos Trans R Soc Lond B Biol Sci. 364:1985–1998. doi:10.1098/rstb.2008.0205.

[25] Derraik JGB. 2002. The pollution of the marine environment by plastic debris: a review. Mar Pollut Bull. 44:842–852. doi:10.1016/S0025-326X(02)00220-5.

[26] Claessens M, Meester SD, Landuyt LV, Clerck KD, Janssen CR. 2011. Occurrence and distribution of microplastics in marine sediments along the Belgian coast. Mar Pollut Bull. 62(10):2199–2204. doi:10.1016/j.marpolbul.2011.06.030.

[27] Andrady AL, Pandey KK, Heikkilä AM. 2019. Interactive effects of solar UV radiation and climate change on material damage. Photochem Photobiol Sci. 18(3):804–825. doi:10.1039/C8PP90065E.

[28] Kniggendorf AK, Wetzel C, Roth B. 2019. Microplastics detection in streaming tap water with Raman spectroscopy. Sensors (Basel). 19(8):E1839. doi:10.3390/s19081839.

[29] Patel MM, Goyal BR, Bhadada SV, Bhatt JS, Amin AF. 2009. Getting into the brain: approaches to enhance brain drug delivery. CNS Drugs. 23(1):35–58. doi:10.2165/0023210-200923010-00003.

[30] Andrady AL. 2011. Microplastics in the marine environment. Mar Pollut Bull. 62:1596–1605. doi:10.1016/j.marpolbul.2011.05.030.

[31] Gregory MR. 1996. Plastic `scrubbers' in hand cleansers: a further (and minor) source for marine pollution identified. Mar Pollut Bull. 32:867–871. doi:10.1016/S0025-326X(96)00047-1.

[32] Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, Thompson R. 2011. Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ Sci Technol. 45(21):9175–9179. doi:10.1021/es201811s.

[33] Gallo F, Fossi C, Weber R, Santillo D, Sousa J, Ingram I, Nadal A, Romano D. 2018. Marine litter plastics and microplastics and their toxic chemicals components: the need for urgent preventive measures. Environ Sci Eur. 30 (1):13. doi:10.1186/s12302-018-0139-z.

[34] Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. Environmental science & technology, 46(6), 3060-3075.

[35] Doyle MJ, Watson W, Bowlin NM, Sheavly SB. 2011. Plastic particles in coastal pelagic ecosystems of the Northeast Pacific ocean. Mar Environ Res. 71:41–52. doi:10.1016/j.marenvres.2010.10.001.

[36] Lusher AL, Burke A, O'Connor I, Officer R. 2014. Microplastic pollution in the Northeast Atlantic Ocean: validated and opportunistic sampling. Mar Pollut Bull. 88:325–333. doi:10.1016/j.marpolbul.2014.08.023.

[37] Cadogan DF, Howick CJ. 2000. In Ullmann's encyclopedia of industrial chemistry. Ind Chem. 599–618. doi:10.1002/14356007.a20_439.

[38] Heudorf U, Mersch-Sundermann V, Angerer J. 2007. Phthalates: toxicology and exposure. Int J Hyg Environ Health. 210:623–634. doi:10.1016/j.ijheh.2007.07.011.

[39] Salvo A, La Torre GL, Rotondo A, Mangano V, Gervasi T, Gervasi C, Vadalà R, Bartolomeo G, Iaria C, Lanteri G, et al. 2019. Accumulation of PCBs, PAHs, plasticizers and inorganic elements in Hexanchus griseus from the strait of Messina (Central Mediterranean sea). Nat Prod Res. 23:1–5.

[40] Perschbacher E 2016. Microbeads - legislative update. http://www.ijc.org/en_/blog/2016/03/01/microbeads_legislative_update_story4/.

[41] Green DS, Boots B, Sigwart J, Jiang S, Rocha C. 2016. Effects of conventional and biodegradable microplastics on a marine ecosystem engineer (Arenicola marina) and sediment nutrient cycling. Environ Pollut. 208(PartB):426–434. doi:10.1016/j.envpol.2015.10.010.

[42] Nazareth M, Marques MRC, Leite MCA, ÍB C. 2019. Commercial plastics claiming biodegradable status: is this also accurate for marine environments? J Hazard Mater. 366:714–722. doi:10.1016/j.jhazmat.2018.12.052.

[43] Moore CJ. 2008. Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Environ Res.108:131–139. doi:10.1016/j.envres.2008.07.025.

[44] Talsness CE, Andrade AJM, Kuriyama SN, Taylor JA, Vom Saal FS. 2009. Components of plastic: experimental studies in animals and relevance for human health. Philos Trans R Soc Lond B Biol Sci. 364:2079–2096.doi:10.1098/rstb.2008.0281.

[45] Gyres. 2015.Why we like the national microbead-free waters Act. http://www.5gyres.org/blog/posts/2015/12/8/whywe-like-the-nationalmicrobead-free-waters-act.

[46] Wright S, Rowe D, Thompson R, Galloway TS. 2013. Microplastic ingestion decreases energy reserve in marine worms. Curr Biol. 23:1031–1033. doi:10.1016/j.cub.2013.10.068.

[47] Faure F, Saini C, Potter G, Galgani F, de Alencastro L, Hagmann P. 2015. An evaluation of surface micro and meso plastic pollution in pelagic ecosystems of western Mediterranean Sea. Environ Sci Pollut Res Int. 22(16):12190–12197. doi:10.1007/s11356-015-4453-3.

[48] Teuten EL, Saquing JM, Knappe DRU, Barlaz MA, Jonsson S, Björn A, Rowland SJ, Thompson RC. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Philos Trans R Soc Lond B Biol Sci.364:2027–2045. doi:10.1098/rstb.2008.0284.

[49] Jeong CB, Kang HM, Lee YH, Kim MS, Lee JS, Seo JS, Wang M, Lee JS. 2018. Nanoplastic ingestion enhances toxicity of Persistent Organic Pollutants (POPs) in the monogonont rotifer Brachionus koreanus via Multixenobiotic Resistance (MXR) disruption. Environ Sci Technol. 52(19):11411–11418. doi:10.1021/acs.est.8b03211.

[50] Alan AF. 2005. Amended final report on the safety assessment of polyacrylamide and acrylamide residues in cosmetic. Intl J Toxicol. 24(SUP 2):21–50.
[51] Lee KW, Shim WJ, Kwon OY, Kang JH. 2013. Size-dependent effects of micro polystyrene particles in the marine copepod Tigriopus japonicas. Environ Sci Technol. 47(19):11278–11283. doi:10.1021/es401932b.
[52] Imhof, H. K., Ivleva, N. P., Schmid, J., Niessner, R., Laforsch, C. (2013). Contamination of beach sediments of a subalpine lake with microplastic particles. Current biology, 23(19), R867-R868.
[53] Rosenkranz, P., Chaudhry, Q., Stone, V., Fernandes, T. F. (2009). A comparison of nanoparticle and fine particle uptake by Daphnia magna. Environmental Toxicology and Chemistry, 28(10), 2142-2149.
[54] Von Moos, N., Burkhardt-Holm, P., Koihler, A. (2012). Uptake and effects of microplastics on cells and tissue of the blue mussel Mytilus edulis L. after an experimental exposure. Environmental science & technology, 46(20), 11327-11335.
[55] Setälä, O., Fleming-Lehtinen, V., Lehtiniemi, M. (2014). Ingestion and transfer of microplastics in the planktonic food web. Environmental pollution, 185, 77-83.
[56] Lee, k. w., Shim, w. j., Kwon, O. Y., Kang, J. H. (2013). Size-dependent effects of micro polystyrene particles in the marine copepod Tigriopus Japonicus. Environment science & technology, 47(19), 11278-11283.
[57] Nobre, C. R., Santana, M. F. M., Maluf, A., Cortez, F. S., Cesar, A., Pereira, C. D. S., Turra, A. (2015). Assessment of microplastic toxicity to embryonic development of the sea urchin Lytechinus variegatus (Echinodermata: Echinoidea). Marine pollution bulletin, 92(1), 99-104.
[58] Cole, M., Lindeque, P., Fileman, E., Halsband, C., Galloway, T. S. (2015). The Impact of Polystyrene Microplastics on Feeding, Function and Fecundity in the Marine Copepod Calanus helgolandicus. Environmental science & technology.
[59] Au, S. Y., Bruce, T. F., Bridges, W. C., Klaine, S. J. (2015). Responses of Hyalella azteca to acute and chronic microplastic. Environmental Toxicology and Chemistry.
[60] De Sá, L. C., Luís, L. G., Guilhermino, L. (2015). Effects of microplastics on juveniles of the common goby (Pomatoschistus microps): Confusion with prey, reduction of the predatory performance and efficiency, and possible influence of developmental conditions. Environmental Pollution, 196, 359-362.
[61] Rochman, C. M., Hoh, E., Kurobe, T., The, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific reports, 3.
[62] Rochman, C. M., Kurobe, T., Flores, I., The, S. J. (2014). Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. Science of the Total Environment, 493, 656-661.
[63] Avio, C. G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., d'Errico, G., Pauletto, M., Bargelloni, L. Regoli, F. (2015). Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environmental Pollution, 198, 211-222.
[64] Browne, M. A., Niven, S. J., Galloway, T. S., Rowland, S. J., Thompson, R. C. (2013). Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. Current Biology, 23(23), 2388-2392.
[65] Napper, I. E. Thompson, R. C. (2015). Characterisation, Quantity and Sorptive Properties of Microplastics Extracted From Cosmetics. Marine Pollution Bulletin (in press).
[66] Sruthy, S, Ramasamy, EV (2017) Microplastic pollution in Vembanad Lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. Environmental Pollution 222: 315–322.
[67] Smith, S (2012) Marine debris: A proximate threat to marine sustainability in Bootless Bay, Papua New Guinea. Marine Pollution Bulletin 64: 1880–1883.
[68] Ziajahromi, S, Neale, PA, Rintoul, L. (2017) Wastewater treatment plants as a pathway for microplastics: Development of a new approach to sample wastewater-based microplastics. Water Research 112: 93–99.
[69] Barnes, DK, Galgani, F, Thompson, RC. (2009) Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences 364: 1985–199.
[70] De Lucia, GA, Caliani, I, Marra, S. (2014) Amount and distribution of neustonic micro-plastic off the western Sardinian coast (Central-Western Mediterranean Sea). Marine Environmental Research 100: 10–16.
[71] Frère, L, Paul-Pont, I, Rinnert, E. (2017) Influence of environmental and anthropogenic factors on the composition, concentration and spatial distribution of microplastics: A case study of the Bay of Brest (Brittany, France). Environmental Pollution 225: 211–222.
[72] Gündoğdu, S, Çevik, C (2017) Micro- and mesoplastics in Northeast Levantine coast of Turkey: The preliminary results from surface samples. Marine Pollution Bulletin 118: 341–347.
[73] Tubau, X, Canals, M, Lastras, G. (2015) Marine litter on the floor of deep submarine canyons of the Northwestern Mediterranean Sea: The role of hydrodynamic processes. Progress in Oceanography 134: 379–403.
[74] Collet, I, Engelbert, A (2013) Coastal regions: People living along the coastline, integration of NUTS 2010 and latest population grid. Statistics in Focus 30: 2013.
[75] Nel, HA, Froneman, PW (2015) A quantitative analysis of microplastic pollution along the South-Eastern coastline of South Africa. Marine Pollution Bulletin 101: 274–275.
[76] Kanhai, LDK, Officer, R, Lyashevska, O. (2017) Microplastic abundance, distribution and composition along a latitudinal gradient in the Atlantic Ocean. Marine Pollution Bulletin 115: 307–314.
[77] Nel, HA, Dalu, T, Wasserman, RJ (2018) Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. Science of the Total Environment 612: 950–956.
[78] Amelineau, F, Bonnet, D, Heitz, O. (2016) Microplastic pollution in the Greenland Sea: Background levels and selective contamination of planktivorous diving seabirds. Environmental Pollution 219: 1131–1139.
[79] Brach, L, Deixonne, P, Bernard, M. (2018) Anticyclonic eddies increase accumulation of microplastic in the North Atlantic subtropical gyre. Marine Pollution Bulletin 126: 191–196.
[80] Eriksen, M, Liboiron, M, Kiessling, T. (2017) Microplastic sampling with the AVANI trawl compared to two neuston trawls in the Bay of Bengal and South Pacific. Environmental Pollution 232: 430–439.
[81] Lusher, AL, Burke, A, O'Connor, I. (2014) Microplastic pollution in the Northeast Atlantic Ocean: Validated and opportunistic sampling. Marine Pollution Bulletin 88: 325–333.
[82] Cincinelli, A, Scopetani, C, Chelazzi, D. (2017) Microplastic in the surface waters of the Ross Sea (Antarctica): Occurrence, distribution and characterization by FTIR. Chemosphere 175: 391–400.
[83] Ruiz-Compean P, Ellis J, Cúrdia J, Payumo R, Langner U, Jones B, Carvalho S. 2017. Baseline evaluation of sediment contamination in the shallow coastal areas of Saudi Arabian Red Sea. Mar Pollut Bull. 123(1–2):205–218. doi:10.1016/j.marpolbul.2017.08.059.
[84] Baalkhuyur FM, Dohaisha EA, Elhalwagy MEA, Alikunhi NM, AlSuwailem AM, Røstad A, Coker DJ, Berumen ML, Duarte CM. 2018. Microplastic in the gastrointestinal tract of fishes along the Saudi Arabian Red Sea coast. Mar Pollut Bull. 131:407–415. doi:10.1016/j.marpolbul.2018.04.040.
[85] Saudi Falcons Club. 2019 May 13. Plastic, microplastics endanger migratory birds. saudigazette.com.sa/article/566277.
[86] Baldwin D 2015. Body care products hide plastics. https://gulfnews.com/lifestyle/health-fitness/body-care-products-hideplastics-1.1563344
[87] Times of India. 2018 Jan 10. https://timesofindia.indiatimes.com/life-style/beauty/microbeads-get-bannedinternationally/ articleshow/62445157.cms.
[88] Toxics Link. 2018 Apr 30. Your facewash might be cleaning your face but polluting the environment! New Delhi. http://www.toxicslink.org/?q=article/microplastic.
[89] Seth CK, Shriwastav A. 2018. Contamination of Indian sea salts with microplastics and a potential prevention strategy. Environ Sci Pollut Res Int. 25(30):30122–30131. doi:10.1007/s11356-018-3028-5.

[90] Vidyasakar A, Neelavannan K, Krishnakumar S, Prabaharan G, Sathiyabama Alias Priyanka T, Magesh NS, Godson PS, Srinivasalu S. 2018. Macrodebris and microplastic distribution in the beaches of Rameswaram Coral Island, Gulf of Mannar, Southeast coast of India: A first report. Mar Pollut Bull. 137:610–616. doi:10.1016/j.marpolbul.2018.11.007.

[91] Kumar VE, Ravikumar G, Jeyasanta KI. 2018. Occurrence of microplastics in fishes from two landing sites in Tuticorin, South east coast of India. Mar Pollut Bull. 135:889–894. doi:10.1016/j.marpolbul.2018.08.023.

[92] KarthikR, RobinRS, PurvajaR, GangulyD, Anandavelu I, RaghuramanR, HariharanG, RamakrishnaA, RameshR. 2018. Microplastics along the beaches of southeast coast of India. Sci Total Environ. 645:1388–1399. doi:10.1016/j.scitotenv.2018.07.242.

[93] Tiwari M, Rathod TD, Ajmal PY, Bhangare RC, Sahu SK. 2019. Distribution and characterization of microplastics in beach sand from three different Indian coastal environments. Mar Pollut Bull. 140:262–273. doi:10.1016/j.marpolbul.2019.01.055.

[94] Vedic V. 2019. Desh ko plastic mukt banana zyada zaruri. Dainik Bhaskar-E-edition. 27 june 2019. p.8

[95] Chellaney B. 2019. Plastic waste is choking India. Times of India. Vol 27. p.10

[96] Hossain MS, Rahman MS, Uddin MN, Sharifuzzaman SM, Chowdhury SR, Sarker S, Nawaz Chowdhury MS. 2019. Microplastic contamination in Penaeid shrimp from the Northern Bay of Bengal. Chemosphere. 238:124688. doi:10.1016/j.chemosphere.2019.124688.

[97] Peng G, Zhu B, Yang D, Su L, Shi H, Li D. 2017. Microplastics in sediments of the Changjiang Estuary, China. Environ Pollut. 225:283–290. doi:10.1016/j.envpol.2016.12.064.

[98] Zhang J, Zhang C, Deng Y, Wang R, Ma E, Wang J, Bai J, Wu J, Zhou Y. 2019. Microplastics in the surface water of small-scale estuaries in Shanghai. Mar Pollut Bull. 149:110569. doi:10.1016/j.marpolbul.2019.110569.

[99] Zhu C, Li D, Sun Y, Zheng X, Peng X, Zheng K, Hu B, Luo X, Mai B. 2019. Plastic debris in marine birds from an island located in the South China Sea. Mar Pollut Bull. 149:110566. doi:10.1016/j.marpolbul.2019.110566.

[100] Tejonmayam U. 2019. Plastic on my plate: study finds microplastics in mussels along kasimedu harbour. Times of India. Chennai E-edition.

[101] Nabizadeh R, Sajadi M, Rastkari N, Yaghmaeian K. 2019. Microplastic pollution on the Persian Gulf shoreline: A case study of Bandar Abbas city, Hormozgan Province, Iran. Mar Pollut Bull. 145:536–546. doi:10.1016/j.marpolbul.2019.06.048.

[102] The guardian. 2018. Microplastics found in human stools for the first time. https://www.theguardian.com/environment/2018/oct/22/microplastics-found-in-human-stools-for-the-first-time.

[103] Ruiz-Compean P, Ellis J, Cúrdia J, Payumo R, Langner U, Jones B, Carvalho S. 2017. Baseline evaluation of sediment contamination in the shallow coastal areas of Saudi Arabian Red Sea. Mar Pollut Bull. 123(1–2):205–218. doi:10.1016/j.marpolbul.2017.08.059.

[104] Baalkhuyur FM, Dohaisha EA, Elhalwagy MEA, Alikunhi NM, AlSuwailem AM, Røstad A, Coker DJ, Berumen ML, Duarte CM. 2018. Microplastic in the gastrointestinal tract of fishes along the Saudi Arabian Red Sea coast. Mar Pollut Bull. 131:407–415. doi:10.1016/j.marpolbul.2018.04.040.

[105] Kunz A, Walther BA, Löwemark L, Lee YC. 2016. Distribution and quantity of microplastic on sandy beaches along the northern coast of Taiwan. Mar Pollut Bull. 111(1–2):126–135. doi:10.1016/j.marpolbul.2016.07.022.

[106] Yabanlı M, Yozukmaz A, Şener İ, ÖT Ö. 2019. Microplastic pollution at the intersection of the Aegean and Mediterranean Seas: A study of the Datça Peninsula (Turkey). Mar Pollut Bull. 145:47–55. doi:10.1016/j.marpolbul.2019.05.003.

[107] Browne MA,Dissanayake A, Galloway TS, LoweDM, Thompson RC. 2008. ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L.). Environ Sci Technol. 42(13):5026–5031. doi:10.1021/es800249a.

[108] Karbalaei S, Hanachi P, Walker TR, Cole M. 2018. Occurrence, sources, human health impacts and mitigation of microplastic pollution. Environ Sci Pollut Res Int. 25(36):36046–36063.

[109] Leslie HA. 2014. Review of microplatics in cosmetics. IVM Institute of environmental studies. Report R14/29.

[110] de Souza Machado AA, Lau CW, Kloas W, Bergmann J, Bachelier JB, Faltin E, Becker R, Görlich AS, Rillig MC. 2019. Microplastics can change soil properties and affect plant performance. Environ Sci Technol. 53:6044–6052. doi:10.1021/acs.est.9b01339.

[111] environ.Sci.Technol. 2015, 49, 18, 10759-10761 Publication Data: September 3, 2015. https://doi.org/10.1021/acs.est.5b03909.