

Microplastics from textiles to the ocean

How clothing contributes to the release of microplastics
into the ocean.



Evelina Norlin

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Author: Evelina Norlin for KIMO Sweden. Evelina received a scholarship from KIMO Sweden to write this report. She is a marine biology student from Gothenburg University.

Partners: Bethanie Carney Almroth PhD, docent. Dept Biological and Environmental Sciences, University of Gothenburg. Bethanie has supported with facts and quality review of the report. This report was translated into English with the support of KIMO International.

Other information: KIMO's aim with the report is to highlight an environmental issue that is unknown to many people. The report is based on several research reports about how microplastics are spread to the ocean and how they affect the marine environment. The report concludes with a discussion and proposals for measures.

Photo front page: Evelina Norlin

KIMO Sweden is a part of KIMO International

KIMO is an international network of local governments, working together for healthy seas, clean beaches, and thriving coastal communities.

With over 80 member municipalities in eight countries, we represent more than five million citizens in Europe.

Contact information

KIMO International

c/o Shetland Islands Council

8 North Ness Business Park

Lerwick, Shetland

ZE1 0LZ. UK

E-mail: info@kimo.shetland.org

www.kimointernational.org

Facebook: KIMO International

Preface

Plastic does not belong in nature. We have heard signals that clothes are spreading microplastics to the sea, which worries us. How is this happening and how serious is the problem? To find out, we announced a scholarship. In this report, we learn that emission of microfibers from manufacturing and use of clothing is a big environmental issue that needs to be researched more and that better wastewater treatment technology is needed. Clothes release a big number of microfibers when washing that spreads from the drain and finally ends up in the ocean where they can cause harm to marine animals.

The idea of this report is to arouse interest in how clothes are produced and how it affects our environment. The report also addresses what one can think of as an individual or at the societal level to make a change.

With this report, KIMO Sweden hopes to arouse interests and to start a conversation about microplastics in the ocean. We would also like to extend our warmest thanks to Evelina Norlin who wrote the report.

Emmyly Bönfors

Chairman of KIMO Sweden

Abstract

Plastic is a material that is widely used in society. A large amount of plastic ends up in the natural environment. Plastics that end in nature up don't decompose. Instead, they break down to small plastic particles, so called microplastics. Microplastic particles in the ocean are abundant, and 35 percent of those particles are in the form of microfibers which originate from synthetic textiles. Microfibers are released in the production and in the washing of synthetic clothes. The amount of microfibers being released in the production of clothing depends on the textile factories wastewater treatment system, and the release of microfibers continue during the lifetime of synthetic garments. Large amounts of microfibers are released when synthetic clothes are washed, how much depends on the material of the clothes and the washing procedure. Water treatment plants can eliminate more than 70 percent of microplastics in wastewater, but the amount of microfibers that reach the ocean is still substantial.

Marine animals in laboratory experiments have shown a variety of symptoms when exposed to microplastics. Those symptoms include change in behavior, reduced growth, and disturbed reproductive capacities. Microplastic particles can get stuck in the animal's gastrointestinal tract which can lead to malnutrition and starvation. Little is known about how microplastics affect animals in the wild, and there are no scientific studies on how microplastics affect humans. There is an urgent need for more studies on the subject.

Clothing manufacturers must reduce the emissions of microplastics in all parts of the manufacturing chain, from raw material to the final product. The textile industry is big, and governance is needed at all levels to reduce microplastic emissions. Examples of measures are to tax synthetic clothing and to demand a transparent manufacturing chain, so that everybody can see where and how the clothes are made. Consumers can influence the clothing industry by buying clothes made from sustainable, natural materials from companies that are actively working with the microplastic problem, and by reducing the consumption of newly produced clothes. Individuals can also reduce their emissions of microplastics by washing less frequently, using products designed to reduce microplastic emissions, and by using liquid washing detergent.

The conclusion is that synthetic microfibers are found in all of the world's oceans, the emissions are continuous, and the concentrations are increasing. We don't know how animals and humans are affected by microplastics, more scientific studies are needed. What we know is that emissions of microplastic needs to decrease to prevent negative consequences in the future. To accomplish this, governments, manufacturers and consumers all need to be aware of the microplastic problem and all need to take action.

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Figure 1. Plastic debris in the west coast of Sweden. Photo: Evelina Norlin

I Introduction

I.1 Aim and scientific questions

This report is written on behalf of KIMO Sweden to highlight the issue of emissions of microplastic from synthetic textiles to the ocean. Emissions of synthetic microfibers are an issue which has recently attracted the attention of researchers, but the research field is relatively new and information on the issue is not easily accessible to consumers. Hopefully, this report will give the reader a perception of the scale of the problem, and knowledge about where the research stands today.

The report is based on three questions:

- How much microfibres are emitted to the ocean in the manufacture and washing of clothing?
- How much synthetic microfibres is there in the sea and in the sediments?
- How does synthetic microfibres affect animals and humans?

To answer these questions, a summary of relevant scientific articles and reports have been made. The discussion of the report also includes suggestions of measures that can be taken to reduce emissions of microplastics to the ocean, both on an individual and societal level.

I.1.1 Scope of the report

To limit the scope of the report, only emissions of microfibers from manufacturing and washing of clothes are being examined. Other sources of emissions of microfibers can be from the air, from sludge, from sewage treatment plants or through runoff from land to sea. Those sources may be significant but are not discussed in this report.

I.2 Background

I.2.1 The history and manufacturing of plastic materials

Plastics have been manufactured on an industrial scale since the 1950s. Today, the material has so many areas of use that it is hard to imagine a society without plastics. Due to the cheap price of plastics, its resilience, and its many different characteristics, plastics can be used to create almost anything. Today, you can find plastic materials in anything from construction materials and cellphones to cosmetics and medical products. Plastics wide range of uses has meant that plastic production has increased sharply since production started. In the 1950s, around two tons of plastics were produced globally per year. 2015, this amount had increased to 380 million tons (Geyer et al., 2017).

There are many different types of plastics. They are all synthetic, solid materials, and are made up of large molecules, so called polymers. Plastic polymers consist primally of organic compounds extracted from crude oil. Six percent of the world's extracted crude oil is today

used to manufacture plastic materials (PlasticsEurope, 2015). To give the plastic its desired properties, additives are introduced in the manufacturing of the plastic. Examples of additives are flame retardants, plasticizers and pigments that give the plastic different colors (Klar et al., 2014).

Plastic fragments slowly, which makes the material very durable. This property is both positive and negative. Plastic items last for a long time, but if they end up in nature, they will stay there for the foreseeable future. In nature, the plastic slowly becomes fragile and eventually breaks down into small particles, those particles are called microplastics. It takes 10 to 20 years for a plastic bag to fragment into microplastics in the ocean. The microplastic particles then stay in the water or sink to the ocean floor, where it can last for hundreds of years or more (Håll Sverige Rent, 2020).

Plastic can be made from renewable materials such as corn and sugar cane. Those plastics are called bioplastics and can be divided into two sub-groups: biodegradable and non-biodegradable bioplastics. Bioplastics are positive from a climate perspective because they are made from renewable material and not from crude oil. However, it is important to highlight that non-biodegradable plastics have the same properties as plastics made from oil. If non-biodegradable plastics end up in nature, they will also fragment into microplastics (Swedish Society for Nature Conservation, 2020). The same is true for some of the biodegradable plastics, though they require a special environment to decompose. Some of them do not decompose in nature or in the ocean (Håll Sverige Rent, 2020)

1.2.2 Plastic debris in the ocean

Approximately 150 million tons of plastic is floating around in the ocean today. This number is increasing every day because the flow of plastic debris from land into the ocean never stops. It is estimated that four to 15 million tons of plastics enter the ocean every year (Geyer et al., 2017). Scientists have calculated that there will be more plastic than fish in the ocean by the year of 2050 if the littering continues at the current level (Håll Sverige rent, 2020).

In the ocean, plastic causes harm to marine animals. Bigger animals, such as sea birds, marine mammals and fish can get entangled in lost fishing gear and plastic debris. Plastic debris can also be mistaken for food. If an animal eats plastic it will experience a false feeling of satiety, which with time will cause malnutrition and starvation. Sharp pieces of plastics can cause serious injuries to the animal's gastrointestinal tract (Bergmann et al., 2015). The most common plastic debris in the ocean are disposable items, such as plastic bags food packaging. Lost fishing gear

and small plastic particles from hygiene products are also common debris in the ocean (Galagni et al., 2015).



Figure 2. Sea bird which have mistaken plastic pieces for food. Photo: Chris Jordan

1.2.3 Microplastics

The issue of microplastics in the ocean has received increased attention for the past decade. There are several different definitions of microplastics. A common definition is that microplastics are plastic particles with a diameter of five millimeters at the narrowest point of the particle. In some studies, microplastics are defined as plastic particles narrower than one millimeter in diameter (Browne et al., 2011). There is no lower size limit on microplastics. Very small plastic particles are called nano plastics. These are formed when microplastics are fragmented into even smaller particles. Nano plastic has no definite definition, though it is common to describe them as particles with a diameter from one nanometer to one micrometer (Gigault et al., 2018).

Microplastics have different shapes, for example, shapes can be fragments, spheres or fibers. Fragments are formed when bigger plastic pieces fragments, and spheres are tiny plastic balls that can origin from cosmetics. Microfibers are small, thin threads which are largely derived from manufacturing and washing of synthetic textiles.

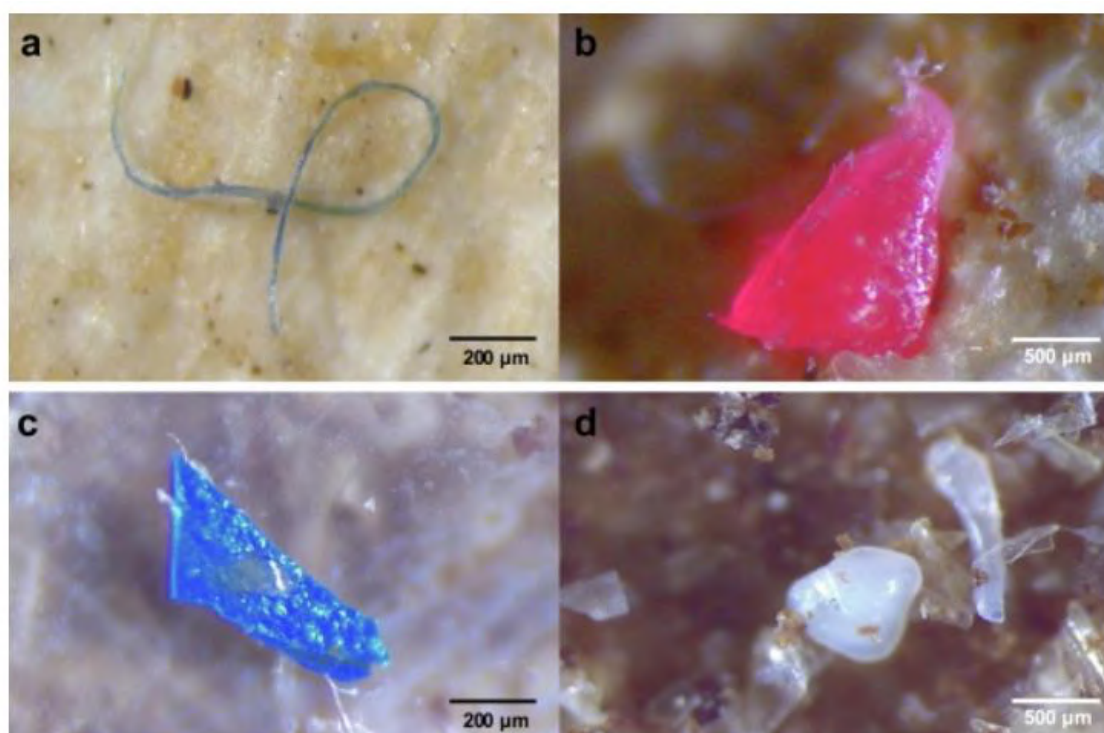


Figure 3. Different shapes of microplastic particles, figure a shows a microfiber, figure b and c shows plastic fragments and figure d shows micro pellets. Source: Barboza et al., 2020

Microplastics in the ocean can be primary or secondary microplastics. Primary microplastics are particles that are already in the form of microplastics before the particles enters the ocean. Examples of primary microplastics are plastic particles from hygiene products, plastic pellets from plastic manufacturing and microfibers which detaches from synthetic clothing when they are being washed. Secondary microplastics forms when larger plastics already in the ocean fragments into smaller particles. There are several reasons why plastic fragments in the ocean, for example it can be due to UV-radiation and mechanical breakdown (Magnusson et al., 2016).

Microplastics have been observed everywhere in the ocean today, from the deep sea to the arctic ocean.

What are microplastics?

- Microplastics are plastic particles with a diameter less than five millimeters.
- Microplastic particles can have different shapes, for example fragments or fibers.
- Primary microplastic particles enter the ocean in the form of microplastic particles. For example, they can result from wear and tear of car tires, washing of synthetic clothes or from cosmetic products.
- Secondary microplastics form when larger plastics fragment into smaller constituents.

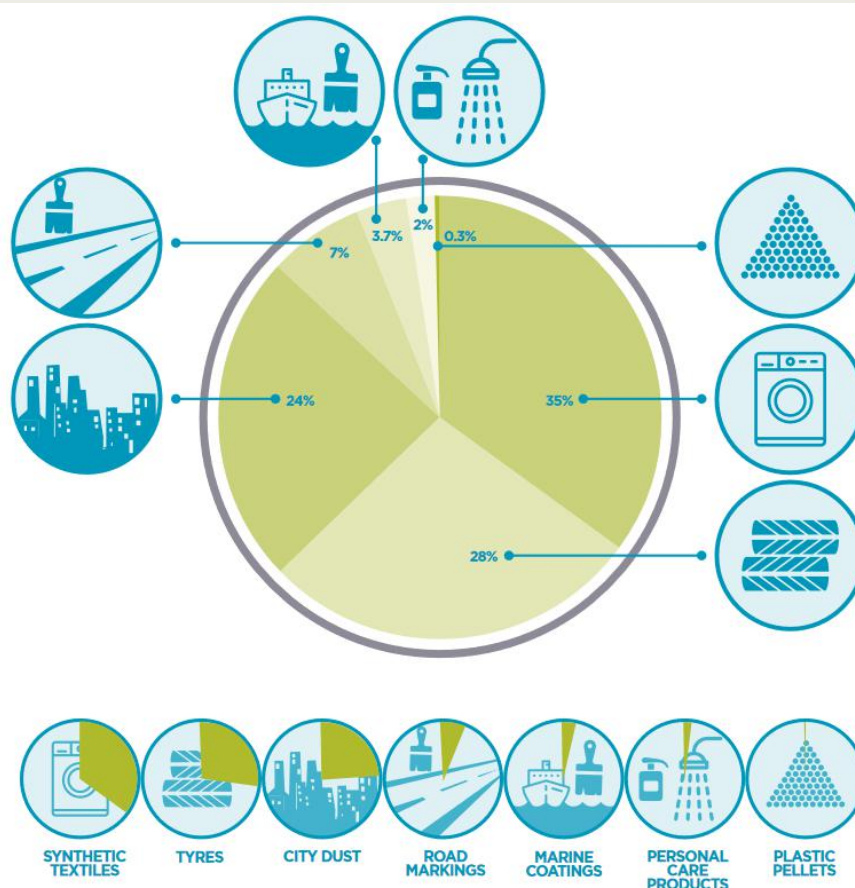


Figure 4. Origin of primary microplastics in the ocean globally. Microfibers from textiles are the largest source of primary microplastics. Source: Boucher & Friot, 2017.

1.2.4 KIMO Sweden's work with microplastic pollution

KIMO Sweden actively work with the issue of microplastics. In 2017, KIMO published an action plan to reduce microplastic emissions from municipal facilities. In the action plan, KIMO identifies sources of microplastic emissions and provide proposals for measures that municipalities can take to minimize the emissions of microplastics into nature.

1.2.5 Synthetic textiles

Clothing can be made of natural or artificial fibers. Natural fibers are derived from plants or animals. Artificial fibers are produced artificially via different chemical processes. There are artificial fibers which are produced from natural materials. Viscose and lyocell are examples of artificial fibers from natural material. Those materials decompose in nature, unlike fibers made from crude oils. Fibers made from oil are called synthetic fibers (Swedish Society for Nature Conservation, 2020). Today it is common for clothes to be wholly or partially made of synthetic fibers.

The most common synthetic material is polyester, also called PET (polyethylene terephthalate). Polyester is used to make many different garments, everything from fleece sweaters and sportswear to dresses and underwear. Acrylic and polyamide are other examples of common synthetic textile materials. Acrylic is often used to replace wool in knitted garments. Polyamide is commonly called nylon and is used, among other things, to make nylon leggings.

1.2.6 Synthetic microfibers in the ocean

It is likely that microfibers found in the ocean originate from synthetic textiles. They can either be released during the manufacturing or washing of clothes. When clothes are being washed, the wastewater from the washing machine flows on to rivers, lakes, and the ocean. Many times, the wastewater flows through a wastewater treatment plant, where some of the microfibers are filtered out. The fibers that are not filtered out will end up in the ocean, where they can cause harm to marine animals. Marine animals that are consumed by humans, for example mussels and fish, might contain microplastics. In this way microfibers from our clothes affect human beings (Barboza et al., 2020; Henry et al., 2018).

This report presents a compilation of current knowledge and research about synthetic microfibers and how they affect marine animals and human beings.

2 Emissions of synthetic microfibers and their effect on marine animals and humans

2.1 Manufacturing and consumption of synthetic textiles

2.1.1 Manufacturing of synthetic clothing

A large part of clothes that are sold in Europe are produced on other continents. For example, in Sweden only 10 percent of clothes that are sold in the country are produced in Sweden. The rest is imported, mainly from countries in Asia (Swedish Environmental Protection Agency, 2019). Therefore, to get a true picture of the microplastic problem it is important to see the manufacturing of clothes from a global perspective.

The world's population is growing and the rate of consumption of clothing increases. The production of clothes therefore increases exponentially. Today, over 100 million tons of fibers are produced annually, compared to the year of 1975, when 32 million tons of fibers were produced (Textile Exchange, 2020). Synthetic clothes are becoming more and more common, two thirds of clothes produced today are wholly or partially made of synthetic materials. 80 percent of synthetic textiles are produced in Asia. China is Asia's and the world's largest manufacturer of synthetic clothing, 69 percent of all synthetic clothes are produced in China (Henry et al., 2018). The production of synthetic fibers is not expected to decline, quite the contrary. A growing population and an increasing demand for cheap clothes lead to an increased production rate of textile fibers. Synthetic fibers are the type of fiber where demand increases the most (Textile World, 2015).

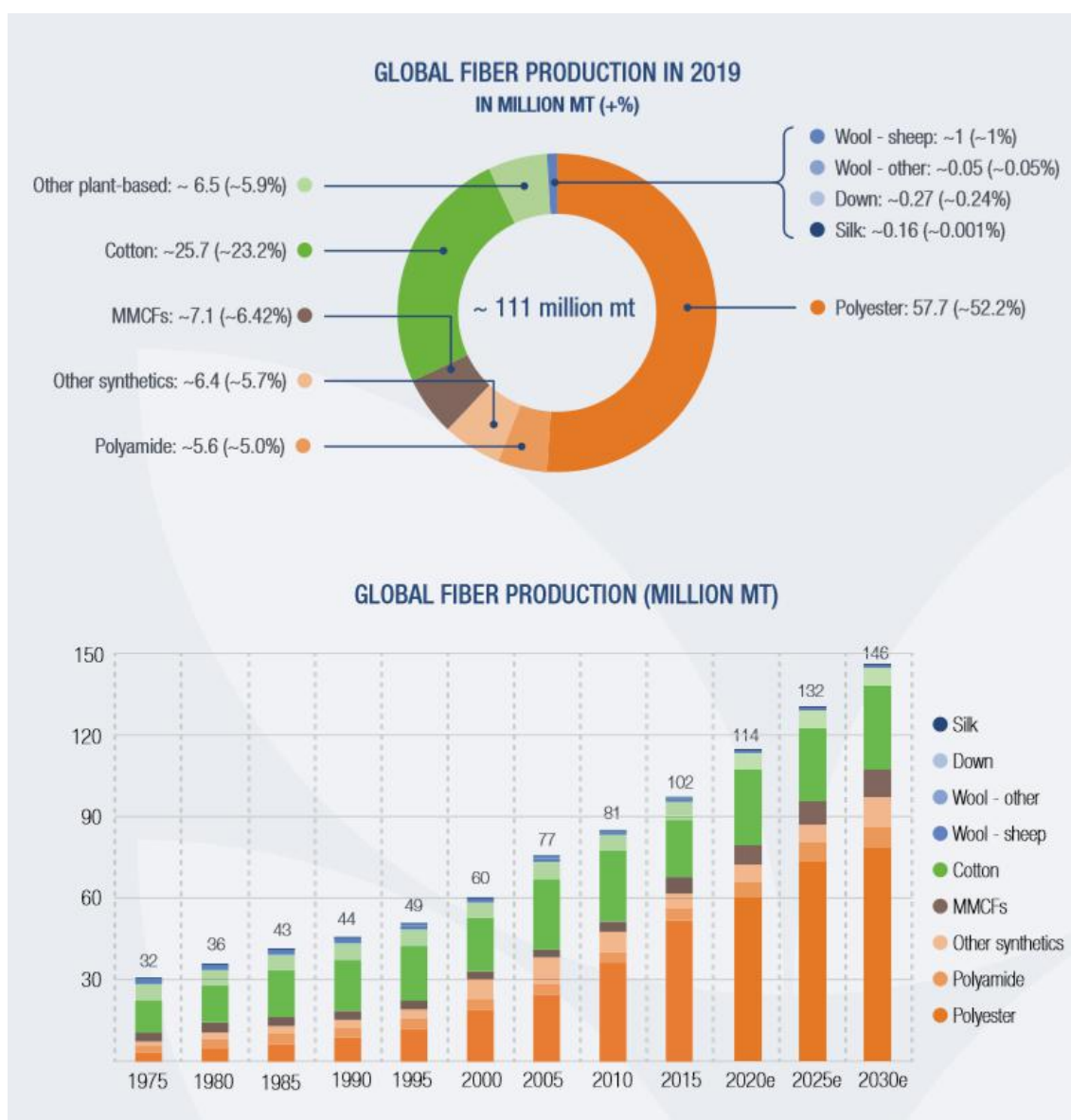


Figure 5. Global fiber production in 2019, the development of fiber production since 1975, and forecast of development of fiber production up to and including year 2030. Source: Textile Exchange, 2020.

2.1.2 Emissions of synthetic microfibers during textile manufacture

The textile industry is very large, and there is a lack of knowledge about emissions of microfibers in the production chain. How much is emitted depends, among other things, on the textile factories' wastewater treatment plants. The efficiency of the wastewater treatment plants varies among factories, and some factories completely lack treatment plants (Deng et al., 2020). Regulations for emissions of microplastics are different in different countries. The

amount of microplastic emitted in the manufacturing of clothing varies between factories and manufacturing countries.

Deng et al. (2020) performed a field study in Shaoxing city, China. Scientists examined the concentration of microplastics in the water and in the sediments in a river located in an area with many textile factories and textile markets. Concentrations from the river were compared with concentrations in water and sediments from a nearby agricultural area. The result showed that the concentration of microplastic particles were twice as high in the industrial area compared to the agricultural area (13.3 particles per liter compared to 6.8 particles per liter). 95 percent of the observed microplastic particles in the industrial area were in the form of microfibers, and polyester were the most common fiber type. Deng et al. states that textile factories in the area often lack wastewater treatment plants. Microfibers and other chemicals are released straight into the river. The study performed by Deng et al. concludes that the textile industry is a source of emissions of synthetic microfibers in rivers and the ocean.

2.2 Washing of synthetic clothes

There are studies on the number of microfibers released during washing of clothes, many of them report different results concerning the number of released microfibers. However, all the studies made on the subject agree that microfibers are released when during the washing of clothes. Three studies are reviewed in this report. All of them examine how many microfibers that are released during the washing of synthetic clothes. The purposes and methods differ among the studies, therefore the results cannot be compared. However, the results provide a clue of which factors that play a role in how many fibers that are released during washing.

De Falco et al. (2017) investigated microfiber emissions from three different materials; woven polyester (PEC), knitted polyester (PEP), and woven polypropylene (PP). Woven polyester released the highest number of microfibers. The number of microfibers released depended on the type of detergent used in the experiment, powder detergent caused the highest amount of release. The reason for this, according to De Falco et al., can be that powder detergent creates a higher friction against the clothes, compared to liquid detergent. A higher friction leads to a higher mechanical stress on the clothes and microfibers are torn from the clothes. The results from De Falcos research showed that a load of 5 kilos of polyester clothes can release 0,43 to 1,27 grams of microfibers. This corresponds to 6 million to 17,7 million microfibers per wash.

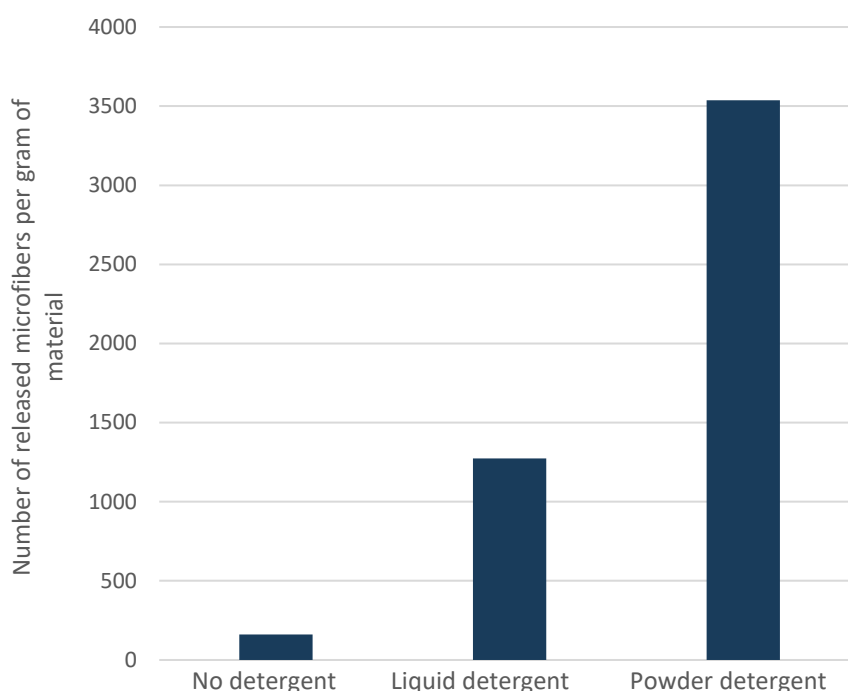


Figure 6. Number of microfibers released per gram of material when washing woven polyester, PEC, using different detergents. The bars show mean values. The figure is based on data from De Falco et al., 2017.

Almroth et al. (2017) also investigated different synthetic materials; polyester, acrylic and nylon. The investigated polyester materials were manufactured in two different ways, knitted polyester or fleece material. The material that released the highest number of microfibers was fleece material. One fleece sweater can release 110 000 fibers per wash, according to Almroth et al. The other materials released on average 900 fibers per item and wash. Two different polyester materials were compared to each other; loosely and tightly woven polyester. The loosely woven material released a higher number of microfibers than the tightly woven material. Almroth et al. used liquid detergent in all their experiments.

The number of microfibers released is lower in Almroth's experiment than in De Falco's experiment. The higher number in De Falco et al. may be due to the type of detergent used in the experiment. Almroth et al. used liquid detergent and De Falco et al. measured the highest numbers using powder detergent.

Type of washing machine can also affect the number of released microfibers. Hartline et al. (2016) observed that a sweater washed in a top load washing machine released a higher number of microfibers than a sweater washed in a front load washing machine. This can be due to the washing machines different mechanical impacts on the clothes. More research is needed to confirm Hartline's results and to give a better understanding of why type of washing machine has an impact on the amount of microfibers released.

2.2.1 Methods for reducing microfiber emissions from washing

There are products that are designed to reduce microfiber emissions from washing machines. Laundry balls, laundry bags and filters are examples of such products. The laundry ball is a ball that is placed in the washing machine together with the clothes, the ball catches some of the released microfibers. Tests have shown that the ball can reduce microfiber emissions by 30 percent (McIlwraith et al., 2019). The laundry bag is a mesh bag which lets water through, but not microfibers. Studies have shown that the laundry bag can reduce microfiber emission by 90 percent (Blekinge Arkipelag, 2018). Both the laundry ball and the laundry bag are cleaned after each wash and the captured microfibers are thrown in the household rubbish. The filter is designed to capture microfibers and is installed in the washing machine so that outgoing water passes the filter. The filter captures around 87 percent of the released microfibers (McIlwraith et al., 2019).

What factors affect the number of microfibers a synthetic garment releases?

- **Material:** Fleece and woven polyester release the most microfibers when washed.
- **Detergent:** The highest amount of microfibers are released when powder detergent is used, liquid detergent is better, no detergent at all is best.
- **Washing machine:** Top load washing machines contribute to higher amount of released microfibers.

2.3 Wastewater treatment plants and microplastics

Wastewater treatment plants receive water from households and industries and purify the water from nutrients, pollutants, and rubbish. It is important to have an effective water purification process to reduce emissions of synthetic microfibers from clothes into the sea. The number of emitted microfibers from one garment depends on the water purification in the manufacturing process and the water purification at the locations where the garment is used and washed.

Most wastewater treatment plants purify the water in three steps: first mechanical, then chemical, and lastly biological filtration. Some treatment plants have one more filtration step where small particles and phosphorus are separated from incoming wastewater (Magnusson & Wahlberg, 2014).

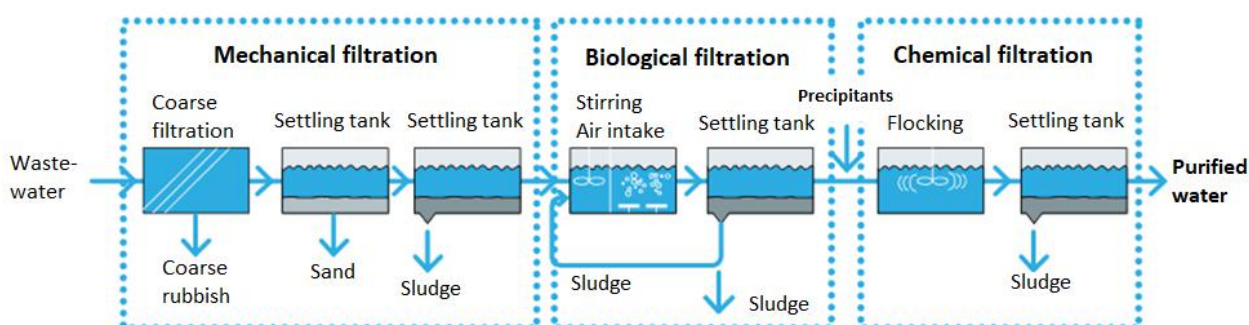


Figure 7. Purification steps in a conventional wastewater treatment plant. Source: Swedish Environmental Protection Agency, 2016.

Wastewater treatment plants can filter over 70 percent of incoming microplastic particles, based on three studies on Swedish, Norwegian and American wastewater treatment plants (Magnusson & Wahlberg, 2014; Magnusson, 2014; Conley et al., 2019). The studies of the Scandinavian treatment plants showed that the efficiency was higher for filtering particles bigger than 300 µm. Smaller particles were often released with the outgoing wastewater (Magnusson & Wahlberg, 2014; Magnusson, 2014).

The number of microplastic particles in the water entering the treatment plant can be very high. Although many particles are captured in the treatment plant, a high number can still follow in the treatment plant's outgoing water. Measurements from a Swedish wastewater treatment plant shows that 350 million microplastic particles can enter the treatment plant every hour. If the treatment plant filters 99 percent of the microplastic particles, 3.5 million particles will flow out from the treatment plant every hour and eventually end up in the ocean (Magnusson & Wahlberg, 2014).

2.3.1 Sludge management

The material that is filtered out in wastewater treatment plants is called sludge. Sludge is rich in nutrients and is often reused as fertilizer on fields (Swedish Environmental Protection Agency, 2016). The concentration of microplastic particles in sludge can be high, and there are suspicions that sludge as a fertilizer contributes to an increased concentration of microplastics and other environmental toxins in agricultural land (Nizetto et al., 2016). As sludge management is outside the scope of this report, no in-depth study will be made on this topic.

2.3.2 Wastewater treatment in the world

Existing data shows that high-income countries purify 70 percent of generated sewage, middle-income countries purify 28 to 38 percent of generated sewage, and low-income countries purify only eight percent of generated sewage (Sato et al., 2013).

Many textile factories in low-income countries lack wastewater treatment plants and large quantities of microfibers and other chemicals are released straight into the surrounding

waters. A high demand for cheap clothing means that manufacturers must reduce production costs. Not purifying wastewater from factories is one of the ways to reduce costs in the manufacturing of clothing. Environmental monitoring is lacking or non-existent in many countries, leading to some factories not complying with existing regulations regarding wastewater treatment (Haque, 2017).

2.4 Synthetic microfibers in oceans and sediments

2.4.1 Synthetic microfibers in the ocean

Synthetic microfibers have been observed in every ocean on earth, from the deep sea to the arctic ocean. The concentration of microfibers varies depending on location. Concentrations are often higher in waters close to coasts and urban areas. Synthetic microfibers move with ocean currents, which affect where microfibers accumulate. Two studies of microplastic concentration were performed, one in the North Sea and one along the west coast of Portugal and Africa (Lusher et al., 2014; La Daana et al., 2017). All studies found that microplastics were present in all the investigated locations. The mean concentration was one to three microplastic particles per cubic meter of water. Microfibers were the most common type of plastic in all investigations. The highest concentration of microplastics were found outside the coast of Portugal, 8.5 microplastic particles per cubic meter of water (La Daana et al., 2017).

In the studies mentioned above, the measured particles were all bigger than 250 μm . Many microplastic particles are smaller than this. It is therefore likely that the true concentration of microplastics is significantly higher than the reported result.

In a study performed by Brandon et al. (2020), the concentration of plastic particles smaller than 333 μm were measured. Particle concentration was measured outside California, in coastal waters and in the open ocean. Brandon's result shows considerably higher concentrations than in the previously mentioned studies. Up to 5000 particles per liter were found in water from the open ocean, and up to 15 000 particles per liter was found in coastal waters. Most plastic particles were in the form of microfibers. A new technology for finding

small plastic particles were used in this study, it is therefore not possible to compare this study with other studies on the subject.

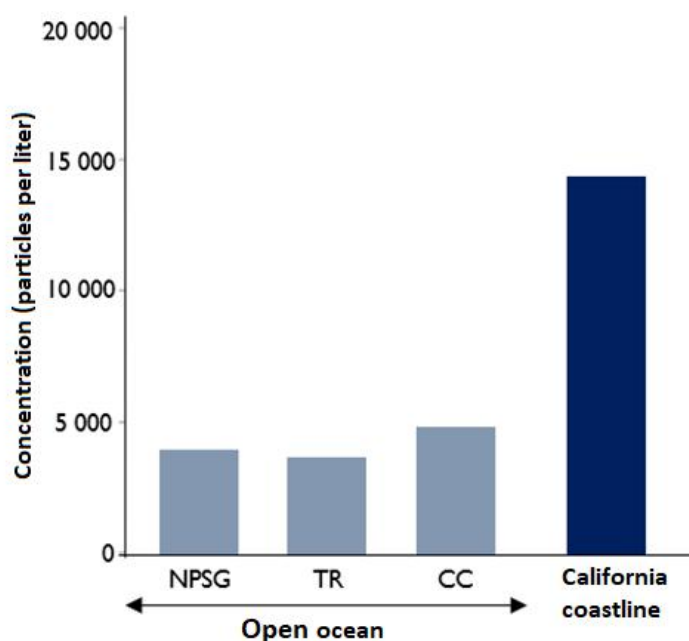


Figure 8. Microplastic concentration of particles smaller than 333 μm in diameter. Measurements from North Pacific tropical gyre (NPSG), California current (CC), a transition region (TR) and California coastline. The bars show mean value. Source: Brandon et al., 2020

Another study by Pabortsava and Lampitt (2020) show that earlier measurements of microplastic concentration have often given a too low value. Pabortsava and Lampitt measured the concentration of microplastic particles between the size of 32 to 651 μm in the north Atlantic Ocean. The scientists found that the concentration of microplastics can be 10 times higher than previously measured, which may be due to inadequate measurement methods in previous studies.

There is no standardized method for measuring microplastics and it is therefore hard to compare and to compile studies of the concentration of microplastics in the ocean. Microplastics are redistributed by ocean currents or by organisms. Some of the plastic particles sink to the bottom of the ocean. Because of this, the concentration vary widely in time and space. What is certain is that microplastics can be found everywhere in the ocean today.

2.4.2 Synthetic microfibers in the sediment

There are many studies on microplastics in sediments close to beaches, as it is easiest to examine sediments in shallow waters. The concentration of microplastics on beaches and in

nearshore sediments are highest in locations close to densely populated areas and harbor areas (Browne et al., 2011; Claessens et al., 2011). Concentrations of microplastics are very high in sediments close to wastewater effluent and the proportion of microfibers are high. It is likely that those microfibers are derived from synthetic clothing (Browne et al., 2011).

Even in sediments from the deep sea, there are significant amounts of microplastic particles. Studies have shown that one square meter of sediment in the deep sea can contain up to 2000 microplastic particles, of which 75 percent are microfibers. The reason for this high concentration is believed to be that microfibers emitted to the ocean flows with the ocean currents and sinks to the bottom in specific locations. When in the sediments, the particles will stay in place and the concentration of microfibers will increase with time (Fischer et al., 2015).

2.4.2.1 Increase of microplastics in the sediment over time

The presence of microplastics has been investigated in sediment cores from the seabed. Sediment cores can be used to study how the seabed and the marine environment changes over time. To sample sediment cores, sediment is trapped in a cylinder that is pushed down into the seabed, without stirring the sediment. Sediment cores serve as a historical archive and it is possible to use the core to analyze how the concentration of microplastics varies in a historical perspective. When particles sink to the ocean floor, they settle. Eventually they are covered by other particles. Particles deep down in the sediment core are older than the shallow ones.

Claessens et al. (2011) investigated sediment cores from the coast of Belgium. They found that the concentration of microplastic has tripled since 1993. An investigation of sediment cores from waters outside of Tokyo found that the concentration of microplastics were seven times higher today than 1950.

2.5 Synthetic microfibers effect on living organisms

2.5.1 Uptake of microfibers by marine organisms

Marine animals can ingest microplastic when they are eating, microplastics can also be taken up through the gills. Some small animals, such as zooplankton, may mistake microplastics for food and eat them. Other animals ingest microplastics involuntarily. Filter feeders, such as mussels and whales, ingest food by filtering sea water and eat all particles of a certain size. There are studies that show that filter feeders of all sizes risk ingesting microplastics when feeding (Van Cauwenberghe et al., 2015; Fossi et al., 2015). Predators can ingest microplastics if their prey have eaten microplastics. In this way, microplastics ascend in the food chain.

There is a possibility that microplastic particles can diffuse from the gills or the gastrointestinal tract into the bloodstream. From the blood, the microplastics can spread to other organs such as the liver, the muscles, and the brain. This is more likely if the plastic particles are very small, so called nano plastics (Mattson et al., 2017; Barboza et al., 2020).



Figure 9. Examples of filtration feeders. To the left: Blue mussel, *Mytilus edulis*. To the right: Humpback whale, *Megaptera novaeangliae*. Source: Max Pixel

2.5.2 Physical and chemical impacts of synthetic microfibers

Physical impacts are the mechanical injuries that microplastics can cause. For example, small organisms can become entangled in microfibers. Another example is that microplastic particles can cause injuries to the animal's gastrointestinal tract. If a small animal eats microplastics, they will take up space and cause blockage in the animal's gastrointestinal tract, which will create a false feeling of satiety and eventually lead to malnutrition and starvation. There are studies where the physical impacts of microplastics have been investigated, but not enough to tell exactly how the plastic particles affect the animals in the wild. There is a need for more studies on the subject (Kersaw et al., 2015).

Chemical effects describe what happens when or if an organism is poisoned by plastic particles, it describes the toxic effects of plastic. Different types of plastics have different properties and contain a variety of substances. It is therefore difficult to say how toxic microplastics are and how they affect marine animal health in general. Studies performed in a laboratory environment have shown a variety of toxic effects on marine animals exposed to microplastics. Examples of symptoms are behavioral changes, disturbed immune system, disturbed reproductive capacity, and reduced growth (Ašmonaitė & Almroth, 2019; Mattson et al., 2017).

In experimental studies, a high concentration of microplastic is often used. The concentration is often higher than the actual concentration of microplastics in the natural environment, which makes it difficult to apply knowledge from experimental studies on to natural environments. Everaert et al. (2018) investigated how high the concentration of microplastic particles must be to have a chronic impact on marine animals. The result from this study shows that microplastics have a negative impact on marine animals if the concentration is higher than 6650 particles per cubic meter. This concentration is rarely found in the open ocean, but often found in polluted waters close to the coastline (Everaert et al., 2018). For example,

concentrations higher than 6650 particles per cubic meter have been measured on the west coast of Sweden (Magnusson et al., 2016). Everaert et al. emphasize that more studies are needed to confirm that 6650 plastic particles per cubic meter is a safe limit.

There is little scientific knowledge on how synthetic microfibers chemically affect marine organisms. In experiments, other forms of microplastics are often used, such as spheres or pellets. There are suspicions that microfibers have a higher toxicity than other types of microplastics, because of the shape of the microfiber. A larger surface comes into contact with the animal that ingested the microfiber, compared to other microplastics. Though more scientific studies are needed to confirm this (Kersaw et al., 2015).

2.5.2.1 Additives and adsorbed environmental toxins

Additives in plastic materials may in some cases be endocrine disrupting or carcinogenic. When plastics end up in the sea or in an animal, additives can leak from the plastic material and are in this way released into the water or into the animal (Kwon et al., 2017). Microplastic particles in the ocean can adsorb environmental toxins. The toxins attach to the plastic particle's surface, microplastic particles can be carriers of high concentrations of environmental toxins. These toxins can be released inside an animal's body, and cause harm to the animal. Examples of chemicals that can be adsorbed by plastic particles are nonylphenol and bisphenol, which are both endocrine disrupting chemicals (Kersaw et al., 2015).

Microplastics are not the biggest source of toxins to marine animals, but the concentration of microplastics in the ocean is constantly increasing. Microplastics and additives may in the future constitute a significant part of environmental toxins in the ocean (SAPEA, 2019).

How do microplastics affect marine animals?

- Microplastics can effect marine animals physically by causing damage to the gastrointestinal tract or by creating a false feeling of satiety, which can lead to malnutrition and starvation.
- Microplastics can affect marine animals chemically, by acting as a poison in the animal's body. Microplastics can possibly cause behavioral changes, disturbed immune system, disturbed reproductive capacity and reduced growth.
- Additives and environmental toxins can accompany the plastics into the animal. Those can be endocrine distruptors or carcinogenic.

2.5.3 Microplastics and human health

Protein from the sea accounts for 6.7 percent of the global protein intake, fish and seafood is an important source of nutrition for many people in the world (FAO, 2020). There are many studies that confirm that fish and seafood may contain microplastic particles. In countries where a lot of shellfish are consumed, for example in southern Europe, one human individual can ingest up to 11 000 microplastic particles every year (Henry et al., 2018).

Another way to ingest microplastics is through drinking water. The World Health Organization (WHO) published a study in 2019 concerning microplastics in drinking water and how great of a threat microplastics pose to human health. According to WHO, most of the ingested microplastic particles pass straight through the body, but there is a certain risk that nano plastic particles can be taken up in the gastrointestinal tract and spread into the bloodstream and other organs. There are no studies on how microplastics affect human health, all science and knowledge is based on animal studies (WHO, 2019).

According to WHO, additives and adsorbed environmental toxins can pose a risk to human health if microplastics are ingested. How those chemicals affect humans depend on the amount of ingested microplastics. It is currently unknown to what extent humans are exposed to microplastics in our day-to-day life. Knowledge of how microplastics affect human health is very limited and more science is needed before any conclusions can be drawn as to whether microplastics pose a threat to human health.

2.6 Awareness of microfiber emissions from synthetic textiles

2.6.1 Awareness in the fashion industry

There are initiatives to reduce the use of plastic materials in the fashion industry. New Plastics Economy Global Commitment is an agreement between 150 companies, including some well-known fashion companies. The parties have agreed to eliminate all unnecessary use of plastic materials and to strive for a circular economy where plastics are recycled as much as possible. The companies must also work towards increased transparency, where they report on how much plastic is used in manufacturing and sales (New plastics economy, 2020).

European Strategy for Plastics in a Circular Economy is an agreement including European textile manufacturers (EURATEX) and outdoor companies (European Outdoor Group), among others. It has been agreed to find common guidelines for quantifying microfiber emissions, share knowledge on the subject and to support research on microplastics from textiles (European Outdoor Group, 2020).

The Microfiber Consortium (TMC) is a collaboration between many outdoor companies. Those companies work actively with research, product development and information exchange in the field of microplastics.

2.6.2 Consumer awareness

A consumer survey conducted by The Swedish Environmental Protection Agency showed that 70 percent of respondents think about microplastic emission when washing, but almost half of them stated that they lacked knowledge of the issue (The Swedish Environmental Protection Agency, 2019). Concerning awareness of the impact of textiles on the environment, 57 percent stated that they think about this when buying clothes, but 27 percent of those stated that they lack knowledge.

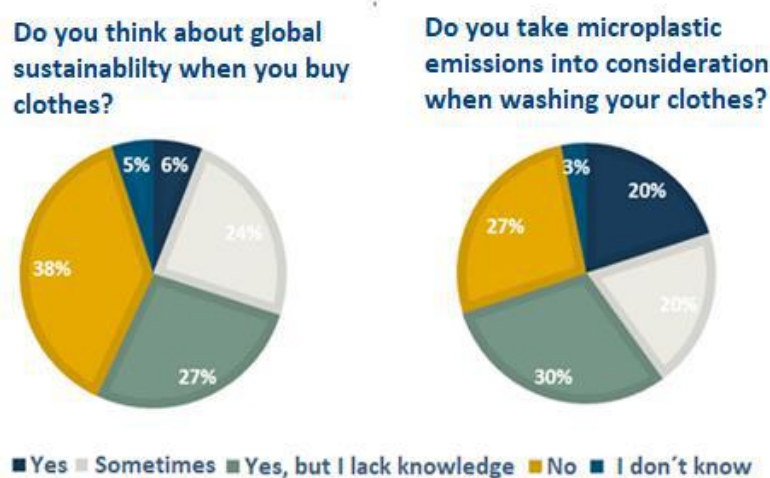


Figure 10. Awareness among Swedish clothing consumers. The figure is based on data from The Swedish Environmental Protection Agency, 2019.

3 Discussion

3.1 Textile industry and textile consumption

If emissions of microfibers are to be stopped, the clothing industry faces a huge challenge as synthetic microfibers make up a large part of the materials used in clothing manufacturing. The demand for cheap clothes is expected to rise, and synthetics are cheap materials that are often used to keep the prices down. The fashion industry is based on fast fashion, where trends constantly change, leading to unsustainable clothing consumption.

Synthetic microfibers are released during the manufacturing of synthetic clothes. The more synthetic garments that are made, the more microfibers are emitted. Some clothing companies work actively with the issue of microplastics by trying to develop better materials and to support research on the subject. This is a step in the right direction, but it is not enough to stop microplastic pollution from synthetic clothing. To achieve sustainable textile production, a

change is required in the entire textile industry, clothing companies must invest in making clothes out of sustainable quality materials that last for a long time. The consumption culture also needs to change, fast-fashion culture will never be sustainable.

It is important to highlight that the textile industry is unsustainable in many ways, not only from a microplastic perspective. For example, cotton cultivation occupies 2.5 percent of all arable land in the world, and the cultivation of cotton is responsible for 16.5 percent of global pesticide use (Laitala et al., 2018). In the wastewater from textile factories, a variety of harmful chemicals have been found, which have also been found in finished garments that are sold all over the world. Those chemicals affect both the nature and the consumer in a harmful way (Swedish Chemicals Agency, 2015)



Figure 11. Fast-fashion. Photo: Markus Spiske

3.2 Wastewater treatment

As emissions of synthetic microfibers into wastewater is significant, efficient water treatment is important to reduce emissions to the sea. Today, sewage treatment plants reduce large parts of the incoming microfibers, but since the number of microfibers that enter the plant is very large, there are also significant amounts of microfibers that leave the treatment plant. To solve this issue, wastewater treatment plants need to become more effective, but also the amount of microfibers emitted from households and industry needs to be reduced.

Many countries do not have well developed systems for wastewater treatment, which is a global issue. Production of textiles, for example, often takes place far from the place where the product is consumed. Microplastics in the ocean don't always stay close to the source of emission, but float with ocean currents and spread all over the ocean.

3.3 Health risks to humans and marine organisms

Research on how microplastic particles affect humans is scarce. There are suspicions that nano plastic particles can be taken up in the gastrointestinal tract and spread in the body, but more science is needed to prove this. In the absence of knowledge on the subject, precautions should be taken until there is knowledge as to whether microplastics are harmful to humans or not.

However, there is research showing that microplastics do affect marine animals. When the concentration of microplastics in the ocean increases, there is a risk of damage to the wildlife, both on the individual level and on an ecosystem level. A disturbed ecosystem can affect fish stocks and further affect the fishing industry. Many people are dependent on fishing, both for food and for the economy. In this way, microplastics effect on fish can affect humans indirectly.

Most scientific experiments carried out to investigate physiological effects of microplastics on living organisms have not been done with microfibers, but with micro pellets and microspheres for example. Therefore, the need for research on how synthetic microfibers affect living organisms is important.

4 Conclusion and suggestions for measures

4.1 Conclusion

Microplastic pollution in the ocean is a big and growing issue. 35 percent of microplastics in the ocean originate from synthetic textiles (IUCN, 2017). Textile production, consumption and washing of clothes play a significant role in the release of microplastics into watercourses and the ocean. There is a lack of knowledge about how microfibers affect humans and other living organisms, more science is needed on the subject. As long as there are gaps in knowledge, precautions are needed, and emissions of synthetic microfibers must be minimized.

In order to minimize microfiber emissions, efforts are required from all levels of society. International agreements, laws and regulations at a state level are needed to overcome the problem, but companies and individuals can also contribute to reduce emissions of microfibers.

This report concludes with suggestions for measures on how emissions of synthetic microfibers can be reduced, both at the societal level and at the individual level.

4.2 Measures at the societal level

The textile industry is big. For change to take place throughout the industry, governance from a higher level is needed, for example through global agreements and governmental control. Economic incentives are an example of measures that can be taken by the state. By raising taxes on synthetic clothes or lowering taxes on clothing made from sustainable renewable materials, the market can be steered in a sustainable direction. Economic instruments have been used in similar ways before. For example, in 2017, Sweden introduced a tax on electronics containing flame retardants. In 2020, the government will evaluate the effect of this tax.

There is a need to expand wastewater treatment plants at textile factories, and companies must invest in research and development of sustainable materials. Companies must take responsibility for minimizing emissions of synthetic microfibers and harmful chemicals throughout the manufacturing chain. One way to get producers to take their responsibility is to legislate that the entire production chain must be transparent. Information about the entire manufacturing process, from raw material to finished product, must be available for everyone.

To make it easier for consumers, an eco-label, that considers microplastic emissions throughout the life cycle of the garment, is needed. Such a label does not exist today as there are no standardized ways to measure microplastic emissions from synthetic textiles. When buying synthetic clothing, advice for the care of the garment could also be included that aims to minimize emissions of microfibers during washing.

To raise awareness of the problem of synthetic microfibers, information needs to be spread to companies and consumers about the problem. School education, information campaigns from national authorities, organizations and municipalities are some ways to reach out to citizens and companies.

KIMO Sweden has developed an action plan for municipalities with advice on how the microplastic problem can be tackled. Among other things, it is emphasized that municipalities should review filters in wastewater treatment plants to achieve the highest possible efficiency

for wastewater treatment. Municipalities can also work actively to measure emissions of microplastic particles from wastewater treatment plants.

What can be done at the societal level to reduce microfiber emissions?

- Economic measures can be used to steer the market towards a more sustainable direction, for example by taxing synthetic clothes that contributes to emissions of synthetic microfibers.
- The whole manufacturing process of synthetic clothes must be transparent and available to the public. Companies should report the environmental impact of a product, from raw material to finished product.
- There is a need for an eco-label that takes into account the emissions of microplastic throughout the lifecycle of the product.
- Information about the microfiber issue needs to be spread to companies and consumers.
- Municipalities can review filters in wastewater treatment plants and actively measure microplastic emissions from wastewater treatment plants.

4.3 Measures on an individual level

As a consumer, there are many ways to minimize emissions of synthetic microfibers. An effective way to reduce emissions is not to buy newly produced synthetic clothes, but rather go for sustainably manufactured clothes made from natural material, preferably second hand. Today there is a large selection of thrift stores, and by buying secondhand clothes you minimize your impact on the environment. However, it is important to remember that synthetic clothing release microplastics when washed during the entire life cycle of the garment. Secondhand clothes should preferably also be made from natural materials.

If you buy newly produced clothes, you can try to examine the company where you intend to shop. It is not easy to know which companies are environmentally conscious. Researching how the company deals with microplastic emissions might give a clue about how they deal with the issue. By buying clothes from companies that work actively to, for example, produce sustainable materials or that fund research, one contributes to drive research and innovation forward. High-quality synthetic clothes are often a better alternative than low-quality synthetic garments, as higher-quality garments are often tighter woven and therefore release less microfiber particles when washed. High-quality garments also last longer, which means that we need to buy new clothes less often and thus reduce microfiber emissions from clothing manufacturing.

It is also important to minimize emissions of microfibers from the clothes you already have. Above all, it is important not to wash clothes more often than necessary. This not only minimizes emission of microplastics but reduces wear and tear and gives the garment a longer life. There are laundry bags, laundry balls and filters for washing machines designed to reduce microfiber emissions. Those products can be ordered online. One can also make sure to use liquid detergent and, if appropriate, air clothes instead of washing them.

How can you, as an individual, contribute to reducing microplastic emissions?

- Buy sustainably produced clothes made from natural materials when possible, preferably second hand.
- Buy high-quality clothes that you can use for a long time.
- Buy clothes from companies that work actively with the issue of microplastic pollution.
- Wash your clothes only when necessary, try to air them instead of washing.
- Use a laundry bag, laundry ball or washing machine filter designed to reduce microfiber emissions.
- Use liquid detergent instead of powder detergent.

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