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Analysis of microfibers in waste water from washing machines.

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This thesis shows how the microscopic particle called microfiber is polluting the oceans. Microfiber generated from synthetic fiber in the process of laundering and its concentration in ocean water are the main themes of this thesis.. The main goal of this thesis is to better understand the cause and consequences of microfiber pollution in the aquatic ecosystem and the way to minimize the quantity of microfiber.

In this thesis, experiment was done by using vacuum filtration. The new and old jacket, each 100% polyester, was washed in a washing machine keeping the temperature at 40°C. The effluent water released from the laundry was collected for the experiment. The sample was collected in three different phases and was experimented with separately. The residues collected after the vacuum filtration were weighed and viewed under the microscope.

The experiment was able to find the mass of the microfiber collected in each phase for the new and the old jacket. The nature and the characteristics of the microfiber were observed. The quantity of the microfibers present in the new and the old jacket separately was calculated.

The microfiber not only affects the environment negatively but also plays an important role in our lives. Microfibers is used in various everyday products from garments to cleaning products. This thesis describes the ways to minimize the quantity of microfiber. This thesis aims to increase the awareness of the negative impacts of using microfiber releasing products and significant use of the seafood.

Keywords	microfiber, microfiber pollution, laundry, quantifying microfiber, alternative solutions.

PREFACE

One of the crucial problems the world is facing today is pollution. This problem has affected the land, water and space of this planet. The existence of living creature such as human beings, animals and plants are in danger. Every year it is observed that the international Environmental Day explicitly indicates the sensitiveness of this issue.

Nature believes in co-existence of all living things in the ecosystem to sustain better and healthier world so long as it is not disturbed. The violent exploitation of land, water and space has created a havoc that this planet is no longer a better place to live in. Such exploitation is manifested in different forms and ways such as maximum utilization of chemicals fertilizers and pesticides, deforestation, nuclear and atomic experiments, industrial wastes and smokes and petro-chemical oil refineries, which not only spoil the earth but the lives of human beings, animals and plants. The acid rain or global warming is a great threat to the ecosystem today.

Pollution is an alarming issue that is too broad to be studied as such but needs to be divided into diverse subtopics according to its causes. Therefore, this thesis focuses on studying ocean water pollution caused by microfiber released from synthetic MMF clothes in the process of laundering.

The thesis aims to reveal the overall impacts of such pollution on marine life and human beings and the ways to overcome or lessen the negative impacts. The purpose is to increase the understanding of this issue and the interest in working harder to resolve this.

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Abbreviations and Units

WWTP	Waste Water Treatment Plant
UCSB	University of California, Santa Barbara
°C	Degree Celsius
MMF	Man Made Fibers
µm	Micrometer or micron
min	minutes
L	liters

Acknowledgement

I am thankful and obliged to all who helped me to complete this report with valuable suggestions and support. Their efforts have contributed a lot in learning about the microfiber pollution and its consequences in real field. I would like to dedicate this thesis to my parents Mr. Bhim Lal Sharma and Mrs. Parbati Lamichhane, and always thankful for their continuous love and support to complete it. Also I would like to thank my wife Mrs. Supriya Sharma Lamichhane for her continuous support and my friends in formation of this report within a limited frame of time.

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Last but not least, I would like to remember the team of Bren School of Environmental Science and Management that greatly inspired me to do the laboratory experiment.

January 2018
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1 Introduction

Pollution is a global issue in the form of dust, smoke from industries, nuclear and atomic experiments. As research and analysis are advancing, different new sources of pollution are found. A very alarming and sensitive issue is the pollution from plastic products and eventually from microfiber synthetic products from textile industries.

Over centuries, people have learnt to utilize the earth's resources to live longer. But for all the benefits, there is an increasing concern that may destroy the planet in the process. Many people believe the environmental challenges facing the world today are greater than anytime in human history. As the world's population continues to expand, it has been challenging to manage the earth's limited resources to ensure both continued growth and healthy planet.

Microfiber, a microscopic particle, is an interesting research to the world. It has no good definition, as it is the outcome or residue of the laundry wash. The microfiber is not created or manufactured in the industries or any construction companies. The marine creatures seem to be unhealthy and various fibers are found in their stomach, intestine that inspired the researcher to attempt to find the actual cause. [1]

The cause of pollution of the oceans/seas is not well known. Every year the quality of the water is deteriorating. It has been shown that the small tiny particles the size of which is smaller than that of human hair are found in abundance in ocean and sea water. It has been so important concern to know the sources of its release. Laundry companies seem to be the major sources of microfiber pollution in the oceans. Microfiber pollution is a very hot topic in the modern world as it not only is polluting the oceans but also is affecting the underwater creatures and the predators as well.

2 Objectives

Human activities are more likely the major source of ocean pollution. Oceans cover 3/4 of our planet; therefore, it is our duty to prevent further pollution of the ocean. This thesis meets this duty by addressing the impact of man-made microfibers in the ocean. Human beings are responsible for the ocean pollution, and now it should be their prominent duty to conserve the ocean from being polluted.

Some objectives of the thesis are listed below:

- To gain knowledge on our own microfiber impact and possible ways to minimize it.
- To know the characteristics of fabrics that are responsible for microfiber release.
- To understand the various sources of microfiber in aquatic environment.
- To know how microfiber reaches the bellies of underwater creatures and those of the humans.
- To promote fabrics that release zero microfibers.
- To compare the garments types.
- To setup an experimental design to know the amount of microfiber release from single washing.
- To provide some suggestions for further research.

3 Background Literature Review

The production of polyester has been increasing every year since 1980. Most consumed natural garment fabrics, cotton and wool, are now replaced by the MMF. Less expensive, shiny, easily washable synthetic garments have made people's lives easier in the modern hectic society.

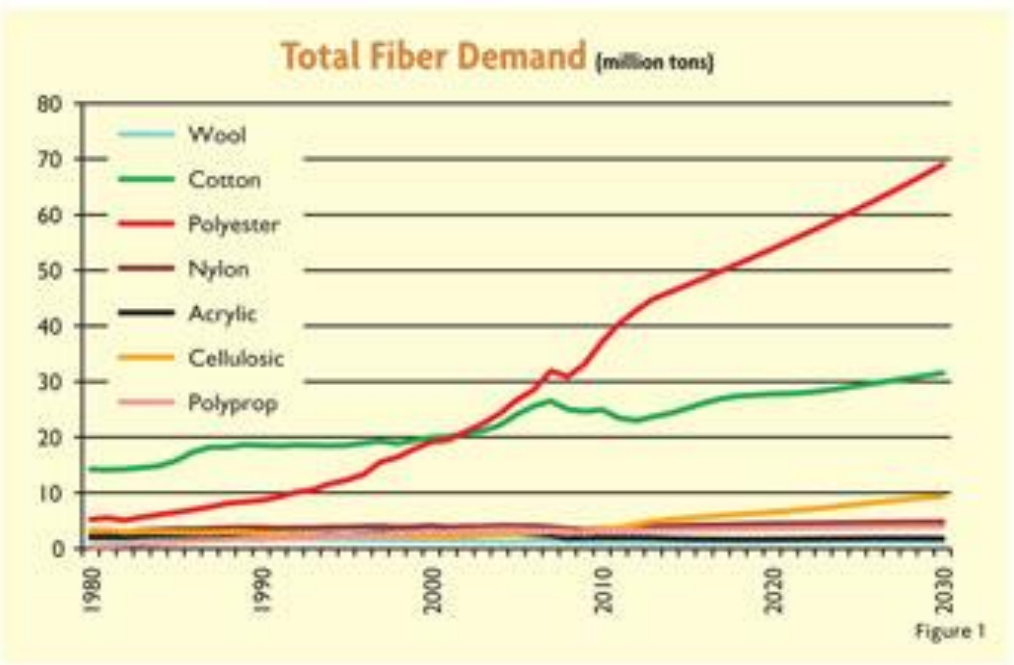

Figure 1: Total Fiber Demand 1980-2030. [2]

Figure 1 illustrates the amount of fiber demand between the years 1980 to 2030. It depicts that the demand of fiber has been rising sharply. Figure 1 shows that the demand will grow 20 million tons by 2030. The use of polyester garments has increased from 5 million tons in 1980 to 50 millions tons in 2017, which is ten times more. The consumption of MMF (man made fiber) is higher than that of natural fibers. Most of the countries are consuming two times more MMF than the cotton and wool. The consumption of MMF products is responsible for increasing the microfiber pollution.

Figure 2 Global Final Consumer Demand (Kg/Capita). [2]

Figure 2 above shows the global final consumer demand of in kg per capita in various parts of the world. The chart shows that not only the developing countries but also the developed countries are using smaller amounts of natural fibers

3.1 Microfiber

Microfiber is a synthetic artificial fiber and is not a naturally occurring material. Microfiber is a polyester and nylon that is used to make fabric. Since past decades, everybody has been using garments, which are made from polyester microfibers. Garments from underwear to fancy outer clothes, all are made from this synthetic fibers polyester.

Some companies reuse plastic bottles to make fancy polyester garments. These types of garments look so attractive and are mostly used by all. But most of the people do not know the negative impact of the use of these garments to the environment, lifecycle of the aquatic creatures or whole ecosystem. [3]

The actual problem is observed when the synthetic garments are washed in the washing machine. Modern research has found that every time the synthetic

fabrics are washed, the very tiny particles of plastics are released which is known as microfiber.

This microfibers are washed off up to 2 gram per wash and flowed down through the drain to the local sewage treatment plant. These fibers are so tiny that water treatment plants do not catch them all so they easily move through WWTP and more than 15% mix up in the lakes oceans. The microfibers have static electric charge making it attract other pollutants such as chemicals and oil and act as poisonous substances. [4]

3.1.1 Sources

The unwanted bottles are recycled to make the polyester and other synthetic fabrics and turned into the various stylish garments. So textile industry is one of the main sources of microfibers. From outerwear to inner wear like fleece jacket, yoga pants, shorts, underwear made from synthetic fabric are the major sources of microfiber.

In the process of manufacturing various synthetic garments tiny particles are flown in abundance and reach into the ocean through drainage and other water channels. Daily human activities like washing these synthetic clothes contribute to the release of microfiber in abundance. [5]

3.1.2 Processing

Microfibers are not the product of any textile industry It is the outcome of the various synthetic polymers and artificial synthetic fabric. When these synthetic fabric products are washed and recycled using different chemicals huge amount of microfiber are released. The microfiber can be found in polyester, nylon, rayon and acrylic. Figure 3 demonstrates how the synthetic fabrics are produced and further reveals the truth about the production of microfiber. [6]

The melt spinning process is a useful process to make a synthetic fabric. Billions of used plastic bottles are recycled through this process starting with the shredding process. Lids and stickers are removed and only the fine shredded plastics are heated up to 270 degrees Celsius and melted.

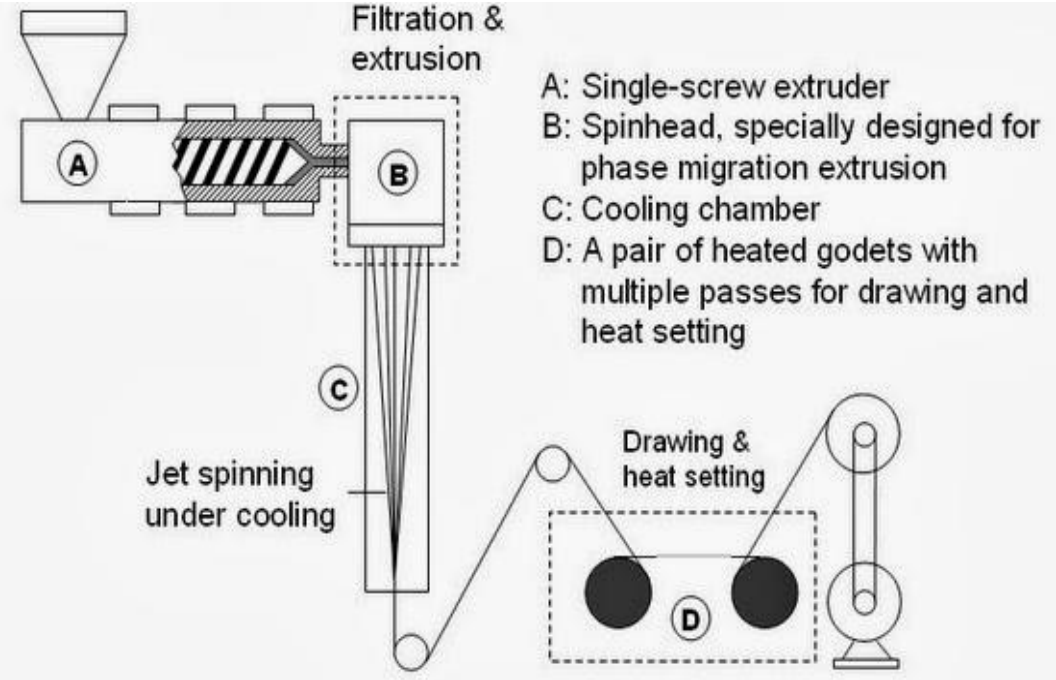

Figure 3: Principle of Melt Spinning. [7]

Figure 3 shows the principle of melt spinning. In this process the liquid plastic is forced through a sieve and emerges as a long thread. The collected threads are not thin enough to make garments. It is stretched several times while being heated. This will bond the fibers together so that they can later be made synthetic fabrics. [3,7]

3.1.3 Quantitative Extract

It is found that single synthetic fleece jacket releases 250,000 microfibers when washed. The old jackets release more microfibers than that of new jacket due to the weakening of the fibers. It is also found that if 100,000 fleece jackets are washed then an average 30kg of microfibers are released and later found in the water across the globe. The microfibers are released 5 times more when the

fleece jacket is washed in the top load washing machine than in the front load machine. The aging of the fleece jackets acts accordingly in the washing machine. Again garments of higher quality and durability shed less in the wash than low quality synthetic products. [8]

Higher percentage of fibers is found to be inside the fish and shellfish. It's already estimated that there are 1.4 million trillion microfibers in the ocean, which is about 200 million microfibers for every person on the planet. [9]

3.1.4 Application

Microfiber is polluting the ecosystem of aquatic environment and then it has an impact on nature's ecosystem; yet, there are some positive aspects of using it. Microfiber containing garments are cheap, wrinkle-resistant and durable. It has been found as a more effective fabric in most areas because of its unique features and qualities. Garments made from microfiber dry quickly after being washed and retain their shape. Microfiber fabric is also used for cleaning purposes.

The size of the microfiber is almost 1/200th of the human hair. There are so many fibers and pockets in the microfiber towel. Because the microfiber is so fine that it mechanically collects 99% of the impurities on the surfaces that we are cleaning including mild fungus, bacteria and all sorts of microorganisms that we cannot see. And what is great about the microfiber is that it collects impurities and holds them in the cloth itself and it will not cross contaminate. These types of microfiber clothes are very essential while moping in hospitals for proper disinfection. [10,11]

And the next important advantage of microfiber is that it has silver in it and the silver gives it anti-bacterial properties. Some microfiber providers will coat their fibers in silver. Silver cannot wear off nor is it a thread that can be pulled out. We do not have to worry about it reaching into our water system when we do laundry. The silver in the cloth inhibits the process of the bacteria so they cannot reproduce, grow and make a stinky smell. The silver acts as the birth control pill for the bacteria. [10,12]

3.2 Microfiber Pollution in Ocean

The studies indicate that the fibers in our clothes could be poisoning our waterways and food chain on a massive scale. Microfibers-tiny threads shed from garments and textile industry's production processes have been found in abundance on shorelines where wastewater is released. [13]

The clothes in our closet may contribute to pollution in the ocean. Mostly the ocean pollution comes from human activities. It is found that fibers like those in synthetic clothing are contaminating aquatic life. The shreds of plastics are shed while washing for example, synthetic clothes, and fleece jackets released to the ocean. Most of the washing machines do not have filters that trap lint so the fibers are passed easily through the washing machine to the ocean via wastewater treatment plant. Synthetic microfibers are harmful as they are likely to poison the food chain. Fish and other marine creatures can easily consume the fiber due to it's tiny size. Larger animals can also be affected by the fibers as they can bio-accumulate toxins in their bodies. [4,5]

Figure 4: Fibers Captured on a 20-Micron Filter. [4]

Figure 4 is an image of microfiber that was taken by the team of Bren School of Environmental Science and Management at University of California Santa Barbara (UCSB) during their project. The fibers were collected by filtering washing machine effluent after washing a Patagonia jacket.

3.3 Impact on Living Beings

The quantity of microfibers in the planet is uncountable. The trend is increasing so that the oceans will be covered with the lump layer of microfibers that can be clearly seen. Microfiber is not a natural disaster. It is an artificial disaster causing pollution that harms the living beings as well as the environment.

3.3.1 Aquatic Creatures

The microfibers that are released during the laundry are finally turned up in the water bodies like lakes, oceans across the globe. The microfibers are so small that the underwater creatures can ingest easily without any difficulty. Those particles are deposited in the intestine of the creatures. The fish, shellfish even large water animals unknowingly are ingesting the microfiber. [14]

3.3.2 Predators

Most of the time we humans are not eating the intestine part so direct ingestion with fish is not a serious concern. But with shellfish the situation is different. Microfibers are actually embedded in the tissue and that is the part that we eat. In addition to as humans, large water predators that eat smaller fish are ingesting microfiber indirectly as well. Similarly, some birds are that are dependent on small fishes are also indirectly victimized. [14,21]

3.4 Sustainable Solution Alternatives

Every aspect has positive and negative effects. The negative effects can also be minimized if taken in consideration. This thesis provides some knowledge regarding minimising microfiber pollution. A new invention that captures the microfiber during wash is also mentioned in subsection 3.4.3.

3.4.1 Use of Natural Fabrics

To reduce the amount of microfiber and to save the ecosystem, we have to use the natural fibers, which are eco-friendly, biodegradable. Some examples are cotton, hemp, wool and linen.
Cotton is probably the most common fabric and it's a natural fiber, which comes from the cotton plant. Natural fibers are soft in nature. They are machine washable and absorbent.

Natural fibers can be good for sensitive skin. Some natural fibers are breathable, meaning that air can move through it and moisture can evaporate through it. The natural fibers are also good in a sense that they need little pesticide and water to grow. [15]

3.4.2 Better Control

The one and only ultimate solution for the microfiber issue may be the ‘’no use of synthetic garments’’. But it is not possible at all. The Patagonia Inc. is looking for a new fabric that sheds less microfibers. It also suggests customers to buy clothes that are really needed and wash them less. Until the new fabric is discovered, there should be less production of these garments. [15]

Microfiber clothes should be washed with liquid laundry detergent only at a low temperature, as powder detergent at a high temperature tends to release more microfibers. [16]

3.4.3 Cora Ball and GUPPY Friend

Cora ball is a newly designed microfiber catching laundry ball. It was designed by a group of scientist who were working with Rozalia Project for a Clean Ocean. It is a round ball, which has tiny gaps similar to those in a hair comb and which is capable of catching the microfiber thread during the laundry. [17]

Figure 5: Cora Ball. [17]

Figure 5 is an image of the Cora ball that is kept in the washing machine to show how it is used. The Cora Ball can work in all types of washing machines. It is easy to use. There is no need to install anything before it is used. The Cora ball is kept in the washing machine along with the washable clothes. It has no negative effects and is environmentally friendly. [17]

Figure 6: Lints Captured by Cora Ball. [17]

Figure 6 shows the lints that are captured by the Cora ball during the wash. The Cora ball can be used again after removing the lint that has been captured. It contributes to making the ocean a little cleaner. [18]. It is not possible to capture 100% of the released microfiber thread as some of them escape through the effluent water.

There is another device, which helps to reduce the release of microfiber in the ocean. It is called GUPPY friend GUPPY Friend is a washing bag, which is made of a specially designed micro filter material. It captures the microfiber that can be seen after each wash. [18]

Figure 7: GUPPY Friend. [18]

Figure 7 indicates the GUPPY friend in which the washable clothes are kept and washed in the washing machine. The residues of microfiber are collected inside the bag. The residues that are collected inside the bag can easily be disposed of after the wash. [18,19]

Figure 8: Ecosystem With and Without GUPPY Friend. [20]

Figure 8 shows the pros and cons to the marine creatures when the GUPPY friend is used. It depicts the actual condition of the marine creatures when a preservative median is not used. The marine creatures are to some extent safer as a result of using GUPPY friend, which captures all the microfiber particles released from the garments. The microfibers are collected inside the bag and can be disposed of. [20]

3.4.4 Consumer Awareness

High quality durable garments liable to shed less lint waste than low quality garments. Washing machine with new technology to absorb or collect the tiny fibers at the initial level is preferred. Outer clothes should be washed only if they are really dirty. Small stains can be removed manually.

Awareness reduces microfiber pollution to some extend if everyone starts to use garments made up of natural fabrics. It is necessary to understand that natural fabrics are eco-friendly and leaves less negative impacts than the MMF in the environment.

4 Methodology

4.1 Experimental Design

The experiment was completed using the vacuum filtration. The apparatus was built with the help of filtering funnel, filters, filtering base, clamp, filtering flask and vacuum as shown in Figure 9.

Figure 9: Apparatus Required for Experiment.

Figure 10: Experimental Design.

Figure 10 was taken during the filtration of sample water from washing the old jacket in the laboratory. There were two such setups built for the new and the old jacket.

While setting up the experimental design, the filter base was placed over the filtering flask and made sure that it was secured. Then the filter was placed onto the filter base. The filter needed to cover the white area of the filter base. After that, the filtering funnel was placed on the top of the filtering base (with filter). Once everything was in position, the frame funnel was secured by using the clamp. After assembling the apparatus, the vacuum was taken into account. The tubing was attached with the filter base as shown in Figure 11 and was turned on the water tap. Then finally the sample water was poured through he funnel. The stirrer was used to stir the sample in the funnel that helped in the filtering process

4.2 Sample Collection

The sample of water containing microfiber was collected by washing two 100% polyester jackets, new and old, in a similar washing machine from the home laundry. The new and old jackets were washed separately to compare the microfiber release. The washing machine was run empty before washing the jackets so that to remove the lint from the previous wash.
The amount of effluent water discharged was recorded and the samples were collected at three different times for both jackets keeping the same temperature that is shown in the Table 1 and Table 2.

Table 1: Sample Collection When Washing the Old Jacket (100% Polyester).

Temp (°C)	40	40	40
Time (min)	14	22	30
Volume (L)	1	1	1

It was found that the washing machine took 39 minutes for a single complete wash for the old jacket. The washing machine released around 22 liters of water

during a wash, but the sample was tested only 3 liters after a well mixing. The sample was collected whenever the washing machine released the effluent water.

Table 2: Sample Collection When Washing the New Jacket (100% Polyester).

Temp (°C)	40	40	40
Time (min)	16	26	37
Volume (L)	1	1	1

Similarly, for the new jacket, it was found that the machine took 36 minutes to complete a wash with almost same amount of water, but the sample was tested 3 liters after a good mixing, which is shown in Table 2.

4.3 Method of Analysis

After setting up the laboratory design, the sample water was poured into the funnel. The filtration was carried 6 times (3 times for old jacket and 3 times for new jacket).

After filtering, the residues can be seen in the filter.

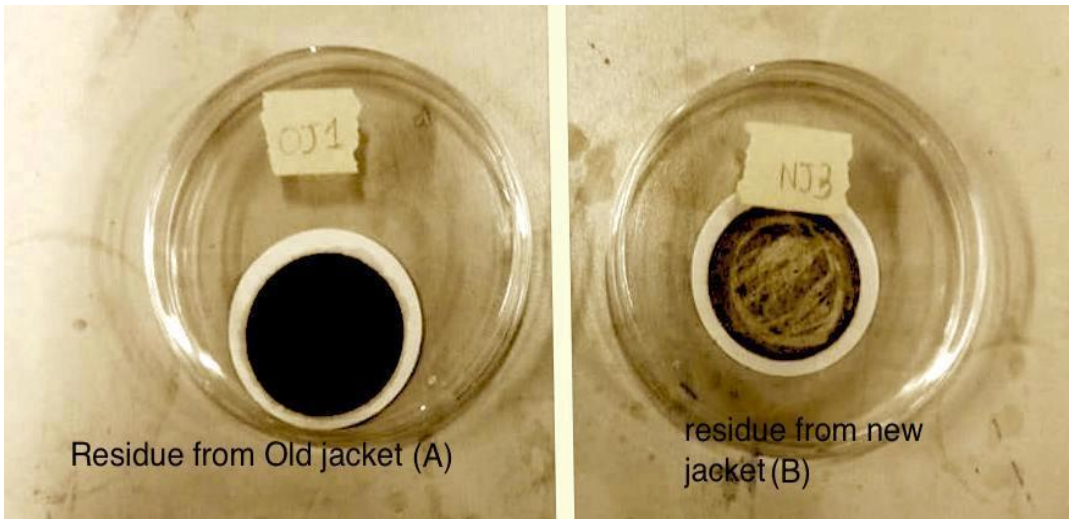

Figure 11: Residue Collected From the Old Jacket (A) and New Jacket (B) After Filtration in the Laboratory.

Figure 11 shows the residue that is collected after the filtration process in the laboratory. A is the residue collected from the old jacket wash and B is the residue collected from the new jacket wash during the filtration process.

The filter papers were kept in petri dishes for drying. The residue is further used in finding the characteristics of the microfiber by observing under the camera fitted microscope.

Six different filter papers of size 0.45 µm were used. The weight of the filter paper was weighed and it was 82.7 milligram (mg) and thus we were able to weigh the mass of microfiber for individual phase using the following concept.

$$M = Wfp\_m - Wfp \qquad \textit{(Equation 1)}$$

Where as,

Weight of microfiber (*M*)
Weight of Filter paper with microfiber (*Wfp_m*)
Weight of filter paper (*Wfp*)

The experiment was repeated 3x2 times. Then M_1, M_2 and M_3 were calculated for both new and old jacket. The total weight of microfiber (M_t) of 3x2 different samples was calculated as follows:

$$M_t = M_1 + M_2 + M_3 \qquad \textit{(Equation 2)}$$

To quantify the number of microfibers, the average of single thread of microfiber was determined by the special kind of weighing machine. If m is the average weigh of single microfiber. The number of microfibers can be determined using the following equation.

$$\textbf{Number of Microfiber } (N) = \frac{\textbf{Total weight of Microfiber } (Mt)}{\textbf{Weight of single thread } (m)} \qquad \textit{(Equation 3)}$$

4.4 Comparison

The residues collected from the laboratory experiment for both new and old jackets are now compared according to their mass. Three samples from old and new jacket are weighed separately as shown in Equation (1) and then added as shown in Equation (2). The main idea of this experiment is to determine the jacket type that releases more microfiber.

The weight of microfiber in each sample and the total weight of microfiber were calculated as follows:

Old jacket

Sample 1: M_1 = 249.2 mg – 82.7 mg = 166.5 mg
Sample 2: M_2 = 221.6 mg – 82.7 mg = 138.9 mg
Sample 3: M_3 = 210.6 mg – 82.7 mg = 127.9 mg (Equation (1))

$$M_t = M_1 + M_2 + M_3 = 433.3\ mg \quad \text{(Equation (2))}$$

New jacket

Sample 1: M_1 = 202.9 mg – 82.7 mg = 120.2 mg
Sample 2: M_2 = 167.8 mg – 82.7 mg = 85.1 mg
Sample 3: M_3 = 149.2 mg – 82.7 mg = 66.5 mg (Equation (1))

$$M_t = M_1 + M_2 + M_3 = 271.8\ mg \quad \text{(Equation (2))}$$

The experiment shows that the old jacket shed more microfiber than the new jacket.

The residues were then viewed under the camera fitted microscope. The image that was captured is shown in Figure 12.

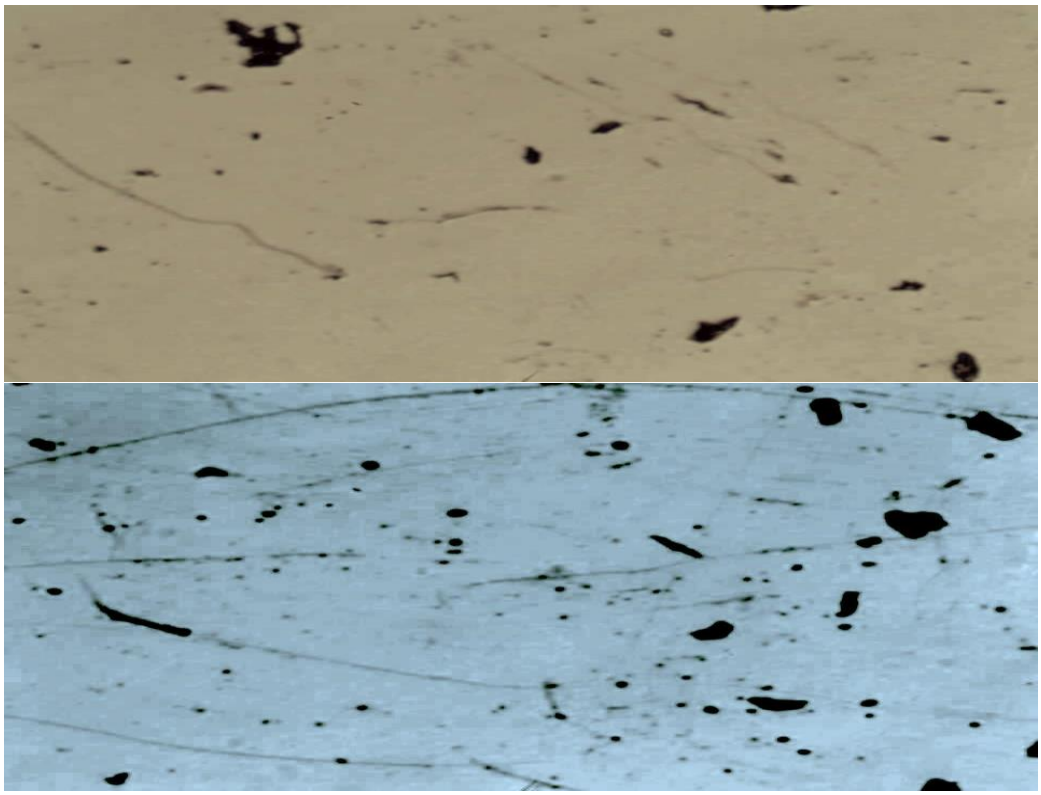

Figure 12: Microfibers Observed Form the Experiment Under a Microscope, Olympus PME3.

Figure 12 is the image of microfiber that is collected and viewed under the microscope in the laboratory. Some portion of the residue from Figure 11 was collected in new filter membrane and was viewed. The length of the microfibers varies, as they do not break in an equal size. Some microfibers were long, thick and some were very small.

5 Results

On the basis of wash experiment, it can be concluded that the older the synthetic jacket, the more microfiber is released compared to the microfiber release of the new jacket. It shows that the first effluent has the higher amount of microfiber mass than the second one; the second wash releases more than the third one and so on. While calculating, it was found that around 225000 microfibers are released in a single wash. According to the experiment, the aged jacket releases 1.6 times more than the new synthetic jacket.

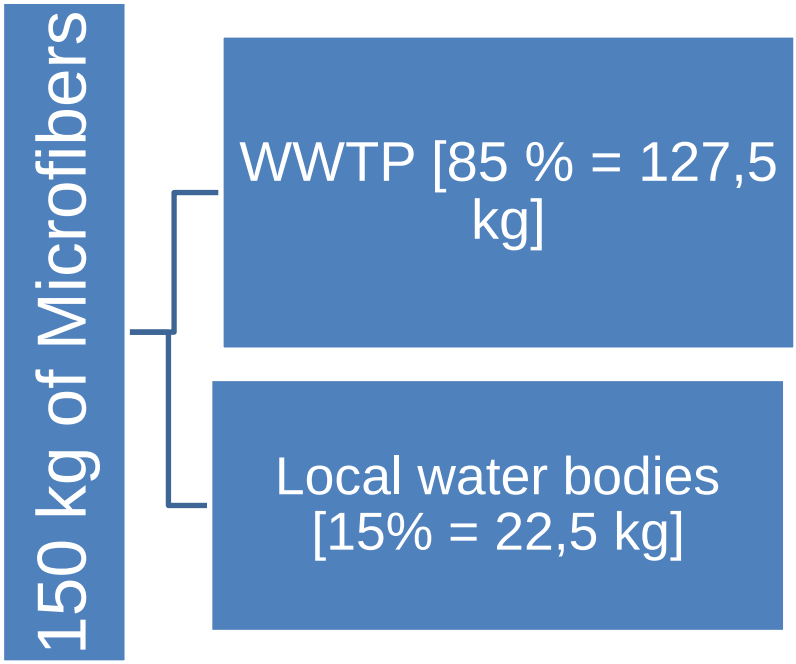

Figure 13: Distribution of Microfibers.

Figure 13 illustrates the amount of microfiber collected when 100000 synthetic jackets are washed. The laboratory experiment showed that the total weigh of the microfiber (average old and new garment) was 1.5 gram. This means that if 100000 synthetic jackets are washed, 150 kg of microfiber is collected.

As reported in the literature review, 15% of the microfiber is released to local water bodies after washing. The amount of microfiber release in the ocean will be 22.5 kg, which is equivalent to 4090 plastic grocery bags. In this experiment, it was found that the smaller microfibers are probably the ones that pass through the waste water treatment plant (WWTP).

6 Discussion

The thesis suggests that the old synthetic garments are the major sources of the microfiber. Worldwide consumption of synthetic fiber, highly consumed polyester fiber in different countries and the increasing demand for it year after year created a microfiber pollution problem, which will worsen in the coming years unless it is checked. So let's think its already estimated 1.4 million trillion microfiber in the ocean, if the man made fibers (MMF) increases by around 20 million tons till 2030, how much pollution will there be in the oceans? It is really an important issue in order to make this earth a safe place. The local government has to respond to the significant ecological and ecological impacts with innovative policies. Otherwise, it results in billions of dollar of damage and cost to fishing tourism and other shipping industries

7 Conclusion

The results of the wash experiment show that aged jackets shed a higher amount of microfiber than the new jacket. The reason behind it is the weakening of the fiber due to multiple wear. The thesis shows how the waste bottles are reused and can be converted into other useful forms, synthetic garments, but it also teaches how the environment, marine environment is affected by microfiber. Every year the trend is increasing. This pollution does not stop until the alternatives are taken into account.

If we study the advantages and disadvantages of microfiber, we need to take measures to achieve the following:
(1) Microfiber particles are checked and controlled to the maximum at the source level with innovative devices.
(2) Recycling and reuse methodology.
(3) Cheap and better alternatives are developed against man-made cloth and the high quality production of such clothes and demand increases.
(4) People's awareness increases and
(5) government policies regarding microfiber is tightened.
However, there is some hope as different countries come forward to discuss such problems through international forums and analyze the ways to resolve it.

We cannot expect a total solution of ocean pollution in the context of microfiber, but it can be minimized.

New research has to focus on lessening the impact of different pollution from the world. Governments should formulate policies, rules and regulations to promote environmental protection to make the earth better to live in.

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Appendix 1. Collecting Sample From the Laundry.

Figure 14: Collecting Sample From the Laundry.