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MICROPLASTIC POLLUTION CAUSED DUE TO SYNTHETIC GARMENTS

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Abstract- Microplastic pollution from synthetic clothes has emerged as a major environmental concern with far-reaching implications. This research investigates the sources, mechanisms, and effects of microplastics shed during the synthetic textile lifespan, which includes manufacturing, usage, and disposal. It investigates the ways by which these microfibers enter ecosystems, collect in diverse environmental compartments, and endanger aquatic and terrestrial animals, as well as public health.

Keyword- Microplastic, Primary Microplastic, Fast Fashion

I. Introduction

The fashion industry is rapidly expanding, but it is also responsible for a variety of negative environmental repercussions. The garment industry is a severe threat to the environment. The garment business accounts for 10% of worldwide carbon emissions, depleting water supplies and contaminating rivers and streams. Every year, 85 percent of all textiles end up in landfills (UNECE, 2018). This industry is one of the world's largest polluters, responsible for 20% of all industrial water pollution globally, trailing only the oil sector. It also requires 93 billion litres of water every year, which is equivalent to the amount required by five million people. Every year, 200,000 to 500,000 tonnes of textile-derived microplastics make their way into the world's marine habitats. Microplastics account for 30% of plastic contamination in the ocean. The growing amount of plastic garbage in landfills and visible litter on shorelines, coastal waterways, and seas has emerged as a major global problem, particularly for the health of the marine environment (Jambeck et al. 2015). Plastic pollution is being redefined to include microplastics, which are particles and fibres smaller than 5 mm in size (Eunomia, 2016; GESAMP, 2015).

Synthetic and natural fibre production climbed from 57 million metric tons (MMT) in 2000 to 111 MMT in 2020 , with projections indicating that it will reach 145 MMT by 2030. Synthetic fibres have taken over cotton as the most popular fibre type in the textile market since 1995, and by 2020, synthetic fibre alone will account for over 65% of global output. Applications for natural and synthetic fibres are numerous and include apparel, home textiles , filters , and protective gear. China and India are the two countries that manufacture the most synthetic fibers geographically, with 66% and 8% of global production, respectively.

Plastic fibres are widely used in the production of clothing and textiles that improve the beauty and utility of our homes. In 2016, 65 million tonnes of plastic were used for textile fibres (The Fiber Year, 2017). Natural fibres of plant or animal origin, traditionally dominated by cotton and wool, continue to account for a portion of overall content, while synthetic fibre production has driven global textile growth (The Fiber Year, 2017). According to Eunomia (2016), up to 0.19 million tonnes of microplastics enter the marine environment each year via the production and typical usage of synthetic textiles, mainly domestic laundry.

II. Microplastic and its Types

According to the European Chemicals Agency and the U.S. National Oceanic and Atmospheric Administration (NOAA), microplastics are tiny fragments of plastic that are less than five millimetres in length. Professor Richard Thompson OBE FRS originally coined the term "microplastics" to describe the accumulation of microscopic pieces of plastic in marine sediments and in the water column of European waters. In 2004, he and his team were the first to establish that microplastic particles have accumulated in oceans since the 1960s and are now globally present in our seas. There are two categories of microplastics, Primary microplastics and Secondary microplastics.

Primary microplastics are microscopic particles that the plastics manufacturers intentionally produce. Among other things, this small size allows for the regulation of the product's viscosity, stability, and physical appearance, as well as the possibility of an abrasive effect. Fishing nets, artificial grass, cleaning supplies, and cosmetics are among the items that contain primary microplastics.Industrial items may also contain primary microplastics.

Secondary microplastics result from the fragmentation of macro- or mesoplastics, primarily caused by a variety of environmental processes, including hydrolysis, photodegradation, thermo-oxidative degradation, biodegradation, and thermal degradation. Plastic oxidizes in the presence of low temperatures and mechanical friction from sand and waves, eventually degrading into scrap. Therefore, the fragmentation of macroplastics yields secondary microplastics.

III. Pathways and Where all have Microplastics Been Found

3.1Microplastic in Water

Washing synthetic fabrics can release microfibers, with waste water being the main route for leakage into the aquatic environment (Boucher and Friot, 2017). Microfibres from polyester clothing that has been used, cleaned, and discarded wind up in the ocean. In a single wash, a single article of clothing can release 700,000 fibres. Sewage treatment facilities receive the wastewater after that.These tiny plastic particles or fibres enter the marine environment through filtration mechanisms and build up in the food chain. Microplastics are ingested by fish and other marine creatures and make their way up the food chain to our plates. According to Peng et al. (2017), estimates of the effectiveness of removing microplastics from wastewater varied widely, ranging from 95 to 99%. Because of the large quantities of discharge, effluent discharge continues to be a major source of microplastics even with high rates of capture (Setälä et al., 2016).

3.2Microplastic in Air

According to reports, wearing textiles has also been linked to the release of microplastics into the atmosphere, which land in soil (De Falco et al., 2020; Napper et al., 2020). Air samples from both outside and indoor spaces have been found to contain microplastics. According to a study, when clothes are dried and worn, up to 65% of microplastics may be released into the atmosphere.Microfibres from discarded textiles may be entrained in microplastics found in wind-blown debris from landfill sites in open environments (Barnes et al., 2009). Deposition of airborne microplastics is common because plastic has a density greater than that of air (for example, polyester has a density of about 1.39 g/cm^3 at sea level and 15 °C).

3.3Microplastic in soil

Terrestrial environments have been found to contain microplastics. Microplastics can enter soil via a variety of routes. Microplastics from the air end up on pavement and highways. They are subsequently carried by runoff to sewers and roadsides, where they are treated into sewage sludge that is applied to fields as fertilizer.-Microfibres were probably produced by using thread or twine to cultivate vegetables and by directly irrigating garments with water from washing machines. Microfibres can seep into soil when textile debris, such as lost clothes, tarpaulins, ropes, and single-use face masks, is disposed of in landfills or left as litter.

3.4Where all have Microplastics Been Found

Microplastics, tiny particles of plastic less than 5mm in size, have been found in various environments, highlighting the long-range transport of these particles and their presence in remote regions, and the widespread contamination of our planet (Cesa et al., 2017). These include the following.

Oceans, lakes, and rivers are examples of aquatic environments where microplastics are present in significant amounts. Furthermore, sediments and freshwater sources including rivers and lakes have been reported to contain microplastics. It appears from a 2015 investigation that microplastics have also been discovered in the Arctic Ocean. Arctic Ocean water samples were taken and examined both at the surface (16 cm below the water's surface) and at deeper depths (6 m below the surface). 20 out of 21 samples had an average of 1.31 particles per millimetre on the surface, or 1310 particles per litre. Microplastics were present in 70 out of 75 samples at depth, with quantities ranging from 0 to 11.5 particles/m3. Ninety-five percent of the plastic forms that were discovered were represented by fibres. Differentiating between the polymers that comprise these fibres was made feasible using Fourier transform infrared spectroscopy (IRTF). Thus, it was possible to identify microplastics of unknown origin in addition to polyester, nylon, acrylic, and polyvinyl chloride fibres. Due to their high density, these polymers will eventually sink and deposit sediment on the seafloor. Another possible explanation for their appearance on the water's surface is turbulence brought on by winds and storms, which cause the particles in the water column to be redistributed.

Additionally, microplastics have been found in terrestrial settings like soil and air. Microplastics have been found in agricultural, urban, and even distant wilderness soils, according to studies. Additionally, researchers have discovered the existence of microplastics in urban air, indicating that they may be carried by atmospheric processes and possibly breathed by humans. High concentrations of microplastics have been detected in urban settings as airborne dust, suggesting that these particles are widely dispersed throughout cities, isolated atmospheric regions, and even interior spaces.

organic fertilizers made from the fermentation and composting of biowaste have been shown to contain microplastics, suggesting that agricultural methods may be a factor in their release.

Food and Drinks: Research has shown that a variety of food and drink items contain microplastics, which suggests that ingesting them can cause them to enter the body.The page lists the foods and drinks that have been shown to include microplastics, such as fish (FPF reported), seafood (FPF reported), salt (FPF reported), sugar, honey (FPF reported), milk, and drinking water. (WHO REPORT)

Drinking Water: The discovery of microplastics in some sources of drinking water has sparked worries about possible human exposure to these particles.

IV. Fast Fashion’s Contribution to Microplastic Waste

Fast fashion is a linear economic structure that encourages consumers to purchase more clothing since it is affordable, only to discard it after a single season. The core ideas of the fast fashion strategy include low quality, quick changes in trends, and consumption, which encourages customers to alter their preferences more frequently. Millions of clothes end up in landfills every year throughout the world. In response to an ever-accelerating demand, fast fashion first appeared in the 1990s. It functions as the hidden engine of continuous, faster production and consumption. It's a never-ending wheel that gathers and returns everything in its path as rubbish. Four seasons have become fifty-two, with fast fashion retailers like H&M, Forever 21, Primark, Zara, Shein, and Target having one for nearly every week of the year. As quickly as they become available, the designs "go out of style."

The fast fashion industry uses 98 million tons of nonrenewable materials annually, which include oil to produce synthetic fibres, fertilisers for growing cotton, and chemicals for manufacturing dye and finishing agents for fibres and textiles.(Watson et al., 2016). Of the materials used, manufacturers lose 73% of them after the last usage of the garment, 10% during production, and 2% to landfills, and these quantities never even make it to market(Ellen MacArthur Foundation, 2017). On average, every second, a truckload of textiles and clothing is incinerated or landfilled (Ellen MacArthur Foundation, 2017).

The "fast fashion" industry's rapid turnover in recent decades has contributed significantly to the rise in production well as waste (Cobbing and Vicaire, 2016).Large volumes of microplastics are finding their way into our oceans as a result of the world's insatiable need for quick fashion. Many people are surprised to learn that the majority of clothing is really made of plastic, which could lead to a microplastic catastrophe (Hartline et al., 2016). This is because, in contrast to natural materials like cotton or wool, synthetic materials derived from fossil fuels, like polyester, are more affordable and readily available when used to make apparel. At the moment, polyester is the most popular synthetic fibre and makes up over half of all fibre produced worldwide. It has been documented that these microplastics can contaminate the water across great distances. According to a recent study on microplastic pollution near the North Pole, polyester fibres that resembled PET found in textiles are responsible for almost 73% of microfiber pollution.The widespread worry over this issue has increased due to the use of synthetic materials. Approximately 75% of the microplastics discovered in the Arctic Ocean in 2021 were from polyester fibre. This is a concerning discovery since it implies that microplastics from the fast fashion sector have affected marine habitats globally.

V. Factors and Stages Affecting the Release and Emissions of Microplastics from Textiles.

5.1Factors

The disintegration of fibres from textiles is dependent upon multiple factors.

5.1.1 Physical-chemical properties of fibres

Typically, natural fibres like cotton release more fibre pieces than synthetic fibres like polyester. This is explained by the fibres' strength, resilience, and resistance to a variety of environmental factors, such as weathering (sunlight, UV radiation, oxidative gases), chemicals (bleaching agents, for example), wear and tear, multiple washings, and drying cycles.

5.1.2 Yarn and fabric structure

Staple yarns or fabrics made from staple fibres usually release a substantially greater amount of fibre fragments than fabrics made from continuous filaments. In this case, the type of yarn spinning (ring or open-end) and fabric interlacing (knitting or weaving) can be quite important. Twisting the yarn increases its flexibility and resistance. This causes the yarn to become denser, which lowers shedding.It goes without saying that a yarn with a higher linear density will have more fibres and lose more.Reduction of the amount of fibre fragments that break out after repeated cycles of washing and drying occurs when the fabric structure is enhanced.

5.1.3 Fabric Finishes

It is possible to reduce friction between fibre-detergent and fibre-fibre and prevent abrasion by using different pretreatment chemicals. By doing this, the textile is shielded from the mechanical stress of washing machines.Following wet operations, some mechanical textile finishes (such as calendering, compacting, and sanforizing) and chemical applications (such as softeners, anti-crease agents, and cross-linkers) can lessen the release of fibre fragments from fabric.

5.1.4 Washing

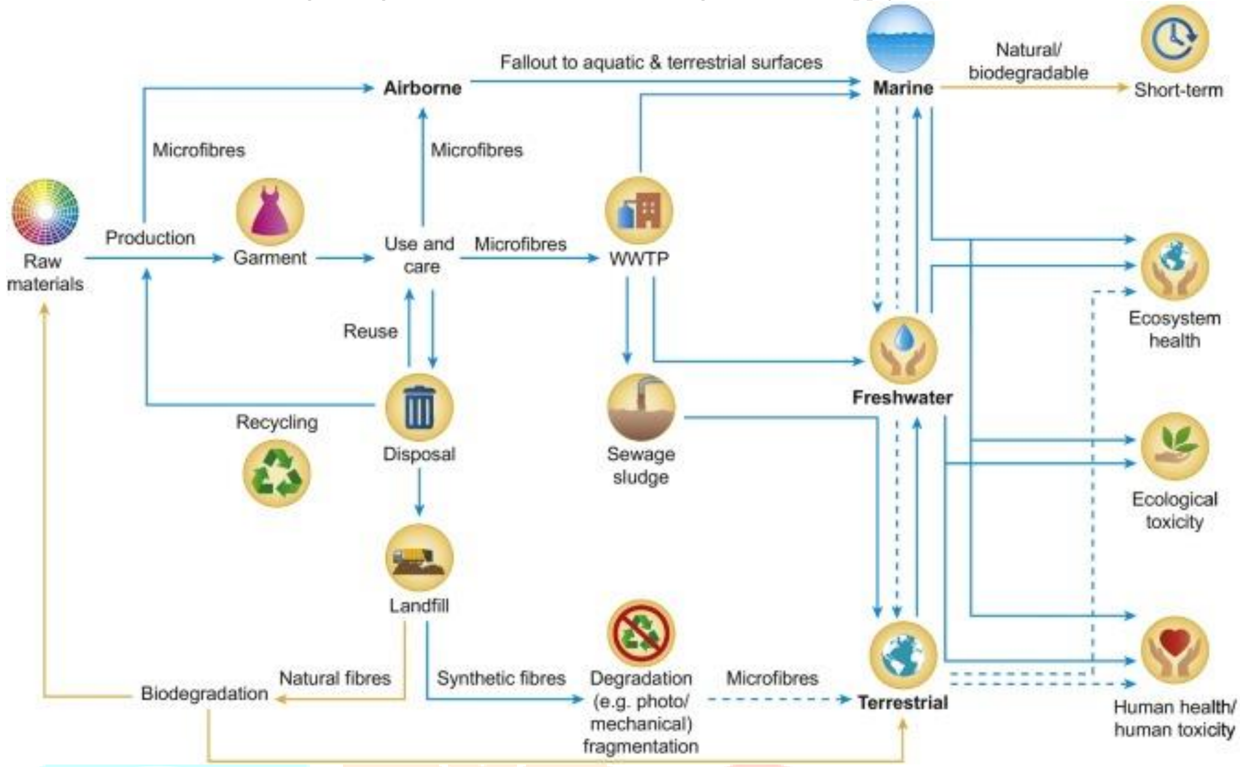
The amount of fibre fragments that break and fall out of textiles can be increased by increasing the concentration of detergents that contain abrasive inorganic salts, raising the temperature and length of the washing cycle, and applying powerful mechanical agitations.

5.1.5Drying

Tumble drying, which combines intense drying temperatures with mechanical agitation, can accelerate the breakup and release of fibre fragments from textiles. The textiles' surface may still include broken and damaged fibres, which could be released into the water stream during the subsequent washing cycle.

5.2 Stages

Fig1. Stages of Microfiber release along the textile supply chain



As shown in Figure 1, microfibres can be released at several points along the textile supply chain and how they can move between habitats through trophic transfers and the fallout of microfibres in the air. It has been demonstrated that a variety of routes exist in freshwater, marine, and terrestrial habitats for both effects on human health and ecosystems. Comprehending these routes is pertinent to the creation of a metric in sustainability evaluation instruments that would be efficient in overseeing and controlling the hazards of microfibre contamination from clothing and household textiles.

VI. Microplastic Shedding from Clothing Post Manufacturing stage

In the study by Brown et al. (2011), the authors found that synthetic clothing is a major source of microplastics in the marine environment. These fibres are mainly made up of polyester (78%) and acrylic fibres (22%). On a global scale, Boucher and Friot (2017) estimated that of all primary microplastics in the world's oceans, 35% arise from laundry of synthetic textiles. Every year, between 200,000 and 500,000 tonnes of textile-derived microplastics find their way into the world's marine environments. While microplastics are emitted into wastewater during the manufacturing stage of clothing products, they are also emitted during the post manufacturing stage as a result of the product's lifetime of wear and tear. Regarding the manufacturing stage of producing fast fashion, clothing materials are processed using over 8,000 synthetic chemicals. After the manufacturing stage, garments are prone to shedding plastic microfibers during laundry cycles, when in a washer and dryer. Due to the mechanical and chemical stresses that fabrics undergo during a washing process in a laundry machine, synthetic textiles frees engineered microplastics through abrasion and shedding of fibres from the fabrics. These microplastics seep into laundry water as washing.

Microplastics are not retained by the purification system because it is not designed to retain such small particles and because of this, after laundering, they get flushed into the sewage wastewater of homes and are consequently dumped into waterways untreated, seeping various chemicals and microplastics into the ocean and adding to marine plastic pollution. Their transport will depend on the size, shape and density of the polymer. The density of the polymer will determine whether or not it floats on the surface of the seawater. Since the density of seawater is about 1.02 g/cm3, polymers with a lower density will float on the surface and those with a higher density will sink. The latter will settle to the bottom of oceans, lakes and rivers and join the benthic fauna and flora. Among the most common polymers, only polyethylene (PE), polypropylene (PP) and polystyrene (PS) will float. Instead, polyvinyl chloride (PVC), polyamide (PA) and polyethylene terephthalate (PET) will sink.

The majority of synthetic fibers discovered in sewage effluent and marine sediments bear a striking resemblance to the fibers found in synthetic apparel. Up to 1900 synthetic fibers can be released from a single synthetic clothing in a single machine. It is clearly evident from an analysis of domestic effluent from washing machines that synthetic fabrics contribute to the contamination of microplastics and that all common household textiles shed fibres. Data on the quantity or **mass of microfibres released from clothing of various types and fibre** content have been gathered through experimental washing (Hartline et al., 2016; Napper and Thompson, 2016).

some determinants of fibre shedding:

Fibre loss is greater in top-loading (vertical axis) or industrial washing machines than front-loaders, assumed due to a more abrasive action (Hartline et al., 2016, De Falco et al., 2018).

Fibre dimensions depend on the type of fibre and fabric characteristics (e.g. tightness of the weave). Fibres shed during washing varied from 11.9 to 17.7 μm in diameter and 5.0 to 7.8 mm in length across polyester, polyester/cotton blend and acrylic (Napper and Thompson, 2016).

Release of fibres during tumble drying can be higher (up to 3.5 times) than during washing (Pirc et al., 2016). This practice very likely contributes to high indoor air concentrations of microfibres (Dris et al., 2017), but consumer behaviour will determine the fate of the remaining collected lint.

Regardless of the detergent's composition or dosage, the amount of fibres released from polyester fabric after machine washing was significantly influenced by the use of detergent (Hernandez et al., 2017). Although fabric structure and wash cycle did not significantly affect shedding in this study, more research is required to determine whether these results apply more broadly to different fabric structures and wash cycles.

VII. Potential Impacts of Microplastics

Exposure to various environments: Microplastics have become ubiquitous in the world's ecosystems. The maritime environment is not the only place where microfibres can be found. Reports on potential repercussions are growing, despite the fact that our understanding of the threat to human health and ecosystems is still restricted (Carbery et al., 2018; Waring et al., 2018; Yu et al., 2018). Concerns over microplastics' possible effects on ecosystems and human health are raised by their pervasive presence in a variety of habitats.

Concerns regarding human exposure to microplastics have also been raised by the discovery of tiny particles in food, drink, and drinking water sources. Microplastics may have negative effects on human health, especially when swallowed or inhaled over prolonged periods of time, however the full degree of these effects is still being investigated. (Lourenço-Amato and others, 2020).

Moreover, the widespread and extensive character of this problem is made clear by the transportation of microplastics through atmospheric processes and their deposition in Arctic ice. The necessity for comprehensive methods to reduce the effects of microplastic pollution is further highlighted by the possible long-term effects on global ecosystems and the interconnection of many areas.

7.1Physical Impact

Microplastic intake has the primary physical effect on living things. Synthetic fibres appear to have a larger potential to enter the food chain in freshwater and marine systems than other types of microplastics because of their size and structure, which make them easier for aquatic creatures to eat and more likely for tangling and stomach retention.Numerous filter feeder species as well as a variety of other species, including vertebrates and zooplankton, have been reported to consume it. Microplastics that are consumed and transferred across trophic levels have an impact on birds like shearwaters and aquatic species like salmon and other fish that are eaten by humans. It has generally been noted that consuming microplastics instead of food can cause gastrointestinal obstructions and false satiation. According to Mattsson et al. (2017), nanoplastics may have an effect on the central nervous system and reproductive system, leading to behavioural abnormalities and possibly affecting the overall operation of the ecosystem. Due to their small size and frequent colour, these microplastics are mistaken for food by a variety of marine organisms, which causes them to be ingested and move up the trophic chain. This process is known as trophic transfer. This could result in detrimental health impacts including digestive tract obstruction or chemical leaching.

7.2Chemical Impacts

Chemicals include polychlorinated biphenyls (PCBs) and carcinogenic persistent organic pollutants (PoPs) can be absorbed by microfibres from water or sewage sludge. Additionally, they may include chemical additives added during the material's manufacturing process, such as flame retardants, plasticizers (substances added to increase a material's plasticity and flexibility), and antimicrobial agents (substances that either kill or stop the growth of microorganisms like bacteria). When animals swallow the microfibres, these toxins can enter their circulation directly from the plastic and seep into the oceans. Once consumed, microfibres can lead to gastrointestinal obstruction, bodily harm, modifications to the body's cell oxygen levels, changed eating habits, and low energy, all of which can hinder development and reproduction. Furthermore, the environment's buildup of microplastics might threaten biodiversity and cause ecological instability. (A growing concern for food security, food safety, and human health is marine microplastic trash., 2018)Leaching of plastic additives like fire retardants, dyes, or antioxidants (Machado et al., 2018) and the transfer of substances like metals sorbed from aquatic environments and persistent organic pollutants (POPs) are two mechanisms that may be responsible for the chemical effects of microfibres in the environment (Rochman et al., 2014a). The possibility of increased bioavailability of harmful chemicals is increased by the ability of high surface to volume ratio microfibres to absorb a variety of contaminants in solution (Besseling et al., 2013). Chemical contamination's impact on organisms is contingent upon the quantity and kind of hydrophobic pollutants present, the degree of bioaccumulation, the release of chemicals, anResearch on potential impacts of exposure to microplastics on organisms has largely been confined to localised encounters over short time periods predominantly in aquatic habitats. Human effects are more likely to be a function of cumulative exposure from diffuse terrestrial sources . Microplastics have been reported in a wide range of human food and beverages, including seafood (Rochman et al., 2015), drinking water (Kosuth et al., 2017; Mason et al., 2018), beer (Liebezeit and Liebezeit, 2014), salt and sugar (Rist et al., 2018) and in the air (Dris et al., 2017), raising concerns about the threat to human health through ingestion and inhalation (Waring et al., 2018).d the commencement of possible health effects in ingesting species.

7.3Impacts on human health

The majority of research on the possible effects of microplastic exposure on species has focused on localised encounters during short time periods, mostly in aquatic ecosystems. Human effects are more likely to be the result of cumulative exposure to dispersed terrestrial sources. Microplastics have been found in a variety of human foods and beverages, including seafood (Rochman et al., 2015), drinking water (Kosuth et al., 2017; Mason et al., 2018), beer (Liebezeit and Liebezeit, 2014), salt and sugar (Rist et al., 2018), and the air (Dris et al., 2017), raising concerns about the threat to human health through ingestion and inhalation (Waring et al., 2018).Recognizing the danger of contamination in food and beverage samples, as well as uncertainties in analytical procedures, has called into question several previous assessments of microplastic ingestion with food (Catarino et al., 2018). However, there is little doubt that some level of chronic exposure is now an expected component of human existence (Wright and Kelly, 2017). Nonetheless, a recent review of the available evidence by Waring et al. (2018) concluded that microplastic contamination of the food chain is unlikely to cause serious toxicity at current exposure levels and rates of microfiber and nanofiber uptake and translocation via the gastrointestinal tract and/or lung. Major knowledge gaps include determining the long-term danger of exposure and understanding the effects of nanoplastic ingestion and inhalation (Gasperi et al., 2018; Waring et al., 2018). Chronic human exposure to microfibers and nanofibers from textiles may lead to bioaccumulation (Revel et al., 2018; Waring et al., 2018). These fibres may expose humans to chemicals such as unreacted monomers, additives, dyes, or finishes such as polybrominated diphenyl ethers (PBDE), which have been linked to toxicity, carcinogenicity, and mutagenicity (Gasperi et al., 2018). This is despite the fact that most ingested microfibers are likely to transit harmlessly through the body (Rist et al., 2018). Airborne textile threads are likely to be too large to be absorbed, but smaller fibres may be easily removed (Dris et al., 2017). Nonetheless, both cellulosic and plastic microfibres have been found in human pulmonary tissues (Pauly et al., 1998), implying that certain smaller fibres may infiltrate respiratory passageways and the lungs (Gasper et al., 2018). In vitro tests (Gasperi et al., 2018) demonstrated the durability and biopersistence of plastic fibres in physiological fluid. Polypropylene, polyethylene, and polycarbonate fibres showed minimal dissolution or changes in surface area and characteristics in a synthetic extracellular lung fluid after 180 days.

VIII.Conclusion

Textiles are the largest source of primary microplastics, accounting for 34.8% of global microplastic pollution, with fast fashion accounting for a particularly high level of microfibre release, as these garments typically contain a high share of synthetic fibres and account for a high share of first washes, as they are used for only a short period of time and wear quickly. Every year, more than 1.5 million metric tons of microplastics are thrown into the ocean; according to a new IUCN analysis, washing synthetic fabrics accounts for 35% of this microplastic pollution. Possible contributors to the departure from a simple proportional relationship between coastal samples and annual production include fibre and product qualities, environmental variables such as deterioration or fragmentation rate, and technique limitations.

Textiles produced from plastic fibres shed microplastic fibres at every stage of their lives, including when they are worn, washed, and disposed of. These microplastics contaminate the air we breathe, the water we drink, and the food we consume. They've been discovered in the deepest parts of the ocean, in unborn babies' placentas, in Arctic snow and Antarctic ice, in rainfall, and in a variety of other places. The bulk of microplastics found in textiles are discharged during the first few washes. Microfibres are also emitted during textile manufacturing, garment wear, and end-of-life disposal, and they end up in water, air, and soil. Although microfiber shedding diminishes with subsequent washing, the wearing out of materials as garments age causes an increase in microfibre shedding. Fast fashion generates more microplastic waste, which contributes to pollution. There are numerous byproducts of rapid fashion that contribute to environmental damage. Microplastics have been linked to pollution of water, land, and air, as well as adverse effects on human health. Clothing, particularly fast fashion garments, is one such source of pollution.

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