Microfiber as an Emerging Pollutant Material to be used in Construction

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ABSTRACT

Microfiber can be narrated as a staple fiber or filament with a linear density of more than 0.3 dtex and less than 1 dtex. Microfibers can be mixed with wool, rayon or cotton or can be used as such as 100% microfiber. The noticeable features of microfiber make them more unique which include their light weightless, resistance to wrinkling, easy to carry, gives a luxurious drape on the body and can pilling resistance. Microfibers not only set a new path in textile industries but also in medical field, construction applications etc. Microfibers, a major element of micro plastics is an emerging pollutant and have been present nearly everywhere mainly in freshwater and marine habitats all around the world. In environmental science research, hence, microfibers have gained considerable attention as an emerging pollutant. In this reearch paper, their application, sources, the impact on environment, how it affects human health and available solutions to be used in construction has been discussed.

Keywords: Microfiber, humans, environment, pollution

1. Introduction

The huge demand for textile industries by the world has paved a path to the tremendous application of microfibers. Microfibers are a subcategory of micro plastics. Micro plastics are either primary or secondary manufacturing origins of synthetic solid particles or polymeric matrix that are water insoluble, ranging from a size of 1 µm – 5mm with a regular or irregular shape [1]. In 2004, Thomas et al. framed the aggregation of microscopic particles of plastics present in marine biodiversity as micro plastics [2]. Sources of micro plastics can be from larger plastic detritus that are degraded into tiny pieces. Micro beads are another type of micro plastics which are miniature pieces of manufactured polyethylene plastics which are commonly used as an exfoliating agent in some cosmetics and toothpastes.These micro beads

can be easily escaped through the water filtration systems and finally end up in water resources such as sea, lake or rivers [3].

2. Classification

To be graded as microfiber, the width of fiber must be less than 1 dtex. They are also fairly strong and durable to other fabrics, more breathable, light weight and comfortable to wear. Microfiber fabrics show lower heat conductivity and higher assets thermal insulation [4]. Microfiber fibers are cooler than conventional fabrics depending on heat, due to the difference in fiber and fabric surfaces in human skin contact. Microfibers are specified by their remarkable properties such as luster, pleasant softness and handle, bulk and outstanding surface properties. Microfibers are fibers or filaments with a linear density of less than 1 dtex (decitex) and above 0.3 dtex. Fibers with 0.3 dtex or less than that are termed as super-micro fibers. According to the fiber count or dtex/f, fibers can be classifies as follow:

Sl.No	Fiber classification	Decitex(dtex)
1	Super Micro Fibers	Less than 0.30
2	Micro Fibers	0.30 to 1.00
3	Fine Fibers	1.00 to 2.40
4	Medium Fine Fibers	2.40 to 7.00
5	Coarse Fibers	More than 7.00

Table 1: Different types of fibers

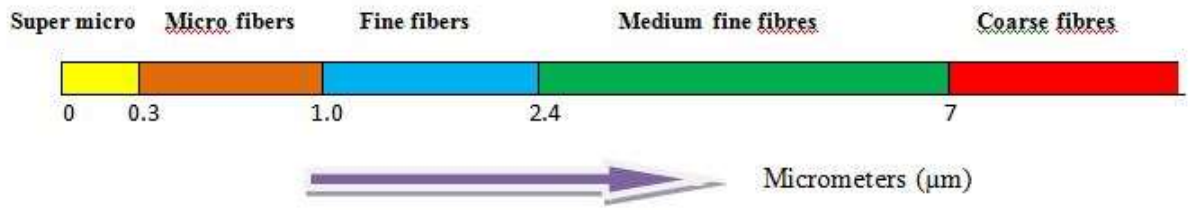

Figure 1: Classification of fibers

Fibers are the most frequent types of debris seen in the environment [5]. Fibres can be either natural or synthetic.Protein fibres which are mainly produced from different animals are known as Silk. The most frequently available silk is manufactured from the cocoons of mulberry silkworms *(Bombyx mori)*. During the final stage of larval development, silk worms produce two proteins namely, sericin and fibroin. Sericin is a sticky material that surrounds

the structural protein called fibroin and will be removed during processing. The fibroin consists of various amino acids such as glycine, alanine and serine. This type of fibre has across-section of triangular shape with rounded edges and thus gives the silk material its soft and shiny texture.

Polymers that are relatively simple with straight polymer chains and units linked through amide bonds repeatedly are known as Nylon or polyamide fibres. Polyamide fibres can be natural or synthetic. Nylon and aramid come under synthetic polyamide fibres while wool and silk are examples for natural polyamide. The condensation reaction of a diamine and dicarboxylic acid results in the formation of Nylon, a thermoplastic polyamide.

Para-aramid fibres (PPTA) are a combination of polymerised benzene-1,4-diamine [p-phenylenediamine (PPD)] and terephthaloyl dichloride (TCL) in a condensation reaction that results in the elimination of hydrochloric acid as a byproduct [6].

3. Properties of Microfiber

- Microfibers are exceptionally drapeable.
- Main advantage is that microfibers are washable and dry-cleanable.
- Microfiber dries faster than regular fibers i.e. within one third of the time taken by other fibres
- Microfibers have an excessively soft texture.
- Shrink resistance.
- Fabrics with microfibers can protect us from different seasons like monsoon, winter etc.
- Microfibers are known as super absorbents as they can absorb over 7 times their weight in water.
- Microfiber is non-electrostatic.
- Super fine filaments give an exceptional strength.
- Light weight
- Presence of anti-microbial agents helps to protect from odour causing bacterias.

4. Sources

The current world is depending too much on polyester fabrics which are the main source of microfibers and is worsening the water quality because of its non- biodegradable waste production [8]. As the microfibers are accumulating the water sources it is very necessary to find the source of their release. When some non-laundering fabrics such as flags and sails

while undergoing disintegration also causes pollution. Another chance of microfiber deposition in water sources are by landfills. Particles of microfiber can leach from those landfills which are near to water bodies directly into domestic drainage systems, oceans and rivers [9]. Microfibers are mainly shedded from fishing nets and synthetic polymer garments but microfibers do not have a direct application as of now. Theses synthetic microfibers can be manufactured from nylon, PolyPropylene (PP) and PolyEthylene Terephthalate (PET) [10]. The amount of microfiber is increasing day by day because they lack to decompose. Several studies showed that the presence of microfibers is commonly found in water sources such as sea, river, sludge and top soil. Textile industries, household laundering, domestic drainages, landfills which are located near to water sources and dumping of plastics and used clothes in water sources are the main source of microfiber pollution. As synthetic microfibers are produced using some chemicals, they are highly dangerous and affects the food chain [11]. Mark Anthony, the ecologist conducted a study on the accumulation of microplastics on shores around the world in 2011. He was the first one who summarized that 85% of the man-made wastes found on coastline were microfibers used in clothing. Textiles made from synthetic materials are the main source of microfibers. Crude oil is the raw material for the production of synthetic fibres through various processes such as polycondenstion, polymerization and polyaddition [12]. In 1950, the annual production of synthetic fiber was 2.1 million tons. The shedding of fibres varies according to the type of fabric, type of yarn used, texture etc. Among the global synthetic fibre production, synthetic fibre holds 60% of account and in synthetic fibres, polyester accounts 91% though polyester is prevailing, nylon still holds a place in the fibre business. In 2014, 4 million tons of nylon was produced globally [13]. Apart from clothes, textile synthetic fibres are also used in furniture, footballs, buildings, geotextiles, agriculture, soft toys and so on. When washing the fabrics or using cosmetics that contains microplastics and fibres, the washed out settles in waste water treatment plants through draining system. Fleece was the clothing which sheds the most amount of fibers, approximately 1900 fibres in each wash [14]. Various human activities end up in the release of microfibers into the marine environment through adjoining rivers. It is reported that in a single wash about, 22,992 poly-cotton, 82,672 polyester and 121,465 acrylic microfibers are discharged into the ocean. The types of micro plastic reported commonly include fragments, fibers and pellets with ropes, sponges, rubber, foams, microbeads and films [15]. Aquaculture, commercial fishing, coastal tourism etc. are another source of both primary and secondary microfibers that enters directly into the marine

environment. The huge demand for synthetic fibers by today's society will gradually results in increased global microfiber pollution [16]

5. Applications

The irreplaceable properties of microfibers such as softness, strength, lustre, surface properties, draping qualities etc. makes them more demanding in the society. The application of microfibers is not limited within the textile industry but also have other applications. Some of them are:

- Energy Conservation
  Enhancement of heat transfer in tubes of heat exchangers by using metal coated microfibers.Increase in the number of metal coated fibers can also increase the heat transfer.
- Fashion clothing textiles
  Woven fabrics was manufactured from a combination of single hollow staple fiber and 0.1 dtex UFF hollow microfiber and that gives the material softness, sense of warmth, light weight etc.
- Protection against weather
  Sportswear woven fabrics are used for on field and off field and gives protection against varying weather. In majority of the cases these woven fabrics were coated with PVC (Polyvinyl chloride). PVC coating assures a total waterproof but the utmost drawback is, it does not allow air passage. But today these PVC coatings can be replaced by micro porous fluorocarbon coatings with air passage.
- Medical applications
  Microfiber nonwoven plays an important role in medical applications. They are low cost when compared to common fabrics and are more adaptable. Microfiber nonwovens are easy to use, safer and can dispose easily and these features give an irreplaceable place in medical application. Microfiber nonwovens are used in surgical packs, protective face masks, surgical gowns, bedding, gloves etc.
- Synthetic game and imitation leather
  Synthetic game leather and other leather materials are manufactured in industries of Japan by infusing nonwovens from PET (Poly Ethylene Terephthalate), PAN (PolyAcryloNitrile) and PA (Polyamide) microfibers with UP (PolyUrethane). When

compared to natural leathers, these products assure uniformity, colour fastness, ease of care and dimensional stability.

- Microfibers for cleaning purposes

  What makes microfibers different from other usual cleaning fabrics is that it literally sweeps the stain or dirt from the surface and collects the dirt substances inside the fabric until the fabric is cleaned. The purpose of trapping dirt particles inside the fabrics is to avoid the spreading of dirt or dust [17]. The benefit of microfiber cloth is that the fabric can be cleaned with water and does not require any chemicals.
- Construction applications
- Microfiber in liquid filters.
- Microfibers are used for hair transplantation to conceal thinning hair.
- In the production of mouse pads.
- For manufacturing footballs and other sports material.

6. Environmental Impact

The emerging microscopic microfiber pollution is a bandwagon that not only pollutes the marine environment but also affects the food chain. Due to the lack of proper treatment techniques, food resources and water ways are concerned with these microscopic pollutants. Studies showed that around 1.4 trillion microfibers are present in the marine habitat and is causing various problems to our biodiversity [18, 19].

6.1. Air Pollution

Microfibers are flammable when they belong to polyester or cellulose fabrics and on burning, emit toxic gases. It is a well-known fact that the toxicity of micro plastics increase with decrease in its size. Though micro plastics are considered as toxic pollutants, there is no standardization for the approaches such as sorting, sampling, extraction, purification and identification. As the clothing requirements and style changes from season to season, the amount of microfibers present in outdoor also escalates [20]. The clothes that we put out to dry can also act as an origin of airborne micro plastic fibers in the environment. Sewerage sludge that can be used as fertilisers also contains micro plastics and can be transferred into the atmosphere via wind after periodical drying. Moreover, the polyethylene foils that are using in agricultural sector can also act as a contributor to the micro plastic pollution. Those foils can disintegrate by the catalytic activity of cobalt or other metal salts present in the soil after a particular time of exposure in the environment [21]. Some authors discovered the presence of airborne micro plastics that are released from clothe spin their working

environment and samples with the help of blanks and open petri plates. Flowering plants are also a victim for micro plastic contamination. It is assumed that those plants are contaminated by the atmospheric fallout. It is reported that micro plastics are found in honey [22].

When emphasising on air borne micro plastic pollutants, humans are highly exposed from their occupational areas and those contaminants affect the human health badly. Factories which are working on high volumes of polymeric materials with poor ventilation and inadequate conditions finally results in chronic exposure to airborne micro plastics. It is also reported that micro plastics exist in particulate matter. Atmospheric particulate matter comprises of a combination of natural airborne liquids and solids or human made sources such as sea, soil, biosphere and combustion [23,24].Along with health, particulate matter also affects the climate by interfering in the formation of cloud and scattering solar radiation [25].

6.2. Threat to Marine Habitat

The man made waste deposited in aquatic environment can affect the growth, reproduction and mortality of aquatic life. Even a small bit of plastic can be consumed by the aquatic organisms [26]. Heavy metals, organic and inorganic contaminants can adhere or adsorbed on micro plastics and their toxicity to marine organisms has been investigated in several studies. Almost everywhere in the universe is affected by microfiber pollution including Polar Regions. Because of its size and density, microfibers can float on the water surface it can affect both aquatic plants and aquatic animals. As these micro particles enter through gills and gastro intestinal walls, these can block the respiratory system of aquatic animals [27].

Ingestion is the most predominant concern when it comes to aquatic life. Aquatic animals including planktons consume these micro fibers mistakenly and those smaller aquatic animals and fishes depending on planktons as their main source of food will consume them and finally passing these micro pollutants up the food chain. Sea foods (mussels, crab etc.) and fishes whose destination is to end upon the dining table will become a victim for this tiny pollutant and so we [28]. Micro plastics were found from an autopsied whale and was evaluated that, about 58% of micro synthetic fibers were present in stomach and 89% in intestine. The polymers recognized were rayon, polyester, acrylic, polypropylene and other polyethylene groups. For instance, the Hudson River itself is contributing up to 300 million micro fibers per day to the ocean [29]. Most of the present filters used are not designed to collect microfibers. Microfibers discharge different toxic chemicals which are harmful to the

organs of fishes and finally contaminate the fish. These chemicals can destroy the endocrine system of fishes as they are highly reactive. And being expose to such chemicals affect their reproductive processes badly. Some studies recently reported that the consumption of such micropollutants can alter the endocrine system in adult fishes [30]. The highest consumer of shellfish in the World is European countries, and is reported that they are consuming around 11,000 microfiber particles per year. While, countries with low shellfish consumption rate has reported that around 1800 microfiber particles are consumed by them yearly. Approximately 175 microfiber particles were estimated in shrimp eating alone per individual per year. Focusing on the consumption of mussels by people, microfibers are commonly seen in two varieties of mussels, *Mytilusgalloprovincialis* and *Mytilusedulis* which were collected from the countries of Europe [31]. It was studied that, about 9% of microfibers were seen in the gastrointestinal tracts of fish sold at USA markets and 28% of microfibers in the sea food sold at markets of Indonesia. The chemicals and microfiber pollutants can reduce the feeding rate in fishes and cause physical damage to different organs, immune function, digestive tract, stomach lining etc. and finally affecting the complete ecosystem including the soil quality.

7. Adverse Effects in Human Health

The micro fibres and related chemicals passing through the food chain can affect human health badly. These micro pollutants contain phthalates, which can cause breast cancer, damage to the kidney, intestine and liver, reduced oxidative stress molecules in liver and blood infection in humans [32]. The phthalates present in microfibers are assessed for their harmful consequences on humans and resulted in reproductive and genital defects, reduced level of sperm count, early onset of puberty, impaired function of hormone system etc. Another chemical present in microfibers is BisphenolA (BPA), which can affect the female reproductive hormones. Other dangerous chemicals can cause disruption in proteins and DNA when they enter into human body.

Airborne micro plastics can cause occupational diseases in industrial labourers who are exposed daily to a high concentration of micro plastics. Industries that can portrait the outcome of air borne micro plastics are synthetic fabric industry, vinyl chloride and poly vinyl chloride industries and flock industry [33]. In 1961, Simonin reported that the workers in nylon factory showed irritation in mucous membrane, burns, bronchial asthma and also hypersensitivity dermatitis because of the frequent and prolonged contact with nylon [34]. Microbes can quickly colonize on micro plastics existing in the environment and results in the formation of biofilms. This type of biofilms can carry harmful human pathogens like

strains of Vibrio species. When such pathogens enter in the human body, additional substrates present in lungs or gastro intestinal tract may promotes the growth of such species and ends up in some alterations. These alterations can affect the functions and structure of micro biomes present in the lungs and gastro intestinal tract and affects human health. There is no doubt that these micro pollutants are not only affecting the marine habitat but also human beings.

8. Microfibers in construction

For a concrete matrix containing Poly Vinyl Alcohol (PVA) concrete or steel micro and macrofibers, the potential of macro, microfibers blends offers strong workability for concrete microfibers [35]. This approach is based on optimal fraction of paste volume between flow and paste consistency. It enhances mechanical efficiency, water impermeability and resistance to crack in casted concrete to shrinkage. The microfibers delayed the macro cracks development in hybrid concrete, so the composite showed greater strength and crack resistance than a matrix reinforced only with macrofibers. A stronger fiber matrix bond resulting from a lower water-to-binding ratio caused the microfibers to break. In hybrid fiber-reinforced concrete, macrofibers were also more likely to split than in the same matrix containing macrofibers alone because microfibers strengthened the matrix, enhancing macrofibers resistance to pullouts. Adding microfibers greatly enhances the mechanical properties of cement pastes, but provides little value to mortars. Microfibers are used as a micro-reinforcing agent in cement and decrease the formation of microcracks within the concrete / mortar / neat cement matrix. This results in surfaces with significantly lower cracks, enhances strength, cleans surfaces, reduces water percolation due to less broken surfaces-the percolation cycle, making structure more durable and maintenance-free. But in road construction, the concept of a chemical coating to avoid microfiber release may create more problems than it solves if those chemicals are also bad for the environment and human health [36]. The values of stress/strain for a selected range of the fibres are discussed in Figure1.

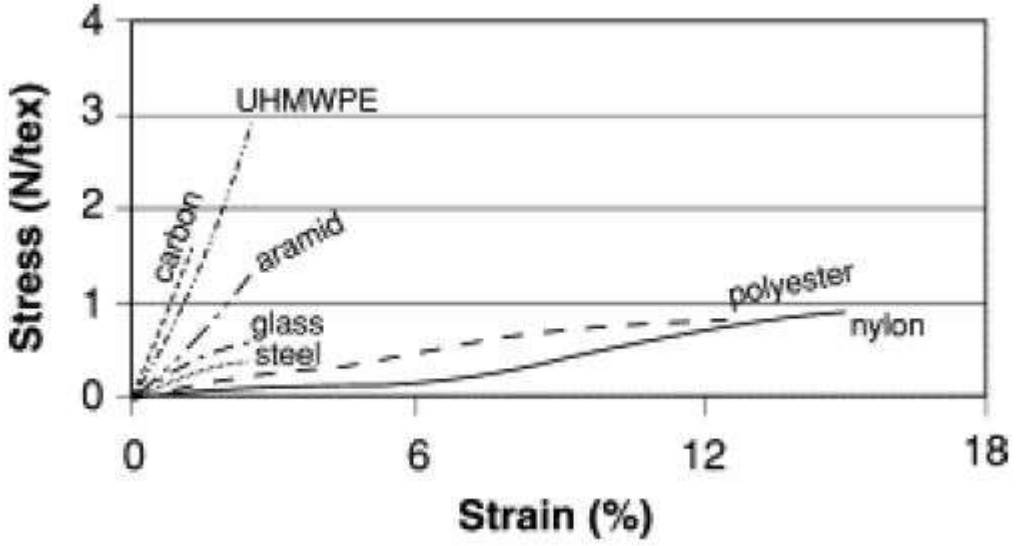

Figure 2: Stress/strain charts of various fibers.

9. Solution,Recommendation and Coclusion

Pollution causing by synthetic microfibers is a serious problem which needs a sudden solution. Membrane reactor can remove microfibers using cross flow filtration, but consumption of high energy is the major drawback. Another method for removing microfibers from water sample is by centrifugation and density separation [37]. But this method is not successful as it cannot filter large amount of samples. Washing clothes at a low temperature can control the shedding of fibers from clothes. A recent finding to overcome this problem is by washing clothes in a separate bag. Using a Guppy bag or Cora ball in the washing machine claims that, it helps to collect the microfibers shedding from the clothes separately during washing. Adding a Cora ball along with clothes in each washing can filter microfibers and never release those microfibers into the drainage systems. It is claimed that Cora ball can remove about 26% microfibers in machine wash. The most important advantage of this product is reusable and can separate the entrapped microfibers easily from the ball. Another similar product is a Guppy bag, a synthetic bag designed to trap micro fleece on every machine wash. Guppy bag is an idea raised from a campaign called “STOP! MICRO WASTE”, by German scientists. Another way to control the release of microfibers is by filling the washing machine. A fully loaded washing machine can reduce the friction between clothes i.e. the clothes cannot rub each other as the machine is full. Clothes get dry quickly at a high spin speed but it can cause more synthetic fibers to shed as the high spin shake the clothes more. Washing clothes at a low spin using cold water can reduce the

shedding of micro fibers. Tumble drying of clothes is more dangerous than air drying, because they can cause more amounts of fibers to shed from clothes. Using woolen fleece rather than polyester fleece can reduce the amount of microfibers. Clothes shed micro plastics more during the first few washes. So use high quality clothes that can last longer than changing wardrobe.Eventhough microfiber is a pollutant is to be used as Construction material.

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