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A Review on Microfiber Pollution: A Silent Threat to Ecosystems and Biodiversity

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ABSTRACT:

Microplastic contamination is a major environmental issue that poses an increasing danger to ecosystems and biodiversity. Microplastics are minute plastic particles smaller than 5mm in size that can be discovered in a variety of aquatic and terrestrial habitats, including water, the deep sea, and the fish and shellfish that people eat. Microplastic pollution comes from a variety of sources, including plastic-containing items, plastic mulch used in agriculture, polyamide fabrics, and cosmetics. Microplastics can injure small aquatic species that consume them and may include hazardous compounds that are deliberately introduced to plastics during the manufacturing process. Daily human exposure to microplastics occurs through two main pathways: inhalation and ingestion. Microplastics have been detected in a variety of human organs, including the placenta of newborn babies. The study of microplastics' environmental influence on species and ecosystems is still in its early stages. Some possible global strategies to reduce microplastic pollution are proposed, including global management of plastic pollution from multiple sources, technical standards for microplastic pollution, and the development of biodegradable plastics. The United Nations Environment Programme (UNEP) has started the Clean Seas campaign to encourage change among consumers, governments, and companies. The campaign intends to promote lifestyle and industry reforms, as well as raise awareness of the issue. It can also help us better understand the true effects of microplastics on human health and identify the appropriate next steps.The effects of microplastics on ecosystems and biodiversity are complex and frequently underestimated. Microplastics in aquatic habitats can be consumed by a variety of creatures, including plankton and apex predators, causing physical injury, toxic chemical bioaccumulation, and disturbance of feeding patterns. Microplastics accumulating in soils and sediments may disrupt nutrient cycle and soil health, affecting terrestrial ecosystems as well. Furthermore, microplastics have been discovered in the atmosphere, raising worries about their ability to carry contaminants and degrade air quality. Despite increased awareness of the problem, effective mitigating methods remain elusive. Efforts to minimize plastic usage and improve waste management methods are necessary, but insufficient to address the scope of the problem. innovations in material science, such as biodegradability plastics, hold promise but require careful consideration of theirenvironmental impacts.

KEYWORDS: *Microplastics (MP), Microfibers (MF), Microbeads (MB), Environmental effects*

INTRODUCTION:

The synthetic production of plastics has tremendously developed since 1940’s with growing range of plentiful applications. The term plastic is a Greek word “plastikos” which gives the synonym of easily mouldable and ability to cast in any desired shape and size and added with colour dyes, plasticizers, thermal, chemical and electricity retarders to augment the resilience and strength (Kamboj 2016). These plastics are excellent multipurpose products which occupies a major part in our modern lifestyle. It is very common to see plastic in myriad forms in our environment as a useful product or a useless litter. Though they have versatile range of applications from a normal house hold appliances to ships and rockets parts, their long-term consequences are undefined.

Plastic Industries have dominated the society for more than 50 years since its inception with a wide range of advantages such as

1. ***Provide job opportunities to local people***
2. ***Trade exchange between countries and thereby increasing the economy of the producer country***
3. ***Material flexibility***
4. ***Improved designs with promising quality***
5. ***More importantly they are available at an affordable cost and aredurable***

But unfortunatelyplastic, a *"fascinating product"* are made up of intermolecular bonds of polymers which are non-biodegradable in nature and take many decades to degrade. Plastic litter threatens the environment substantially and an alarming increase in landfills and the litters found in our beaches or other water column makes us to have acrucial concern over the plastic contamination which is termed as *"global culprit"*. Since it is a durable, widely useful material along with improper disposal ways and their very slower degradation rate.

The macro level plastic pollution is ascended to micro level pollutants which affects the aesthetic views and further its serious implications now turned out to be eco-toxic effects. In spite of all the existing waste management practices, plastic debris are prevailing all over the globe in various spectrum of sizes and forms. The term "Microplastics" normally refers to Plastic particle that are less than 5 mm in size (Thompson et.al, 2004). The pervasive presence of Microplastics in different environmental conditions such as aquatic conditions (both marine and freshwater), terrestrial (soil invertebrates are studied) and even atmospheric air which recently subjected to microplastic pollution were studied by the researchers. Though the fresh water plays a key carrier of transport for plastic litter from terrestrial environment (Macro or Micro plastic litters, WWTP or by Wind) to marine environment. There exist a lack of knowledge in fresh water system than marine environment which holds a good number of published articles.

The recent findings state that macro plastic particles >5mm in size after severe fragmenting, weathering and radiating action converted into microplastics.The microplastics are categorized into primary and secondary microplastics which predominantly includes Microfibers (MF) especially from synthetic fabrics and Microbeads (MB) from personal care products. The Microbeads were almost banned in developed countries like U.K, U.S, etc., but unfortunately still their usage is evident in developing countries like India. The Microbeads can be easily controlled by strict regulatory strategies and replacing it with natural alternatives. The much needed precedence is given to Microfibers (MF) since the so far identified primary source of Microfibers were Textile industries and domestic or commercial laundry waste water which is less understood in detail. In this review the term "*Microfibers"*refers to fibers less than 5mm in size and not the synthetic fabric made of polyester fibers finer than one denier or decitex.

The Microplastics in general, track their route to the environment by multiple means like Domestic and Industrial Waste Water, Waste Water Treatment Plant, Run off from roads. The micro litter particles can be predominantly found in marine environment. The recent reports on microplastic pollution reveals its ubiquitous presence in fresh water ecosystem, drinking water, salt and even in atmospheric air. There are evidences that microplastics in any form can be easily ingested to the biota and enters the food web. There is huge chance of vector transport of other priority organic pollutants and other inorganic toxic contaminants get sorbed which leads to poisoning of the food chain which was reported in the previous studies(Teuten et al., 2007, Besseling et al., 2013, Bakir et al., 2012 & 2014). The microfibers can travel in the food chain and finally end up in human plates. The microfibers are said to be filamentous in nature and get entangled easily with our digestive system, nervous system and cardiovascular system(Dey, S et al.,2023) and which can affect the living organism in any means. There is still a knowledge gap exist on the impact of microfiber pollution but few literatures state that it poisons the food chain and alter their metabolism process and characteristics in a drastic manner.

The natural fiber such as cotton, hemp, wool, etc., are replaced by the synthetic fibers which later become significant contributor in the release of microplastics in the form of Microfibers into the environment. The man-made fibers like polyester, acrylic, rayon, etc., are frequently utilised in the making of clothing, upholstery items, carpets, and screens since 5 decades ago. (Geyer et al., 2017).

The fibers may be natural (cotton, wool, jute, linen, etc.,) or artificial (Polyester, nylon, rayon, viscose, etc.,) or sometimes blended (polyester cotton or poly cotton) in nature which depends upon the production of textiles. The ultimate usage and repeated washing results in the release of microfibers.
The study has stated that washing synthetic fleece jacket released an average of 1.7g of microfibers (Patagonia Company Report). Both natural and synthetic fibres were predominantly present in the marine and other ecosystems (Mathalon and Hill, 2014). Though the washing effluent are treated by Waste Water Treatment Plant in many countries, still 70-99% of Microplastics get retained in the sludge which will be disposed later over the terrestrial and aquatic ecosystem (Habib et al, 1998). Owing to their micro and nano sizes which is very much difficult to trap microplastics in water environment. This review focuses on proper sample and isolation procedures, separation processes, quantification and evaluation methodology, impact studies on various environmental elements, and the efficacy of microfiber reduction and control measures for microfiber pollution.
A single wash of a garment can shed 100s to 1000s of microfibers and this conforms the significant source (Browne et al., 2011; Hartline et al., 2016; Hernandez et al., 2017; Napper and Thompson, 2016; Pirc et al., 2016). From the literature reviewed and based on our fundamental views in studying the effects we hypothesize that textiles shed significant amount of microfibers during productionprocess, their ultimate usage and at their disposal point. It is now necessary to uptake stringent measures to control the Microfiber release and more research priority should be given to the quantifying techniques of shedding and Microfiber characterisation.
This review will definitely give a brief assessment of microfiber pollution and make the public, textile manufactures and other dependent sectors and policy makers to understand the catastrophic effects on Microplastic Pollution. This paper may help in identifying the technical gaps related to microfiber pollution and may helpful for the future research to be carried out in a standard manner.

MICROPLASTICS – A POORLY DEFINED ISSUE:

There is no a proper definition for the term “microplastics” yet in worldwide. The technical definition should satisfy a proper substantiation of analytical and experimental methodologies with respect to the reference material. The reviewed literatures have defined the term microplastics in few different ways. With respect to the particle size the macro plastics ranges >25mm, meso ranges from 5mm to 25mm and microplastics <5mm in size (Imhof et al, 2017). It was said that due to fragmentation of larger piece of plastic litter into smaller plastic fragments which are undetectable to the naked eye (Thompson et.al, 2004, Browne et. al, 2007, Cooper and Corcoran, 2010, Andray, 2011). It was alsoassumed that plastic particles less than 5 mm (0.2 inch) in diameter and or in length are microplastics which can be identified by the use of microscopes (Arthur et.al. 2009). The maximum size in micro scale level is 5 mm and nano scale level is fixed and 1 nm to less than 5mm in diameter (NOAA – National Oceanic & Atmospheric Administration Workshop, 2008). In common it is said that plastic litter or debris of 5mm to 100nm in size are microplastics (GESAMP, 2016; Thompson et al., 2004). In recent times, the submicron level nano sized plastics are of recent research priority (Hartmann et al., 2019)with respect to the sea food source safety and other environmental adulterations which may act as risk factor for human life (Zeng et al., 2018). The basic definition and proper nomenclature remains conflicting and elusive. The quantification of microplastics itself is still an unresolved issue so in this review the microplastics are given importance for further exploration than nano plastics.

Sources of Microplastics:

The evident footprints of microplastics from cradle (production) to grave (waste management) are clearly visible in our environment along with the possible contaminant rate of trophic transfer in the ecological cycle by risking the human health. (Bank & Hansson, 2019; GESAMP, 2016). The ample source of microplastics are based on the exposure conditions and their behavioural changes in different environmental conditions. Due to the countless usage of plastics, they occupy an irreplaceable material in our routine and modern hectic life. The sources are classified into two types majorly. They are land

based and marine or Aquatic based, out of which 80% of the source is land based. The possible source of microplastic generation are listed out below:

TABLE 1: SOURCES OF MICROPLASTICS

S.NO	ANTHROPOGENIC ACTIVITIES/ CAUSES	SOURCE
1.	Throwing away or improper disposal of single use plastic bottles and other plastic packages /wrapping/ bags	Land Based Source
2.	Plastic litter on streets blown away by the wind	Land Based / Atmospheric Air Source
3.	Automobile parts and rubber tyre fragments	Land Based Source
4.	Plastic resin pellets used in industries – discharged through effluents	Land Based Source
5.	Illegal Garbage dumping in Ocean/ Sea	Aquatic Based Source
6.	Accidental spills from shipping vessels / Sandblasting	Aquatic Based Source
7.	Scrubbers to remove rust and worn out paint from ship hulls and engines (Sharma and Chatterjee,2017)	Aquatic Based Source
8.	Fishing nets, hook lines and gears (mostly Polyethylene and Poly vinyl chloride, Polypropylene)	Aquatic Based Source
9.	Boats and trawls on the shores of water bodies (GESAMP , 2015)	Aquatic Based Source
10.	WWTP effluent contaminated with microplastics and sludge released into the water bodies / application of sludge as bio fertilizers	Land Based Source
11.	Agro mulch textiles used as a liner for crops which are not properly disposed	Land Based Source
12.	Discarding or frequent laundering of the fast fashion Synthetic polymer based clothes	Land Based Source
13.	Intentionally added plastics in Personal care / Cosmetic products	Land Based Source
14.	Construction sites – Plumbing Pipes / Electrical Fixtures (PVC)	Land Based Source
15.	Strom Water Run off / Run off from unlined dump yards	Land Based Source

Categories/ Types of Microplastics:

In general, the microplastics are categorized into two types based on their major source of generation, Primary and Secondary Microplastics.

a) Primary Microplastics:

They are raw manufactured plastic products which is intentionally used in cosmetic products like ***Microbeads, virgin plastic resin pellets, scrubbers, scourers used in cleaning products***(Browne et .al. 2007, Arthur et.al, 2009) and ***microfibers used in the synthetic textiles***(Patagonia, 2016, Henry et.al,2019).

b) Secondary Microplastics:

They are the macro and meso size plastic particles which undergo ***physical or chemical or biological weathering and degradation action*** which ultimately results in lowering the structural integrity. The microplastics are formed by ***degradation by microbes*** or sometimes partial ingestion of superior aquatic organisms like Whale (Andrady, 2017),***Photo degradation by Sunlight UV rays*** resulting in colour change of the buoyant plastic particles,***Hydrolysis*** process when plastics are incessantly exposed to water environment which gets wear and tear due to the tides and waves, ***Bond cleavage or Breakage*** and ***Thermal degradation*** at high temperature or by ***thermo-oxidative degradation*** which means oxidative breakdown(Thompson et. al, 2004, Browne et .al. 2007, Cooper & Corcoran, 2010, Andray, 2011).Out all these types of microplastic pollutants, Microbeads and microfibers are taken into serious account as a major identified source in recent times.

Microbeads:

Microbeads are small plastic particles less than one millimeterand are commonly seen in cosmeticslike face wash, cleansers, sunscreens, Body wash, shampoos, conditioners, Foundation and blush make up items, exfoliates or facial scrubs, and other personal care or cleaning products like tooth paste, laundry detergent powders, etc.

Why Microbeads?

They are deliberately used for the following factors:

1. ***To increase the product volume or bulking agent for the products***
2. ***To improve the adhesive quality***
3. ***To add aesthetics***
4. ***To control viscosity and formation of thick layer***
5. ***To be used as an abrasive***

They are not easily degradable and dissolve in water. They are available in cheap price but they are better adsorbents to the other toxins like priority organic pollutants (POP's), organo-chlorine pesticides and other endocrine disruptive chemicals. The commonly used polymers in Microbeads are Polyethylene Terephthalate (PET), Nylon (PA), Polypropylene (PP), Polymethyl Methacrylate (PMMA), etc. Since they are micro sized particles less than 1mm they are not possible to get filtered in the Waste Water Treatment Plants of the city. They enter the nearby water bodies easily from the wash off drains. Finally they affect the aquatic life and end up in human plates through sea food. The only way to stop this pollution is by preventing the use of Microbeads in the products used in developed nations like US, U.K., and Australia. It is unfortunate that still our country India is using those harmful products in our day to day life, though BIS has declared the Microbeads are unsafe. They can be avoided by using natural alternatives like bees wax, corn wax, oats, etc.

Microfibers:

Microfibers one of the predominant subcategory of Microplastics, which are fibrous in shape and particle size less than 5mm in length. The major source of microfibers are synthetic textile fibers which are intentionally utilized in our daily clothing and sometimes the hard truth the textile fibers were prepared from the reused plastic bottles.

Over 60 % of our daily clothing is made of synthetic textiles like polyester, nylon, acrylic, rayon, etc., (Sait et al.,2021) It is due to our fast fashion trend, we need the new fashionable clothing's directly from fashion ramp to our wardrobes. There are few factors why natural fibers like cotton, wool, etc., lost their significance because of their *limited accessibility, higher cost for fabrication and very less life expectancy*

Why Microfibers?

The positive features of using microfibers are:

1. ***Inexpensive***
2. ***Long-lasting***
3. ***Shimmering Look***

4. ***Easy dry material***
5. ***Wrinkle – Resistant***
6. ***Microfiber Cleaning cloth or mops are manufactured with antibacterial coatings (Silver) to prevent the bacterial contamination***

Microfibers – Source to Sink:

Microfibers trail their routes to therudimentary constituents of the environment such as water, air and soil. It is quite difficult to know the pattern and source of microfiber generation in the environment. Before investigating the mitigation measures to the microfiber issue, categorising the source and dispersion mode is substantial.

Categories of Microfiber Source:

The primitive source of the microfiber is synthetic textile fibers of <5mm in size released into the living environment during the production and its ultimate usage.

Due to the secondary factors like abrasion, fragmentation, etc., microfibers were released from the waste clothes as tiny particles which is very difficult to identify and analyse their pervasive presence in the environment.

It is clearly understood that if deliberately used microfibers in various applications are mismanaged or disposed into the environment directly leads to the root cause *(Table No.1).* Later on due to the secondary parameters as mentioned above the microfibers are generated from the macro polymer based materials. It is strongly assumed that microfibers are majorly shredded from the frequent domestic laundering of the clothes. During washing progressions, shedding of fibers depends on the following parameters such as *fabric type, texture, yarn type, number of fiber types involved, shorter fibers or filaments, age of the clothes, washing machine type, washing conditions, etc.,*

The belief may be a part of the reason but there are other sources of occurrence such as discarding of our old clothes in domestic wastes, cloth flags, Textile sector wastes, etc., which may be the secondary cause. The cloth wastes may continuously unravel into tiny micro particulate matters and enters into the water bodies, blown into the air and few get dumped in the soil which mainly depends on the used raw material blends, type of weaving and ageing of the clothes.

The synthetic textiles are not only used in clothes, they can be used in the manufacturing of automobile cloths, furniture fabrics (Upholstery), fancy curtains for house decors, geotextiles, foot balls, back packs, soft toys, buildings, agro uses, etc.,.

Around 91% of Polymer made fibers are used in the production which is not easily biodegradable and act as a carrier for other harmful chemicals and infectious diseases from the environment. There are various issues related to the release of emerging contaminant into the environment which later distresses the human with serious impacts.This review may foster the mind sets of manufacturers and consumers to use natural fibers. The other intention is to encourage the future research in handling the microfiber issue by provide large scale solutions to degrade the millions of discarded plastics subjected under different environment settings.

General Overview of Microplastics in Indian Scenario:

The reports on microplastics for the past two decades the future and current potential havoc associated with it. In last 4 years, around the Globe developed nations like U.S., most of the European nations, Australia, Canada, have banned the production and materials made of microplastics. United States has stopped the production and consumer use of Microbeadsin the personal care products in 2015 by passing law Microbead - free Water Act. But in developing countries like India we are decades behind the term Microplastics. In 2017, National Green Tribunal court of India and BIS listed the microplastics are not suitable to use in the personal care products still the law doesn't get into action. There is no accurate data on contamination level at present situation but many studies all over the globe says that impacts are worsening. Only few researches were conducted on microplastic contamination in India. There is a statement in a research article that Indian people uptakes 11kg of plastics per year, which is a

heart wrenching news.(Kurapati, R. 2023)In southern Asia, India is one of the leading contributor which releases more than 200kgs of plastic litter as primary microplastics into the water environment*(International Union for Conservation of Nature in its study* Primary Microplastics in the Oceans: a Global Evaluation of Sources*).*

In the state of Kerala, a southern part of India, a research group has done an initial study on microplastics in the Vembanad Lake during the monsoon period. They reported the presence of microplastics in the sediments present in the water column and ingestion of microplastics by the fishes were also reported in addition to it. Fish being the major staple food of the surrounding people and it is very hard to know that people are consuming the plastics associated with other toxic chemicals.
In 2013, there is a report stating that microplastics were evident in the beach sediments of Mumbai. In IIT Bombay, the table salts of leading Indian brands were subjected for microplastic assessment. Thereport says they are contaminated with microplastics and needs a thorough assessment in future.

Only few studies like Delhi-based NGO Toxics link claimed that microplastics are associated with other endocrine disruptive chemicals which can easily inhibit the human body and other organisms resulting in serious health disorders. There are huge possibilities for the pathogens contamination with the microplastics in addition to the other toxic chemicals. Less number of data and risk assessment was done due to the microplastics exposure in India. The presumed theories concerned with the microplastics ingestion into the humans and other higher level organisms has started to make worse health impacts. This should be taken in a serious deeper note by the World Health Organisation and IMA (Indian Medical Association) to conduct intensive studies on the microplastics for better understandings and put forward the legislative measures to ban the microplastics in future.
In our monotonous lifestyle that is from the morning to night we are intended to use microplastic based personal care items or microplastic contaminated products like bottled waters, table salts, honey, beer, etc.,. Being very tiny in size it is very much easier to contaminate them in all the possible products for their added advantages but it is quite difficult to trap or treat from the water environment which later results in countlessailment to the living beings. India one of the leading producer and consumer of the plastic based products with world's second highest
populated country should be responsible in taking actions legally and also to make available mitigation measures to evade the issue at this level in prior to the worsening situation similarly to the plastic pollution.

Impacts on Biotic and Abiotic Components:
Microplastics in any form can counter with biotic components and they interact physically or chemically with the biota resulting in malfunction of the organisms.
In early 1970s' the presence of microplastics was obviously reported in the guts of seagulls' (Kenyon and Kridler, 1969). There were many reports which stated the plastics ingestion from macro level to micro size in the marine ecosystem than the freshwater sources. But there are fewer number of studies for the microfiber ingestion in the biota than other sorts of microplastics.
In 2013, it was identified that Microfibers were predominantly seen in some of the few samples of demersal and pelagic species of English Channel. The microfibers are of Rayon and Poly Aromatic groups (Lusher et al., 2013).
The sediment samples from various shore lines across the globe was assessed. The presence of microfibers in the sediments were reported and traced the major source from WWTP discharge.(Browne et al., 2011). This states that textile industries, domestic and commercial laundry are the largest source of microfibers in the environment. Though the contribution may directly from washed textile effluents but the striking source is WWTP. Since the bulk amount of release is greater than the domestic or textile processing waste water (Browne et al., 2011 & Murphy et al., 2016).
The harmful impacts on the biota due to the ingestion of microfibers was studied with the help of gold fish since they are the widely used species for bioaccumulation research (SefanGrigorakis et al., 2018).

After 48hrs of fasting the fishes were exposed to consume the fish feed amended with few microbeads (Polyethylene – Source: Commercial facial cleanser) and microfibers (Polyester – Source: Scarf shredded to fibers). 80-100% recovery of microfibers and 0-3 microbeads were visible in fish gut. The study concludes there is no net bioaccumulation is entertained at the time of assessment. The work should be forwarded to longer retention time and exposure to other categories of microplastics under different conditions.

The gaps were identifiedand future work should focus on the detailed realistic exposure of all types of plastic fibers irrespective of shapes, size and polymer groups which are predominant in the environment. There should be an extensive knowledge on interaction of microfibers with the biotic and abiotic components.

Atmospheric transfer of Microfibers

Microplastic pollution is evident in all the environmental compartments which are interlinked with diversified sources. The recent research explorations on the atmospheric air quality has found the presence of microplastics in the air samples which was quite shocking. The air which is one of the ultimate source, transports the microplastics and deposits them on the aquatic and terrestrial environmental cubicles. (Zhang et al., 2019 & Liu et al., 2019). There may be a robust impact on the source-sink dynamics of plastic pollution in different ecosystem (Bank & Hansson, 2019). The factors like density and shape of the microplastics dominates their transportation behaviour within the atmosphere (Dris et al., 2020).

In the late 90s', cellulosic and plastic microfibers were observed in the human respiratory tissues (Pauly et al., 1998). Latest findings have revealed the presence of microplastics in both the indoor and outdoor air samples. The major outdoor source identified so far is the open landfills from where the shredded litter or debris includes the discarded textile fiberscan be easily carried away by the wind(Barnes et al., 2009). The study says that the concentration of microfibers in indoor is higher than outdoor air. (Dris et al., 2020).The textile fiber dust mass deposited on the indoor house environment was measured and approximately equals to the mass of fibers discharged in the laundry effluent. The studies was carried out in Norwegian houses and the majority of the polymer captured was Polypropylene, commonly used in upholsteries like carpets and other furniture. The studies says that risk exposure of larger sized microplastics in the ambient air which are visible to the naked eye have less chances to be inhaled but there are greater chances of dust inhalation of the microfibers by younger community (Dris et al., 2020). This exposure may results in cardiovascular and respiratory illness to the exposed human.

As of now, only very few researchers have published their research findings on airborne microplastic contamination. One of the findings was the snow clad mountains of the Alps and Tibetan Glaciers were contaminated with microplastics by wind or sometimes snowfall to higher altitudes (Ambrosini et al., 2019 & Zhang et al., 2019). Allen et al.,2019 says that there is an evident chance for transporting the microplastics to 100km distance which is claimed to be a remote place without any local source of contamination. The findings were justified with the basic concepts of meteorological and particle settling velocity with the help of modelling toolcalled Hybrid Single ParticleLagrangian Integrated Trajectory Model (HYSPLIT). Though the tools detect the pollutant source and distance travelled but the essential characteristic parameters were failed to obtain. Hence theforthcoming research is to be concentrated on thethorough characterisation of atmospheric microplastics dynamics.

Overall there is an urge to evaluate theserious rate of toxicity in long term exposure. The research can focus oncurrent status of the knowledgeon the interaction among the atmospheric microplastics with other priority organic pollutants (POP's), heavy metals, etc. Thus the microfibers become a non-trivial source which distress the human health through food web to cause serious impacts on the various environmental compartments and ecological health.

CONCLUSION

In conclusion, microfiber contamination is a huge environmental issue that poses an increasing threat to ecosystems and biodiversity. Microfibers are synthetic fibres designed to assist humans, yet they destroy Earth's organisms and ecosystems. Microfibers can be found in a wide range of land and aquatic environments, including shorelines and the seafloor, remote places in US national parks, and even snow in the Alps and the Arctic. Washing garments is a major source of microfiber contamination, and while wastewater treatment plants remove the majority of microfibers, some microfibers pass through and end up in our streams and oceans. Microfibers can injure small aquatic species that ingest them, and they may include harmful substances that are purposely put to textiles during the production process. Daily human exposure to microfibers occurs through two main pathways: inhalation and ingestion. The study of microfiber's environmental impact on species and ecosystems is still in its early stages, and additional research is required to fully comprehend the scope of the problem. However, feasible global measures to mitigate microfiber pollution are proposed, such as global management of plastic pollution from textile sources, technical standards for microfiber pollution, and the use of chemical fibres with a length of less than 5 mm as an environmental pollutant. Consumers can also take action by purchasing laundry balls and clothing bags specifically designed to catch microfibers in the wash. Addressing this issue is crucial for protecting our ecosystem. The consequences of microfibre contamination go beyond environmental concerns, with significant ramifications for human health and socioeconomic well-being. As these fibres aggregate in aquatic and terrestrial habitats, they can act as vectors for harmful contaminants, bioaccumulating in creatures ingested by humans. Furthermore, the economic expenses of mitigating the consequences of microfibre pollution, such as cleaning up contaminated areas and addressing related health conditions, are significant and frequently borne by communities and industries. Addressing microfibre contamination involves a multidimensional approach that includes scientific study, technical innovation, regulatory initiatives, and public awareness efforts. Efforts to reduce microfiber pollution should focus on improving product design, sustainable fashion processes, and customer education. Furthermore, improvements in wastewater treatment infrastructure and filtering technology can assist catch microfibers before they enter natural habitats.

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