Identification And Characterisation Of Microplastic Along The South Goa Coast, Goa, India

A Dissertation Report for

GEO 651 Dissertation

Credits: 16

Submitted in partial fulfilment of Master's Degree

MSc in Applied Geology

by

DIVYA DAMODAR FULARI

22P0450004

116766536616

201900885

Under the Supervision of

DR. NIYATI KALANGUTKAR

School of Earth, Ocean and Atmospheric Sciences

Applied Geology

GOA UNIVERSITY

April 2024

SEOAS, GOA UNIVERSITY
TALEIGAO PLATEAU GOA

Seal of school

Examined by:

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Identification and Characterisation of Microplastic along the South Goa coast, Goa, India" is based on the results of investigations carried out by me in the Applied Geology at the school of Earth, Ocean and Atmospheric Sciences, Goa University under the Supervision of Dr. Niyati Kalangutkar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed.

Divya D Fulari
22P0450004
Applied Geology
School of Earth, Ocean and Atmospheric Sciences

Date: 02/05/2024
Place: Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation report "Identification and Characterisation of Microplastic along the South Goa coast, Goa, India" is a bonafide work carried out by Ms. Divya Damodar Fulari under my supervision in partial fulfillment of the requirements for the award of the degree of Master of Science in the Discipline Applied Geology at the School of earth, ocean and Atmospheric Sciences, Goa University.

Kalangutkar 2/5/2024

Dr. Niyati Kalangutkar
Assistant Professor
Applied Geology

Date:

SEOAS, GOA UNIVERSITY
TALEIGAO PLATEAU GOA

School Stamp

Ghadi 3/5/24

Senior Professor Sanjeev C. Ghadi
Dean
School of Earth, Ocean & Atmospheric Sciences
Date:
Place: Goa University

Identification And Characterisation Of Microplastic Along The South Goa Coast, Goa, India

A Dissertation Report for

GEO-651 Dissertation

Credits: 16

Submitted in partial fulfilment of Master's Degree

MSc in Applied Geology

by

DIVYA DAMODAR FULARI

22P0450004

116766536616

201900885

Under the Supervision of

DR. NIYATI KALANGUTKAR

School of Earth, Ocean and Atmospheric Sciences

Applied Geology

GOA UNIVERSITY

April 2024

Examined by: Seal of school

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Identification and Characterisation of Microplastic along the South Goa coast, Goa, India'' is based on the results of investigations carried out by me in the Applied Geology at the school of Earth, Ocean and Atmospheric Sciences, Goa University under the Supervision of Dr. Niyati Kalangutkar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed.

Divya D Fulari
22P0450004
Applied Geology
School of Earth, Ocean and Atmospheric Sciences

Date:

Place: Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation report "Identification and Characterisation of Microplastic along the South Goa coast, Goa, India" is a bonafide work carried out by Ms. Divya Damodar Fulari under my supervision in partial fulfillment of the requirements for the award of the degree of Master of Science in the Discipline Applied Geology at the School of earth, ocean and Atmospheric Sciences, Goa University.

Dr. Niyati Kalangutkar
Assistant Professor
Applied Geology

Date:

Senior Professor Sanjeev C. Ghadi
Dean
School of Earth, Ocean & Atmospheric Sciences
Date:
Place: Goa University

School Stamp

ACKNOWLEDGEMENT

I humbly offer my gratitude on successful accomplishment of my work to all those who have contributed and helped this project.

Firstly, I would like to offer my sincere gratitude to my supervisor, Dr. Niyati Kalangutkar, Assistant Professor of Applied Geology, for her valuable guidance and unwavering support throughout this research journey. Her feedbacks and expertise has helped me push my boundaries and achieve my goal.

I would like to thank professor Shritesh Mhapsekar for being a mentor and helping us in the laboratory and providing instrument knowledge. He has shown his valuable support throughout this project.

I am grateful to our lab attendant Mr. Rajesh, for providing their assistance and helping out with the equipment and chemicals used in this study.

Special mention to Sahina Gazi, Scientific assistant and Sati Chauhan, lab assistant at NCPOR, Goa for helping me with SEM instrumentation in order to complete an objective of my dissertation.

I would like to acknowledge all my friends Veena Naik, Dixita Vengurlekar, Aaron Pereira, Mohammad Kaif, who generously shared their insights, and experiences which helped me with my work. Special thanks to Rudresh Kanekar and Sarthak Fulari who helped in throughout my sampling and thereafter. Without them this project would not have been successful.

I am deeply indebted to my parents and family for being my greatest strength. Their patience, support and belief in my abilities that sustained me during challenging times. Their presence has been invaluable.

Lastly , I would like to offer my thankfulness to God, the almighty for giving me the strength and blessings to Fight against the odds. I acknowledge God's role in my success, for it is through his blessings that I have found unwavering determination to complete this work. I am also grateful to myself for not giving up and acknowledging my own limitations and boundaries.

INDEX

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Plastic has known to become an essential material in people's lives and is used in almost all sectors namely packaging, construction, auto motive, medicine, agriculture, etc. In the 1940s and 1950s the production of plastic materials started flourishing on an industrial scale. It has emerged as an international challenge since the extent of pollution caused by plastic litter is not limited to land ecosystem. The most common way of disposing plastic after its use is in the domain of marine environment and its dispose at the landfills. The increase in use of plastic worldwide is due to its mass production of lightweight , resistant, durable, inert and non-corrosive nature of plastic but this has in turn increased the environmental concern. In India, every year, around 9.46 million tons of plastic waste is produced and only 30% is recycled every year The impact of plastic waste can be seen on at least 367 species worldwide, 86% of sea turtles, 44% of seabird species, and 43% of marine mammal species. These plastic wastes are more commonly found as litter on the shores of urban areas compared to rural areas (Jayasiri et al., 2013). Along with macro plastic, hazard issues are also raised by small plastic fragments, fibres and granules, collectively termed as microplastics.

Microplastic is a term recently coined to attributed to the size range of <5mm. Plastic that is purposefully manufactured as microscopic is called as Primary microplastic. It is manufactured primarily to be used in cosmetics as microbeads, for use in air blasting technology, use in medicine as vectors for drugs is increasingly reported (Patel et al., 2009). Secondary microplastics are described tiny plastic fragments derived from the breakdown of larger plastic debris, both at sea and on land (Ryan et al., 2009; Thompson et al., 2004). This degradation can take place due to prolonged exposure to sunlight, oxidative damage and weathering secondary microplastic. Various sources of microplastic are present, it can come from the fragmentation of plastic waste in the environment, as well as from the abrasion of plastic particles in paints, coatings, and personal care products. Microplastics are naturally inert but can serve as a suitable site for hosting trace metals that are reactive.

Large plastic debris hosted onto the beaches, tends to have an exposure to direct sunlight and have high oxygen availability hence it will degrade rapidly, in time turning brittle, forming cracks and "yellowing" (Andrady, 2011; Barnes et al., 2009; Moore, 2008). When it comes to the distribution of microplastics, it has been observed that Asia, Africa, and Europe have relatively higher levels compared to other continents. The microplastic further disintegrate into nano plastic. The most common ways by which these microplastic accumulate in the ocean is through Coastal tourism, recreational and commercial fishing, marine vessels and marine-industries, human interaction.

Microplastics are a growing threat for marine biota and ecosystem. Accumulated microplastics certainly leads to a wide range of adverse effects directly on organisms that tends to ingest them. These effects include both internal and external injuries, blockages in the gut tract leading to a physiological stress, alterations in feeding behaviour, growth retardation, reduced fertility, fecundity, and diminished survival rates of offspring (Cole et al., 2015; Nelms et al., 2015; Ogonowski, et al., 2016; Sussarellu et al., 2016; Welden et al., 2016; Wright et al., 2013) . According to a study, for human intake on consumption of shellfishes in Europe, countries with high shellfish consumption generally ingest up to 11,000 microplastic particles (size range 5–1000 μm) per year whereas, consumers ingest an average of 1800 microplastics per year in countries with low shellfish consumption (Cauwenberghe and Janssen, 2014). Studies indicate that in humans, oxidative damage, DNA alterations, and gene activity changes -known risk factors for cancer development can be caused by microplastics. According to Zhang et al., ingestion of particles depend on the size and colour of particles since crabs are visual predators. Apart from the gut, researchers found exposure of microplastics in the gills of crustaceans. According to Jeong et al., some of the effects of microplastics on physiology of crustaceans include developmental delays, delayed moulting and reduced fertility. Negative effects on immunity of crabs, including reduction in oxygen consumption and sodium (Na+) concentration are observed as a result of chemical additives microplastic that are taken up by crustaceans. Hence the consumption of these species readily can lead to various ill effects on wellbeing of humans.

The effects and scale of this pollution can also be better understood from The Great Pacific Garbage Patch, also known as the North Pacific Subtropical Gyre which is a vast marine region characterized by a high concentration of plastic debris. This gyre, formed by ocean currents and the earth's rotation, encompasses two main areas: the Western and Eastern Garbage Patches. The structure of the gyre tends to facilitate the accumulation of floating plastic waste, creating an environmental challenge.

Recent studies have highlighted the spatial heterogeneity of plastic pollution within the gyre, revealing a complex distribution pattern that varies over multiple spatial scales. The majority of the debris consists of microplastics, with concentrations being particularly high in areas of low wind and calm sea conditions. These microplastics pose a threat to marine life and ecosystems due to their persistence and potential for bioaccumulation.

The Indian coast tends to have a higher presence of plastic litter from the fishing industry on its beaches. According to estimates, around 80% of the plastic debris found in the ocean comes from land. Additionally, about 21 to 42% of the world's plastic waste is stored in landfills (Gregory, 2009). In a study by Veerasingam et al. in 2016, unintentional spillage from ships releases around 3000 different micro pellets in the northern and southern coasts of Goa. Additionally, Eriksen et al. found that during the rainy season, wind and ocean currents transport micro debris from the north to the south coast of the Bay of Bengal in India.

Along with ocean current transport it is also found that the play a crucial role in the determining the distribution of floating debris in different areas as indicated by many researchers (Browne et al., 2010; Thiel et al., 2013; Kukulka et al., 2012; Sadri and Thompson, 10 2014; Liubartseva et al., 2016). In case of Goa, the winds are predominantly from north - northeast direction during the NE monsoon, and between southwest and west during SW monsoon. Hence the fate of microplastic in marine is decided based on various factors.

OBJECTIVES

- Identification and characterisation of microplastics found along the coastal waters of South Goa
- To evaluate the abundance and polymer composition of microplastics
- To predict the potential sources of microplastics in the region of study

CHAPTER II

LITERATURE REVIEW

The issue raising most concern over the globe is plastic pollution. It is capable of affecting the environment, marine ecosystem, terrestrial well-being, humans and animal species. Apart from the disposal of plastic being a rising issue, the consumption of plastic has also led to worsening of the effects that are caused by such large- scale problem. Dealing with plastic pollution is a challenge since their degradation tends to take endless time in the environment seriously affecting all the biotas.

Approximately 80% of global annual riverine plastic emissions into the ocean can be attributed to around 1,000 rivers. These rivers contribute between 0.8 and 2.7 million tonnes of plastic per year, with small urban rivers being among the most polluting. Since the 1970s, the rate of plastic production has outpaced that of any other material. If historical growth trends persist, it is projected that global production of primary plastic will reach 1,100 million tonnes by 2050. Furthermore, of the seven billion tonnes of plastic waste generated worldwide thus far, less than 10% has been recycled. This highlights the urgent need to address the issue of plastic waste.

On a regional scale this pollution has affected many countries some studies that draws attention include the Detection of Microplastic pollution risk in surface waters of the Changjiang Estuary which was based on risk assessment models was conducted and it showed an average microplastic concentration of 23.1 ± 18.2 n/100L. Shape, size, colour and composition types. The carrier of these plastic is the strong hydrological force of both the Changjiang Estuary and Hangzhou Bay which tends to cause high pollution in the area in the vicinity of stations. Study conducted in China by (Xu et al., 2018) suggests polymers in MP particles can also exhibit environmental risks.

PVC is considered to be the most harmful polymer in this study and once it reaches in the environment it can release carcinogenic monomers and intrinsic plasticizers.

When studies on one of the cleanest city in the world Dubai ,was conducted a by (Aslam et.al.,2019) 16 beaches in Dubai were evaluated. Blue coloured microplastics were found to dominate the extracted microplastics in terms of number of particles (items). Blue coloured MP is known to be ingested by most of the marine living beings due to its colouration as suggested in many studies. In terms of shape, fibrous microplastic is dominating in the beach sediments of Dubai.

Among the many plastic consumers in the world ,one of the major plastic consumers is India, generating around approximately 5.6 million tons of plastic waste annually. In 2021-22 India's demand for plastic reaches 20.89 million tonnes and it is projected to continue growing to 22 million tonnes by 2023. The oceans around Mumbai, Kerala, and the Andaman and Nicobar Islands are among the world's most polluted.

As per (Sruthy; Ramasamy 2016) , there are two reports on microplastics in India. One study found small plastic debris, like polyurethane and nylon, in the marine sediments of Gujarat coast. The other study assessed plastic debris on Mumbai beaches, recording a mean abundance of 7.49 grams per square meter and 68.83 items per square meter. The study reproves the relationship between salinity and abundance of microplastic, higher abundance of MPs at the marine influenced sites were attributed to the higher salinity. In this study, Low density polyethylene(LDPE) was the most abundant polymer found representing a range of 26-91% of the plastic particles.

The southern part of India is studied wherein Sathish et al. (2019) quantified the microplastics in five beach sediments of Tamil Nadu and explored the dominance of polyethylene (81%) with the maximum amount of 309±184 items kg-1 in the sample of Marina beach. Study conducted in the Marina beach. The abundance in microplastics in the coastal stretch of Marina beach is thought to be a result of the maximized urbanization of the Chennai City which is one among the major metropolitan Cities of India.

Further studies by (Karthik, Robin et al.,2018) in India revealed, that the south coastal region of India due to extensive use of beaches for multiple purpose causes higher pollution along the coastal regions of the country. The range of microplastics collected from the High tide line beach sediments (48.9 to 4747.6 mg/m2), was four times higher than those recorded from Low tide line (14.3 to 1020.4 mg/m2)

Amongst other states of India, studies conducted in Goa by (Saha, Naik et.al.,2021) showed the average numbers of MPs in the water column to be 48 ±19MP particles/L (MPs/L) in the Sal estuary Goa . Water samples showed a slight dominance of fibres (56%) (Saha, Naik et al., 2021). The indication of Sal estuary interacting with various types of pollutants is given by presence of significant number of MPs. Additionally, with water samples, sediment and fishes samples were also taken in order to determine the abundance of microplastic in all three matrices.

Goa is also studied for ecological risk of microplastic by (Ranjani, Veerasingam, S.et.al., 2021). The study suggested that Overall, PE (47.7%) and PP (18.8%) were the most abundant polymer types found in the sediment samples. MP polymers (i.e., abundance of PA) and shapes found along the southeast coast of India revealed that the sea-originated plastic debris comes from aquaculture and fisheries have become significant sources of MPs. In research by (Veerasingam, Saha.et.al.,2016) the distribution, abundance, weathering and chemical characteristics of Microplastic

Pellets on the beaches of Goa, and their transport to the coast during the southwest (SW) monsoon was studied, Maximum number of MPPs was obtained in Galgibag beach during June and Vagator beach during January and minimum on Keri beach. From various studies it can be inferred that the coastal zone acts as a hot spot for MP pollution.

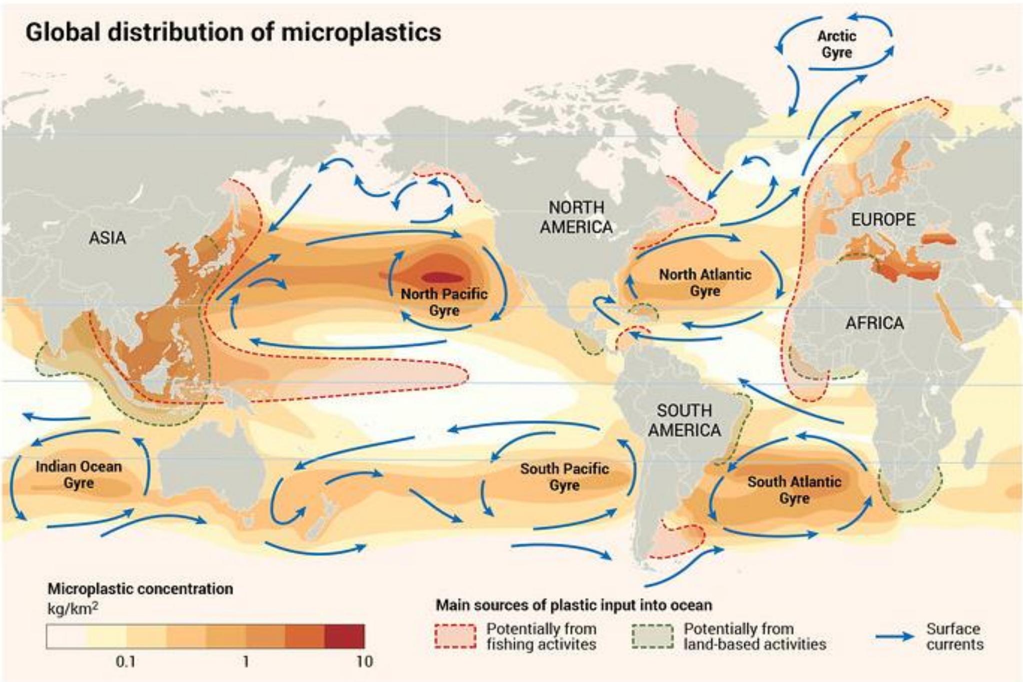


Fig 2.1: Global distribution of Microplastics

CHAPTER III

STUDY AREA

Goa is located on the southwestern part of India. Goa is visited by large numbers of international and domestic tourists each year because of its beaches, active nightlife and, cultural heritage sites. It is surrounded by the state of Maharashtra to the north, Karnataka to the east and the Arabian Sea to the west. Goa receives a rainfall of 330 centimetres annually from period of June to September. July is considered as the wettest month of the season , the sampling in the area was also done during this month. The coastline of Goa extends approximately up to 105km. This coastline can be divided into North and South Goa coastline. The south Goa hosts around 205 villages with 640537 population (according to Census 2011). The beaches along the coast of Goa hosted a total of 38,32,306 tourists until May 2023.

The study area is in the south coastal Goa including beaches of Velsao, Cansaulim, Utorda, Colva and Bogmalo. Velsao Beach lies on the southern coast of the state. This beach enjoys proximity to various other popular beaches, namely Majorda Beach and Colva Beach on its south and Bogmalo beach to its north. The coastal stretch from Velsao to Colva are interconnected covering 9 kms, Bogmalo is a small bay in the shape of a horseshoe with coastline of approximately 600 metres.

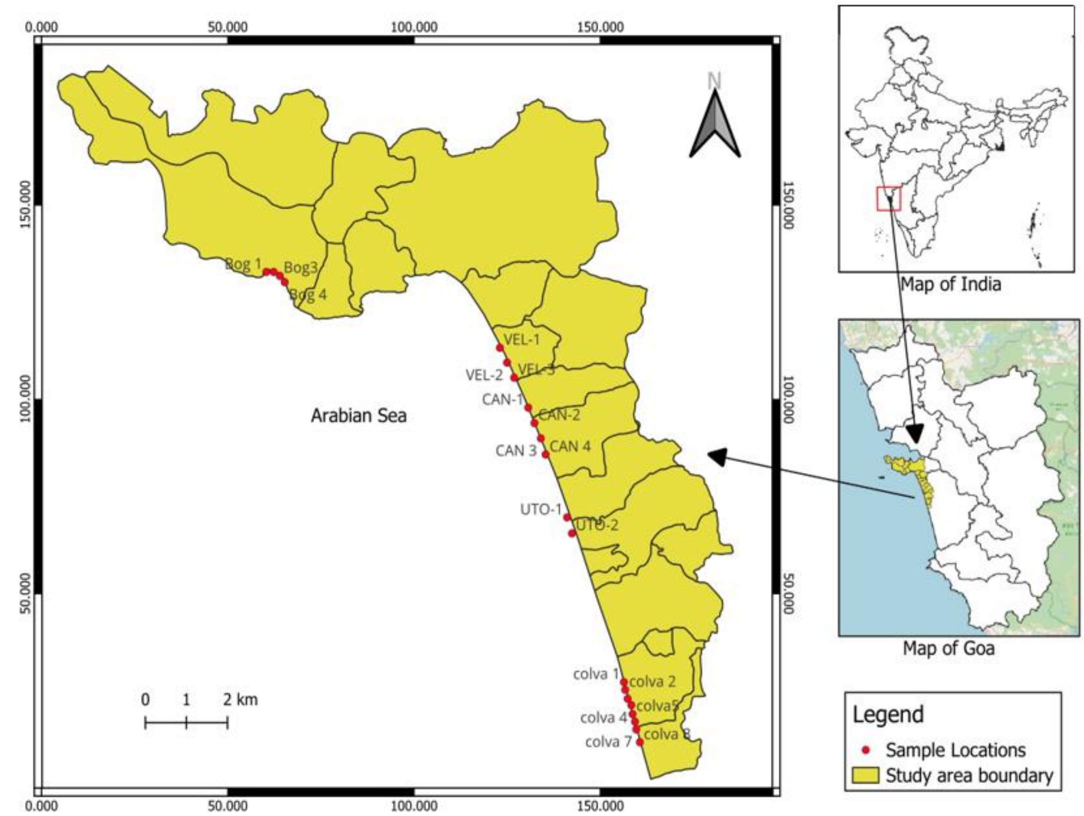


Fig 3.1: Study area map

MATERIAL AND METHODOLOGY

Sample Collection

The water samples were collected during monsoon of 2023, from 21 sampling stations in South Goa. The samples were taken at 200 metres intervals. Using a stainless-steel bucket of volume 10 Litres, 100L of water was drawn from each station, sieved through < 5mm sieve and was further transferred to collection bottles. The samples were brought back and stored in a cool place.

Sample Processing

The samples were oven dried at 50-60°C until all the water content was removed (Fig 3.9) The dried samples were then taken to the laboratory. In order to eliminate organic matter , Wet Peroxide Test (WPO) was conducted on the samples 20 mL of aqueous 0.05 M Fe(II) and 20 mL of 30% hydrogen peroxide solution was added to the beaker containing the dried samples. The mixture was the heated at around 75°C (Fig 3.10). The samples were then kept overnight for dilution of any organic matter left. Before density separation zinc chloride was added to the samples according to the volume of each sample in the beaker. The samples were transferred to the density separator, settling was allowed overnight separating floating solids from settled solids. Wet sieving was carried out and samples were transferred to the Petri dishes. The petri dishes were kept in the oven for drying at 50-55°C.

Identification

After drying the petri dishes were taken for identification. Microplastics in the samples were classified based on their shapes, compositions, colours and sizes (5-1 mm and 1-0.3 mm).The dried samples were examined under a SZ2-ILST Stereo zoom

Microscope of 8x to 40x magnification range.(Fig 3.12) The categorization was done based on the type, shape, kind and colour of microplastic observed into namely fibre, foam, film, fragment, pellet and other. To ease the process of identification and understand the scale, white lines with an interval of 5mm were drawn on a black paper. The pictures of different forms of Microplastic were taken on the Stereo zoom microscope with an attached camera lens.

FTIR ANALYSES

FTIR (Fourier Transform Infrared Spectroscopy) analysis were also carried out. It is known to find the composition of unknown samples. FTIR works when an infrared light is passed through the sample, the light eventually gets absorbed and some amount of light gets reflected. This reflected light is measured and determined by its wavelength. Each sample has a characteristic wavelength which helps in identification of the unknown material. The chemical structures of unknown polymers can mainly be recognized through their specific IR absorption frequency.

SEM ANALYSES

Scanning Electron Microscope provides information about the sample's surface topography and composition. A scanning electron Microscope operates by directing a focused beam of electrons across a sample's surface. SEM typically requires samples to be conductive. However, for non-conductive samples, there are several techniques to enable effective SEM imaging. In most cases, non-conductive samples are often coated with a thin layer of conductive material, such as gold, carbon, or platinum. . The SEM images were taken with the help of JEOL J6M-636OLA Scanning Electron Microscope at various magnifications at NCPOR Goa, India.

Fig 3.2: Material retained on 5mm sieve during sampling

Fig 3.3 : 5 mm and 0.3 mm sieves used for sampling

Fig 3.4 : Litter visible on the sampling site at Cansaulim

Fig 3.5 : Plastic on the sampling site at Velsao

Fig 3.6: Plastic sheets used as covering at Utorda

Fig 3.7: Hotel located adjacent to sampling station at Bogmalo

Fig 3.8: Image showing boats and nets used for fishing at Colva

Fig 3.9: Beakers containing samples
kept for drying at 50-55°C

Fig 3.10: Heating of sample (WPO test)

Fig 3.11: Gravity setup done for separating floating and settled solids

Fig 3.12: SZ2-ILST Stereozoom microscope

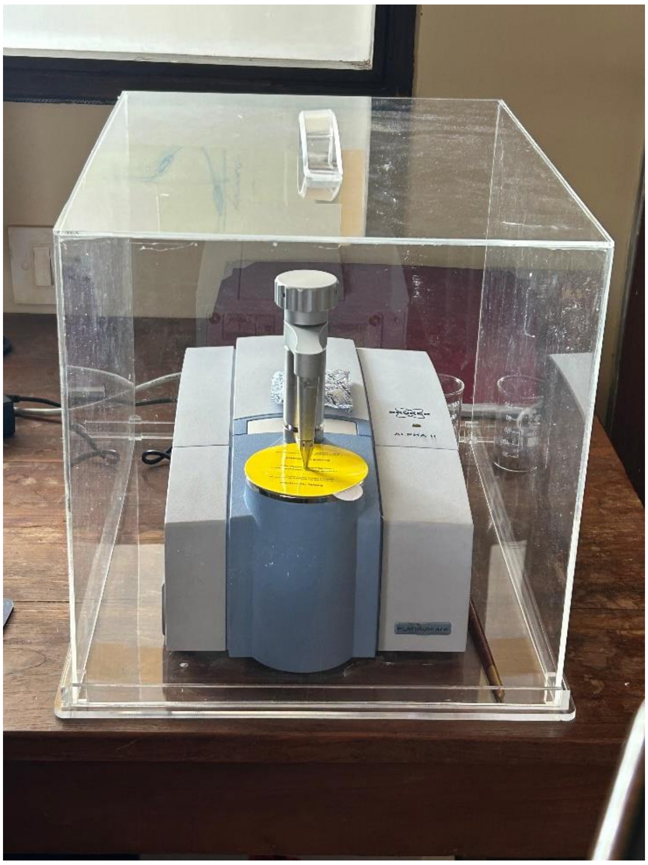


Fig 3.13: Bruker Alpha II FTIR spectrometer

Fig 3.14: JEOL-6360LA SEM at NCPOR

CHAPTER IV

RESULTS AND DISCUSSION

1) Station wise categorization of microplastic

Velsao

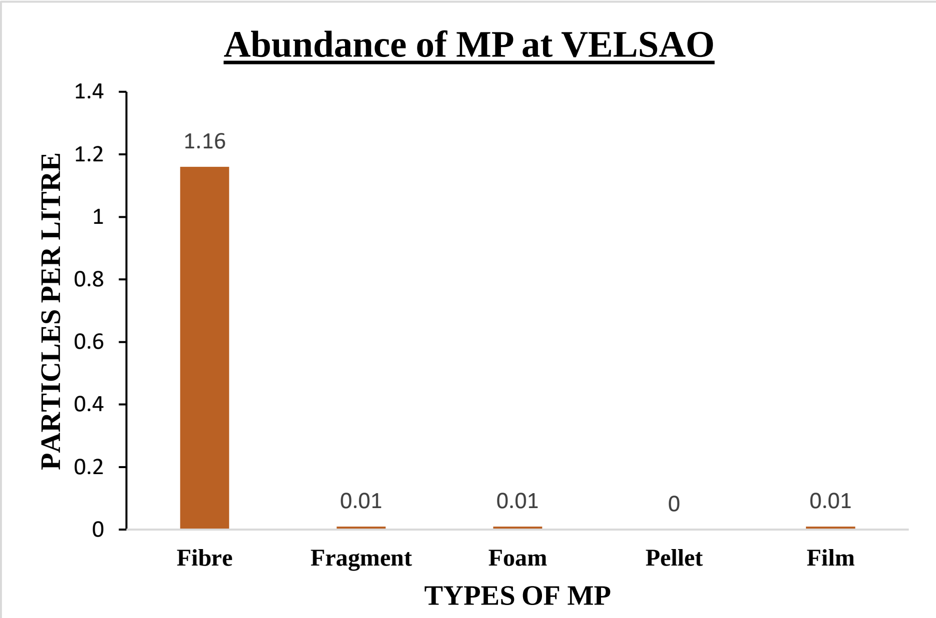


Fig 4.1: Total number of microplastic found in Velsao beach

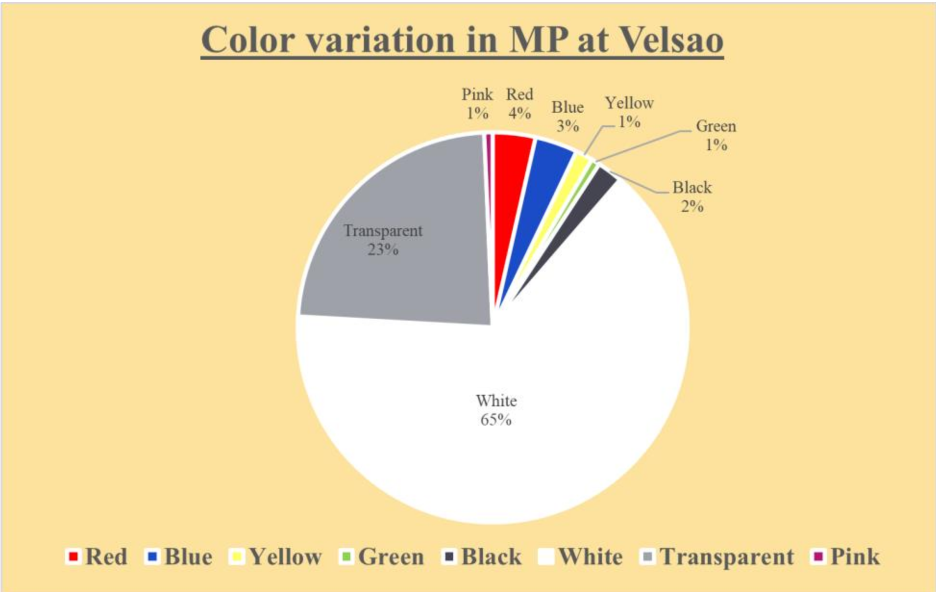


Fig 4.2: Colour variation observed in MP at Velsao

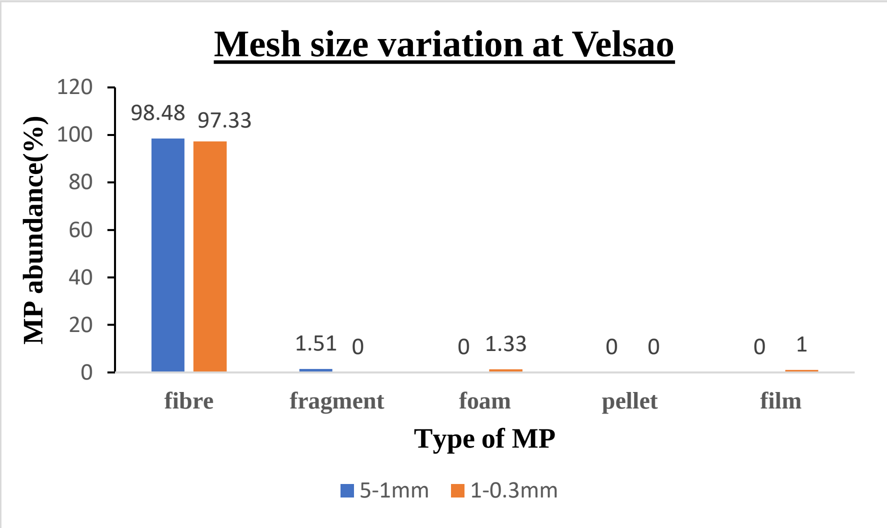


Fig 4.3: Mesh size variation in MP at Velsao

The Velsao beach in south Goa is considered as one of the pristine beaches in the area. The graph (4.1) shows microplastic abundance in the coastal waters of Velsao beach. The graph shows higher number of fibrous MPs (1.16 particles/litre) compared to other forms such as fragment, foam, film and pellet. The percentage of film, foam and fragment in the area is observed to be equal (0.01particles/litre). The possible sources for these fibres could be the settlements in and around Velsao Goa, it can also be as a result of the ongoing fishing and boating activities in the area. The litter observed on the beaches due to human interaction will also disintegrate and generate microplastic on the beaches. The pie chart Fig (4.2) shows percentage distribution of different colours of micro plastics found in water samples from Velsao beach. The highest percentage found is white microplastics. White micro plastics can be mostly derived from products that are manufactured in standard white colour without addition of colour pigments. The white colour (65%) was followed by transparent (23%), red(4%), blue(3%), black(2%), other colours such as pink, green and yellow were found in low percentage (1%) in the waters. Variation in the mesh sizes suggest that size 5-1mm recorded more MPs than the size 1-0.3mm.

Cansaulim

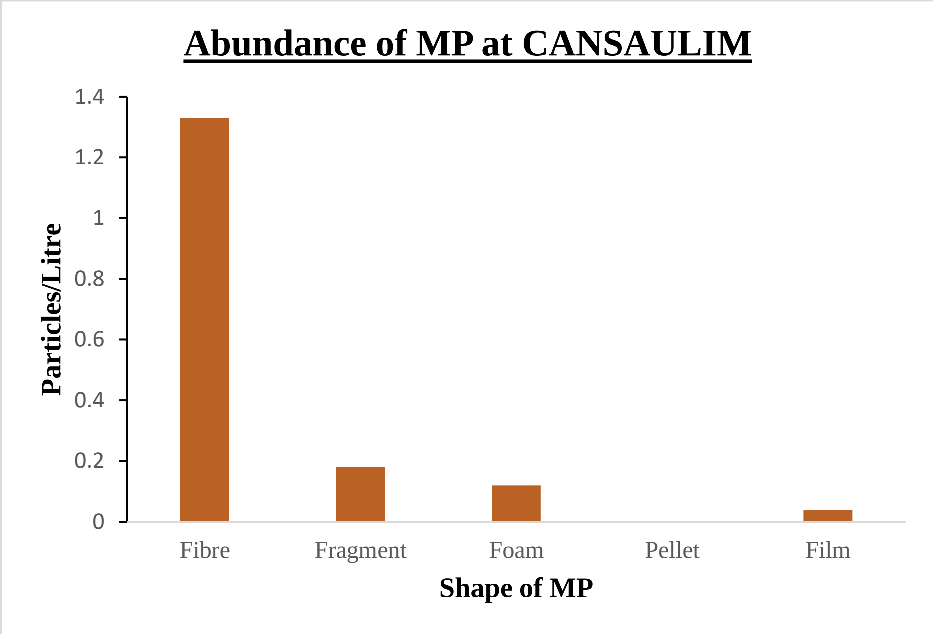


Fig 4.4: Total number of microplastic found at Cansaulim beach

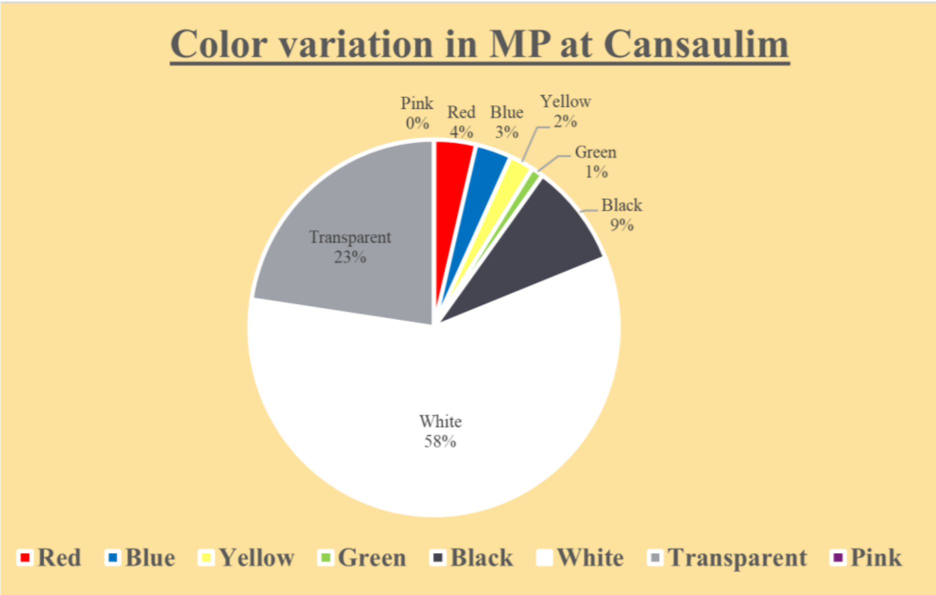


Fig 4.5: Colour variation in MP at Cansaulim

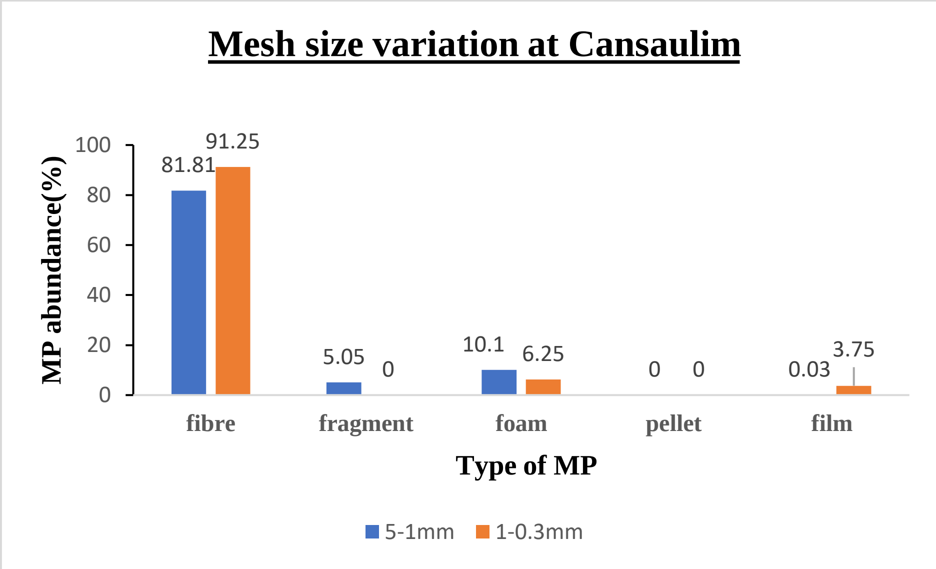


Fig 4.6: Mesh size variation in MP at Cansaulim

The graph (Fig 4.4) represents abundance of MPs in the coastal waters of Cansaulim. Fibres seem to dominate the beach waters with 1.33 particles/litre followed by fragments, foam and film. Although all types of MPs were found on this beach, the extent of contamination was less compared to other beach locations.

The sources of these MPs is the settlement around the beaches and the fishing sector. Loads of plastic waste either washed off by waves or by anthropogenic sources was seen on the beach such as bottles, rope and plastic bags as can be seen in (Fig 3.4). The results show more pollution on this beach compared to Velsao.

Colour variation in MPs can be observed using pie chart (Fig 4.5), the percentage of colour obtained suggest dominance of white MPs over others. It is followed by transparent(23%), black (9%), red(4%), blue (3%), yellow (2%) and green(1%). Colour can serve as an indicator for the use of particular MP, most packaging and manufacturing industry uses transparent or white coloured plastic products.

As observed in (Fig 4.6), fibres and films dominate the size range 1-0.3mm whereas fragment and foam found in the range of 5-1mm are more compared to 1-0.3mm mesh size.

Bogmalo

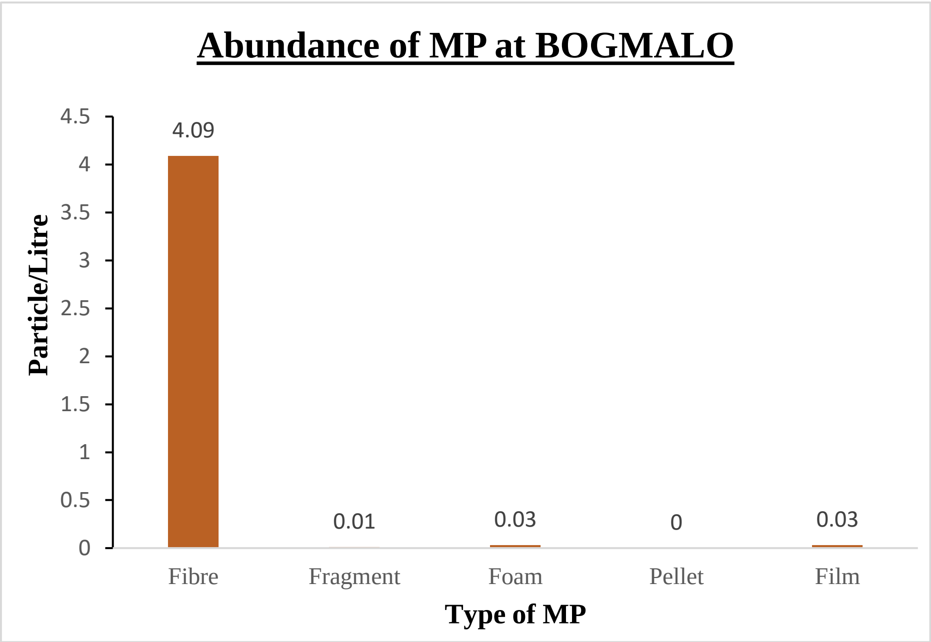


Fig 4.7: Total number of microplastic found at Bogmalo beach

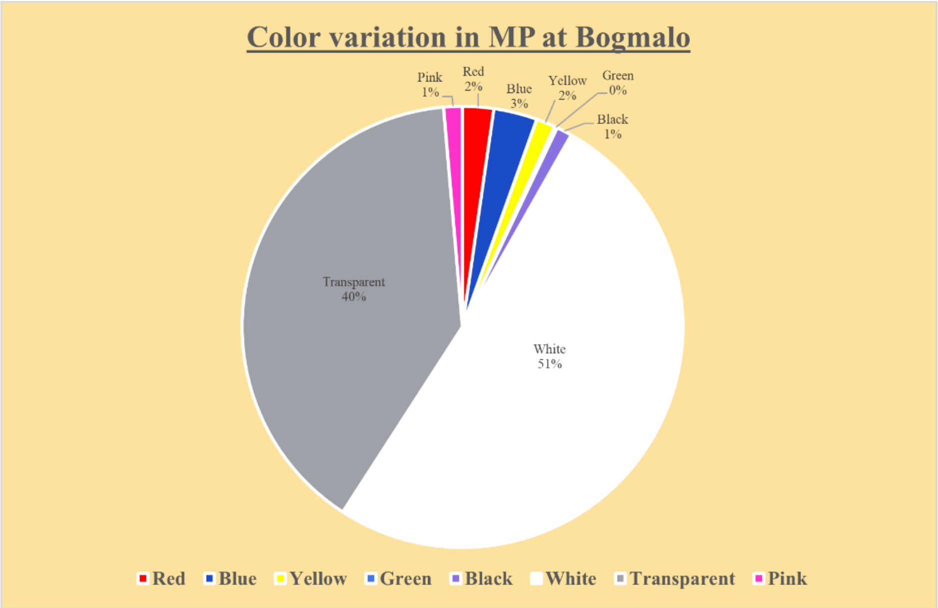


Fig 4.8: Colour variation in MP at Bogmalo

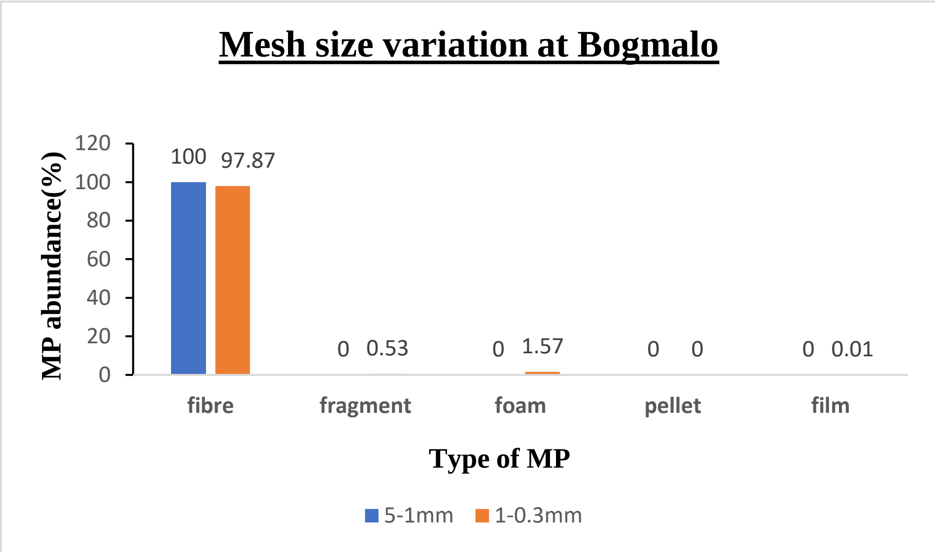


Fig 4.9: Mesh size variation in MP at Bogmalo

The bar graph (Fig 4.7) shows a similar trend for increased number of fibres as followed by all sampling locations. Fibres are usually generated from synthetic textiles, city dust, tires, marine coatings. Fishing was largely followed at this beach in addition to the local vendor shops, tourist interaction and a multi-floor hotel next to the sampling site(Fig 3.7). Most foam found was white in colour. Although Bogmalo beach is a small beach according to its area and coastal stretch, the amount of micro plastic observed was more compared to other beaches of longer coastal and areal extent.

The pie chart shows results for colour variation recorded in MPs. White(51%) and transparent (40%) MP were dominant, followed by blue (3%), red(2%) , yellow(2%). Pink and black colour was least common (1%). Colours in MP can be of indicative of their source. The mesh size variation observed at Bogmalo beach shows higher fibres in size range of 5-1mm while other forms of MPs are more in number in the range of 1-0.3mm .

Utorda

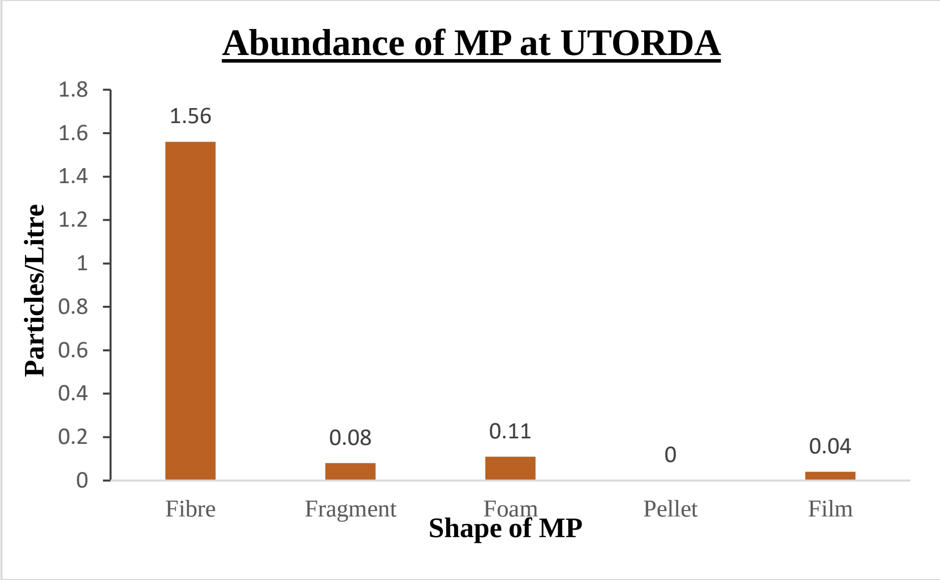


Fig 4.10: Total number of microplastic found at Utorda beach

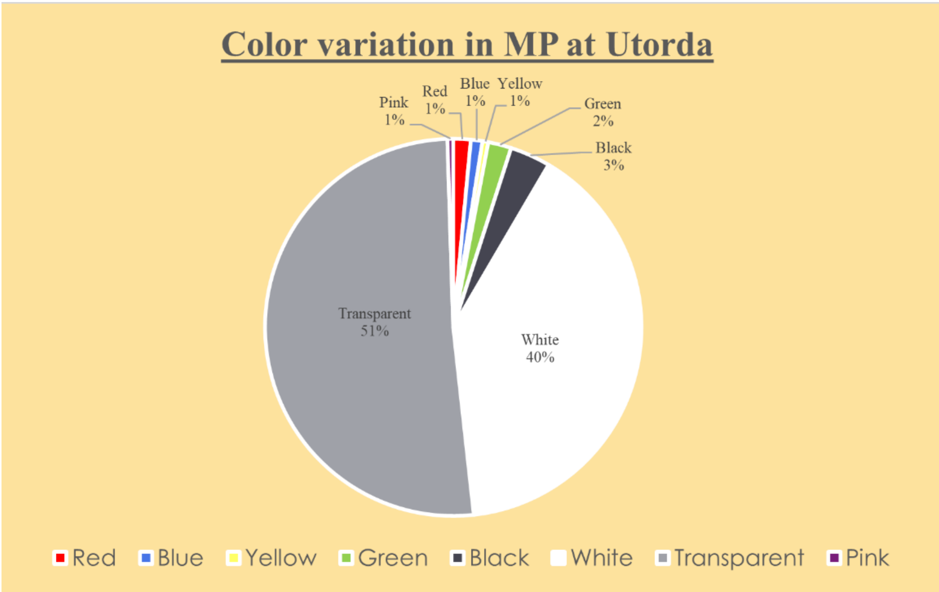


Fig 4.11: Colour variation in MP at Utorda

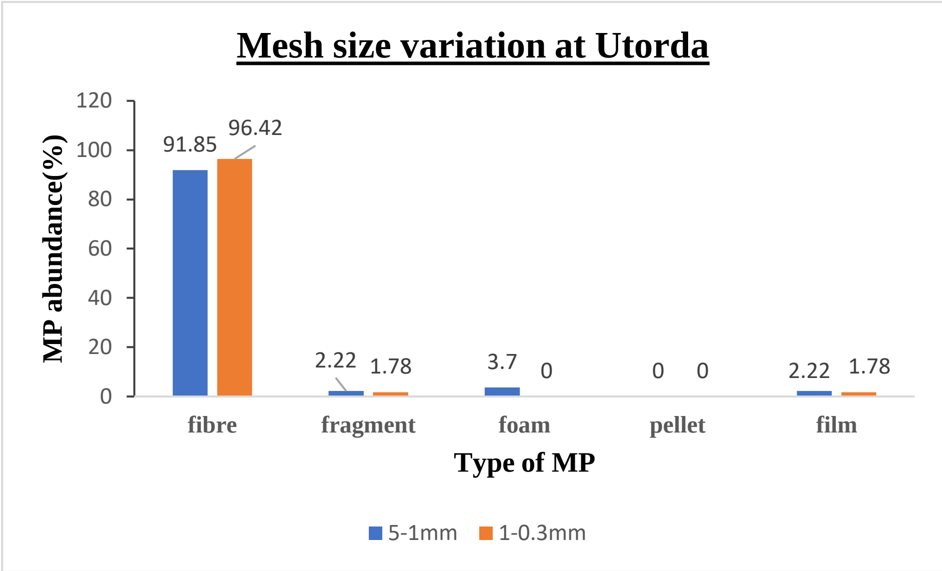


Fig 4.12: Mesh size variation in MP at Utorda

The graph represents percentage of microplastic in the samples taken from Utorda beach (Fig 4.10). Highest number of the fragments in this study were found in this location. Fibres dominated the study area.

The beach when observed for sampling was one of the cleanest beaches but the waves carry the plastic waste onto the shore and also transports it back to the ocean. The potential sources in this area can be the water sports centre on the beach and the presence of beach facing restaurants. The transparent MPs were found in higher percentage (51%) in this location. Second most common colour found was white (40%), followed by black (3%) and green (2%), pink, red , blue and yellow (1%).

The microplastics hosted in a size range of 1-0.3mm has higher number of fibres. Other types of MPs such as fragment , film and foam are higher in 5-1mm size.

Colva

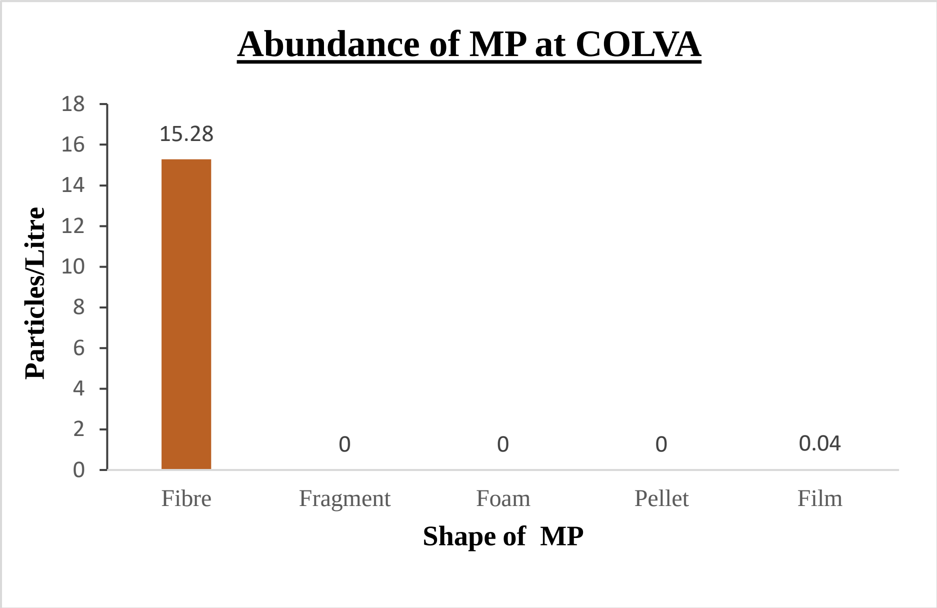


Fig 4.13 : Total number of microplastic found in Colva beach

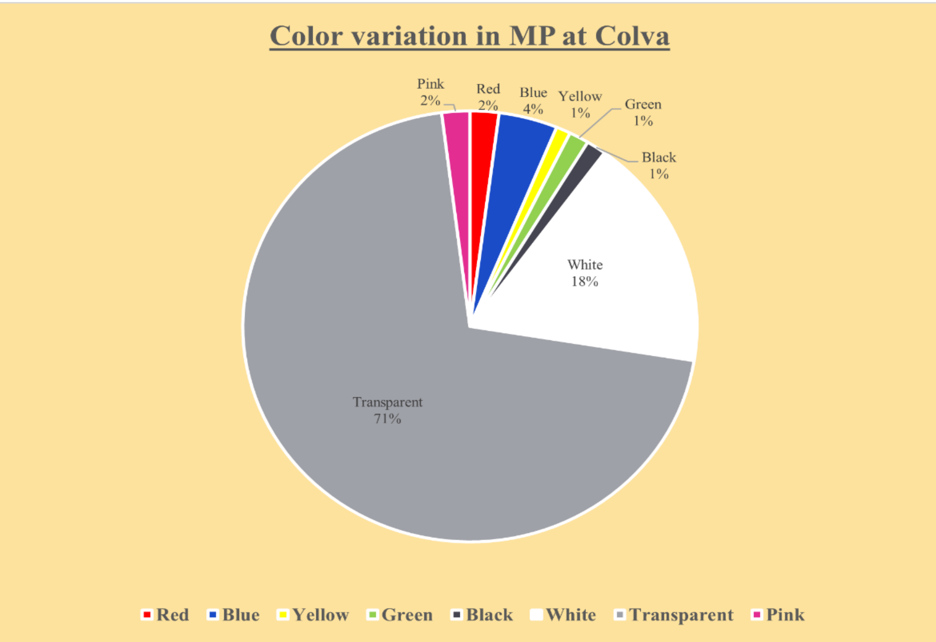


Fig 4.14: Colour variation in MP at Colva

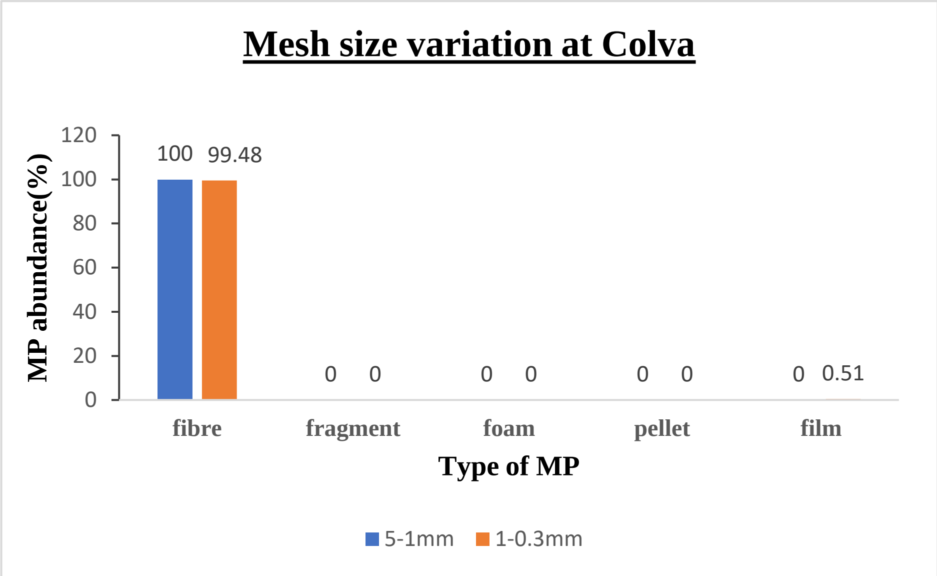


Fig 4.15: Mesh size variation in MP at Colva

Colva beach being a major tourist attraction experiences comparatively more human interaction. Thus, in this study it was expected to receive a higher count of micro plastic which can be proved with the help of the graph. The beach is known for attracting highest number of tourists in the South Goa. The coastal stretch of this beach is extended up to approximately 2.4 kilometers. The Colva beach is surrounded by beach shacks, villages, hotels, spa, resorts and many other sectors contributing majorly to the production and disposal of plastic onto the beaches. Fishing practices are also dominating this area as can be seen in (Fig 3.8). These can serve as potential sources of MPs in Colva.

As can be seen in Fig (4.13) fibres were recorded with almost little presence of other types of MPs. The fibres found were as intervening clusters shown in Fig (4.43H). Transparent fibres were in abundance in the region followed by white (18%), blue (4%), red (2%), pink (2%), green (1%), black (1%) and yellow (1%) in a decreasing order of abundance. More fibres were encountered in size range of 5-1mm in the waters of Colva.

2) Abundance of Microplastic on different stations

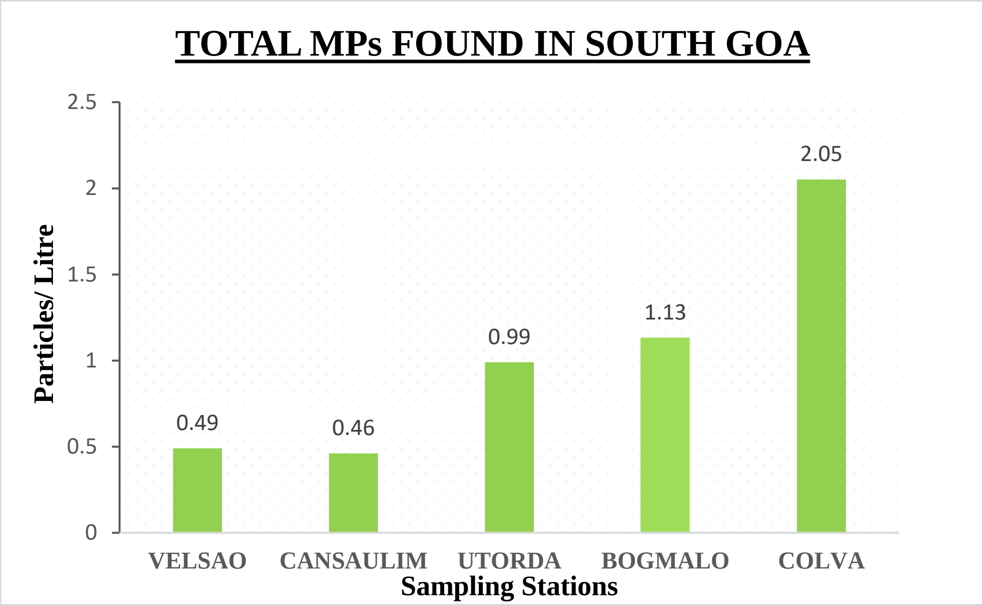


Fig 4.16: Total MPs found in South Goa

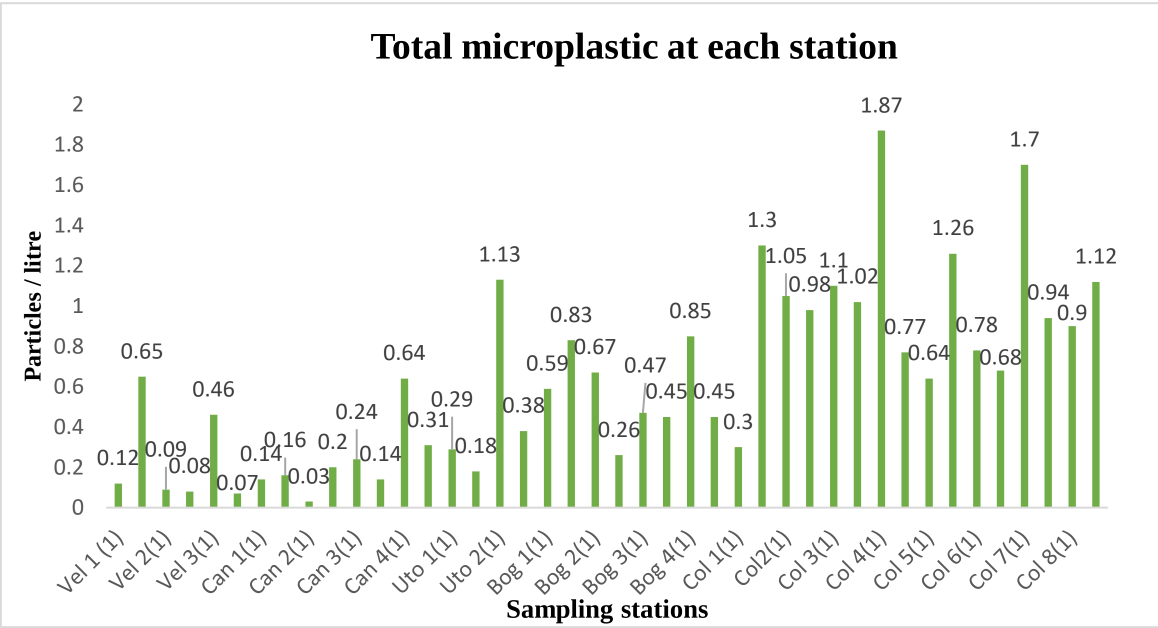


Figure 4.17 Microplastics found at each station

In this study we have divided the microplastic into different forms, all the microplastic found on each station were quantified and plotted. This graph (Fig 4.16) shows a comparative perspective on the abundance of microplastic on the beaches.

The Colva beach showed a higher number of microplastic particles per litre than rest of the locations since Colva has been a tourist attraction since a long time. The beach is surrounded by hotels and guesthouses contributing to the tourism sector serving as a hotspot for MP contamination. Along with Colva, Bogmalo beach is known to be a hotspot for MP contamination.

The graph (Fig 4.16) also shows very low number of microplastic for Velsao and Cansaulim beaches due to comparatively less human interaction in these regions. The Cansaulim and adjacent regions have an agricultural area within 5km radius, less human settlements compared to Colva, lesser number of shacks and hotels thus it has less contamination. Bogmalo showed higher number of MPs when compared to its coastal stretch and extent of 800-1000 metres. This shows that active tourism and fishery conducted on this beach is directly serving a source for MP pollution. Water sports activities are also an ongoing service at the beach attracting more tourists. Fig (4.17) displays microplastics found at each station and gives an insight on the overall distribution of microplastic throughout the study area.

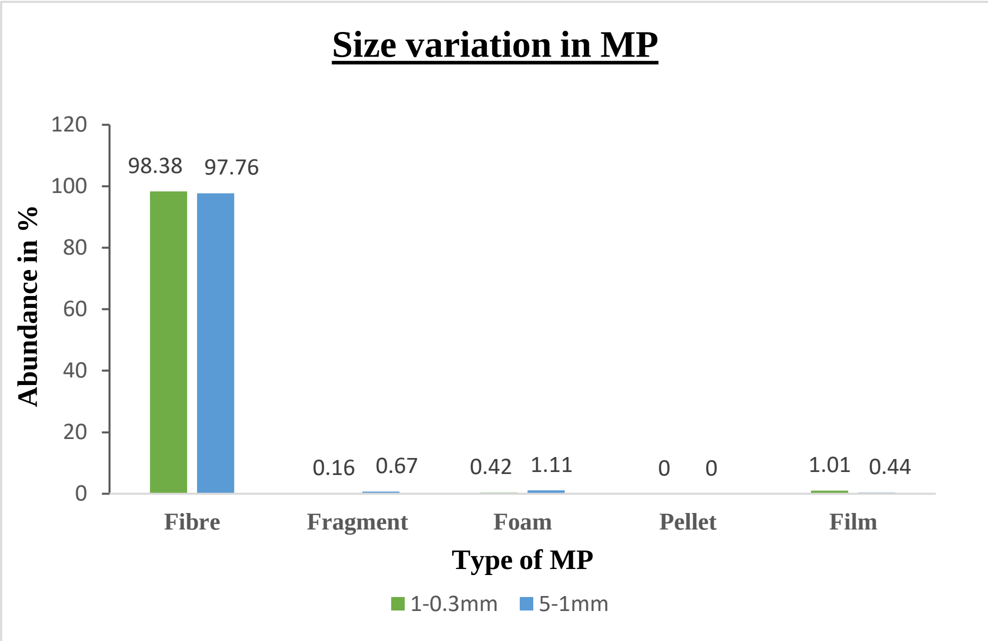


Fig 4.18: Mesh size variation in MP at South Goa

The overall variation in size for all the sampling stations shows increased number of fibres and films for mesh size 1-0.3mm whereas fragment and foam was found in higher number for size range of 5-1mm.

3) Total Microplastic categorization into colours

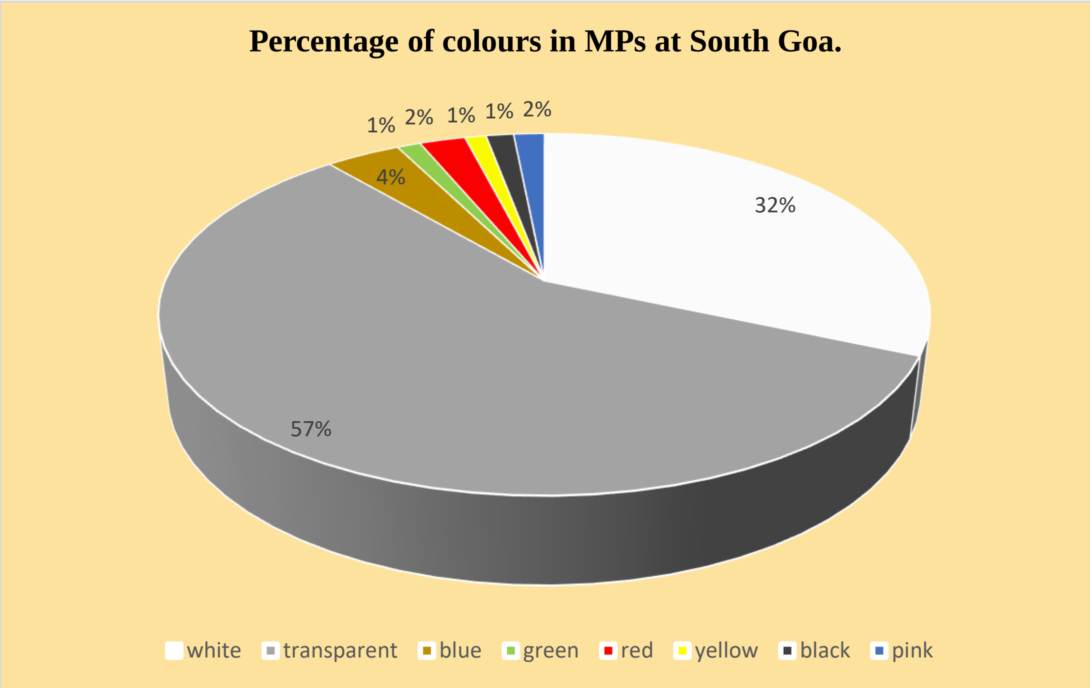


Fig 4.19: Pie chart depicting percentage of colours in MP at South Goa

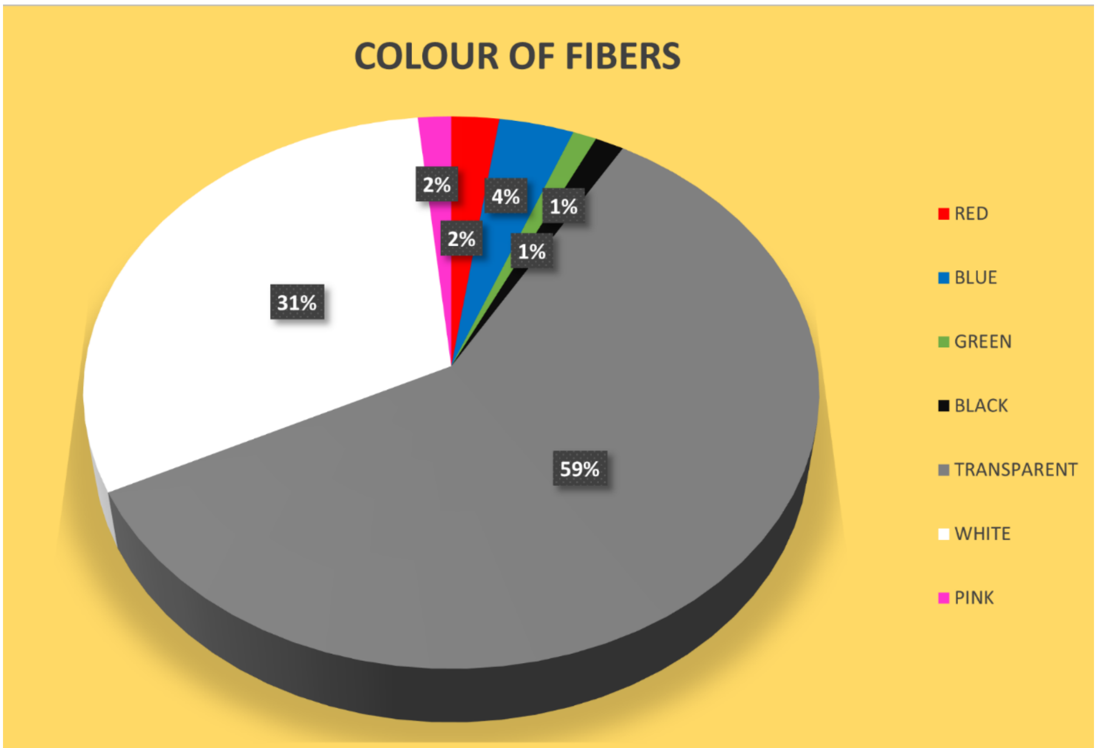


Fig 4.20: Pie chart showing percentage of different colours of fibres

The pie chart (Fig 4.19) shows the distribution of different colours of Microplastic found on all the stations. Colour pigments are added to micro plastic to make them attractive along with its actual usage. Photoaging caused by various factors in the environment, plastic aging can be easily recognized from the fading of colours. Colours of micro plastic can also affect certain organisms which tend to be visual predators.

Transparent fibres, films and fragments are seen to dominate the study are, with white being the second most abundant colour. The abundance of transparent colour since most of the plastic production and packaging can be seen as transparent. Transparent plastics are prevalent in everyday items such as food containers, water bottles, and packaging films. Breakdown of such macro plastic will result in higher microplastic formation. (Fig 4.20) Pie chart shows percentage of different colours of fibres that are encountered during the study.

FTIR ANALYSIS RESULTS

Fourier transform infrared (FTIR) is a spectroscopy technique widely used in order to identify the chemical composition of unknown material. The exact chemical structures can only be deduced from IR spectra when compared to a known data of IR spectra.

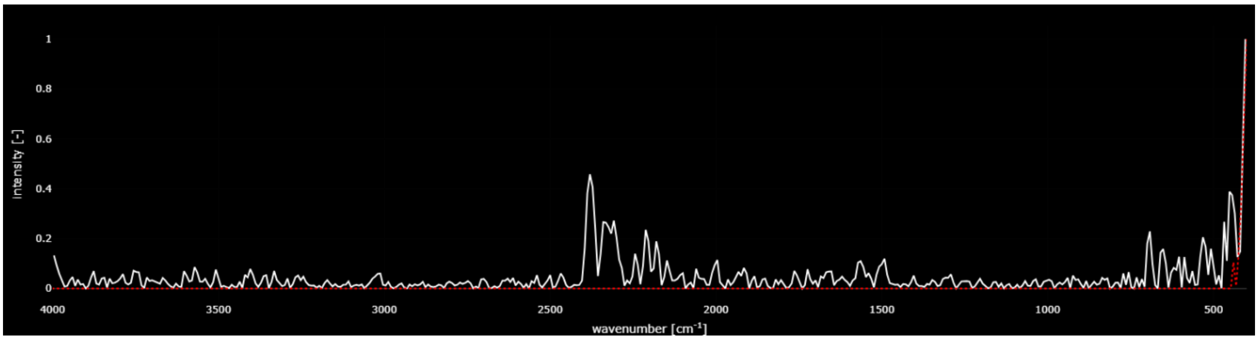


Fig 4.21: This sample(A) was collected in Utorda from Uto1(1) and it is found to be Polystrene.

Type: Fibre, colour, white

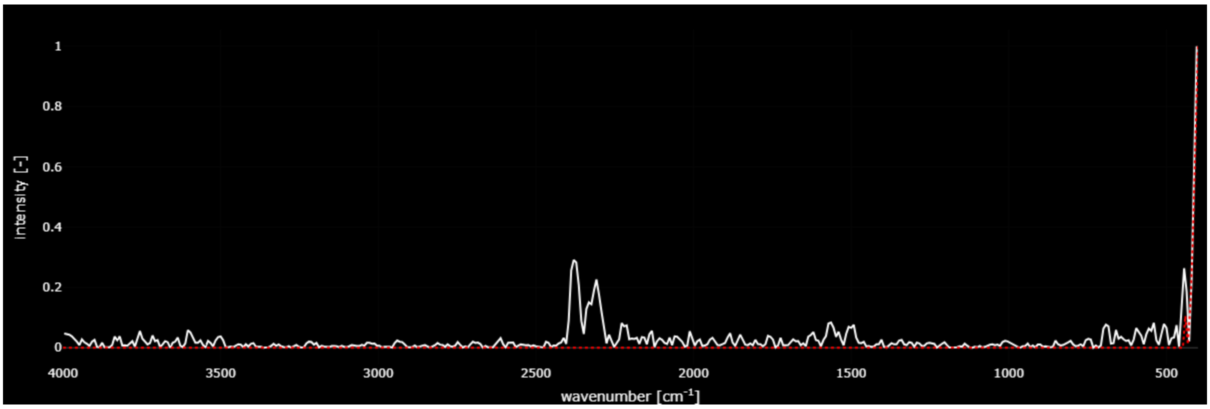


Fig 4.22: This sample (B) was collected in Utorda from Uto2(2) and it is found to be

Polystrene   Type: Film, colour, white

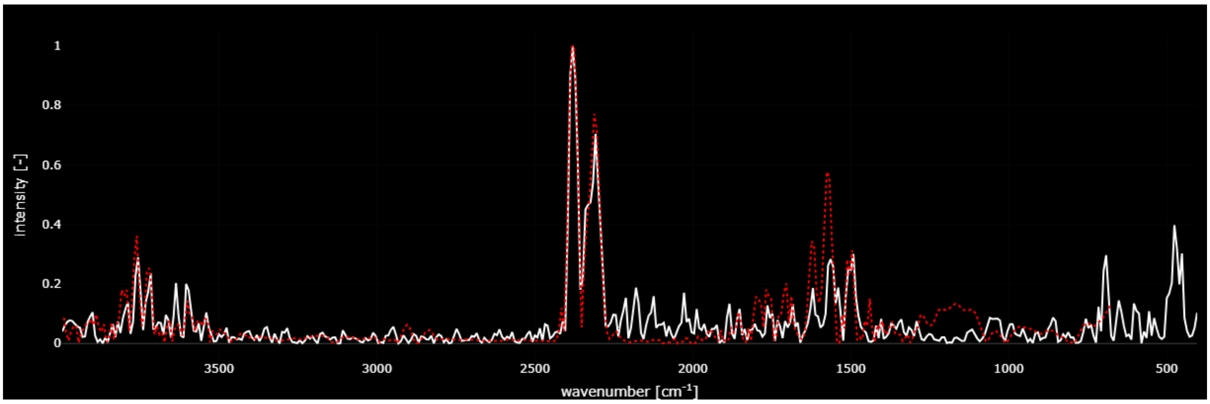


Fig 4.23: This sample (C) was collected in Bogmalo from Bog4(1) and it is found to

Polyketone   Type: Fragment, colour, transparent

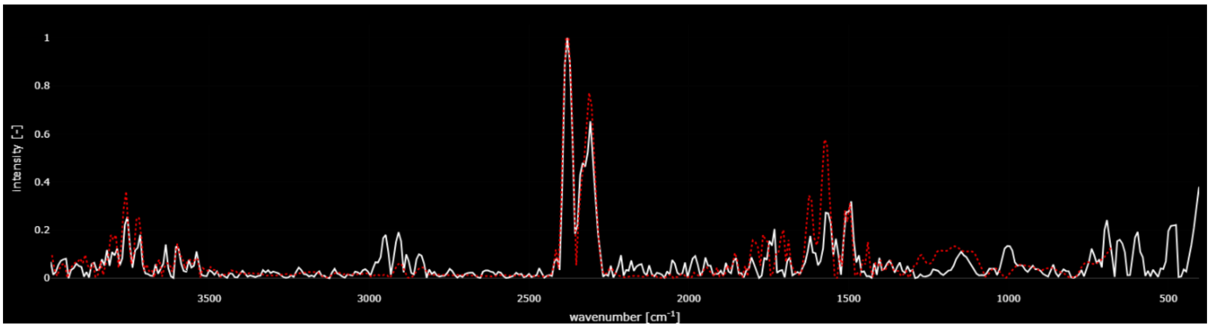


Fig 4.24: This sample (E) was collected in Utorda from Uto1(1) and it is found to be

Polyketone   Type: Foam, colour, white

SAMPLE ID	TYPE OF MP	COLOUR	POLYMER TYPE
UTO1(1)	Fibre	White	Polystrene
UTO1(1)	Foam	White	Polystrene
UTO2(2)	Film	White	Polyketone
BOG4(1)	Fragment	Transparent	Polyketone

Table no.1.1: Identified polymers using FTIR

SEM ANALYSIS RESULTS

I) White fibre cluster

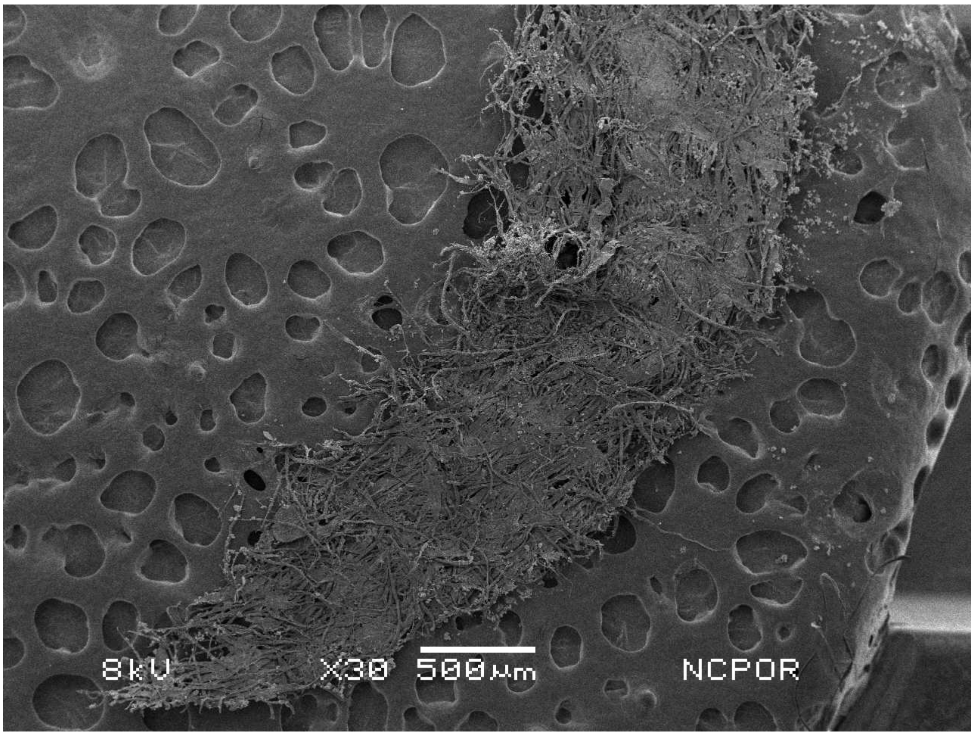


Fig 4.25: Zoomed out SEM image of White cluster fibre

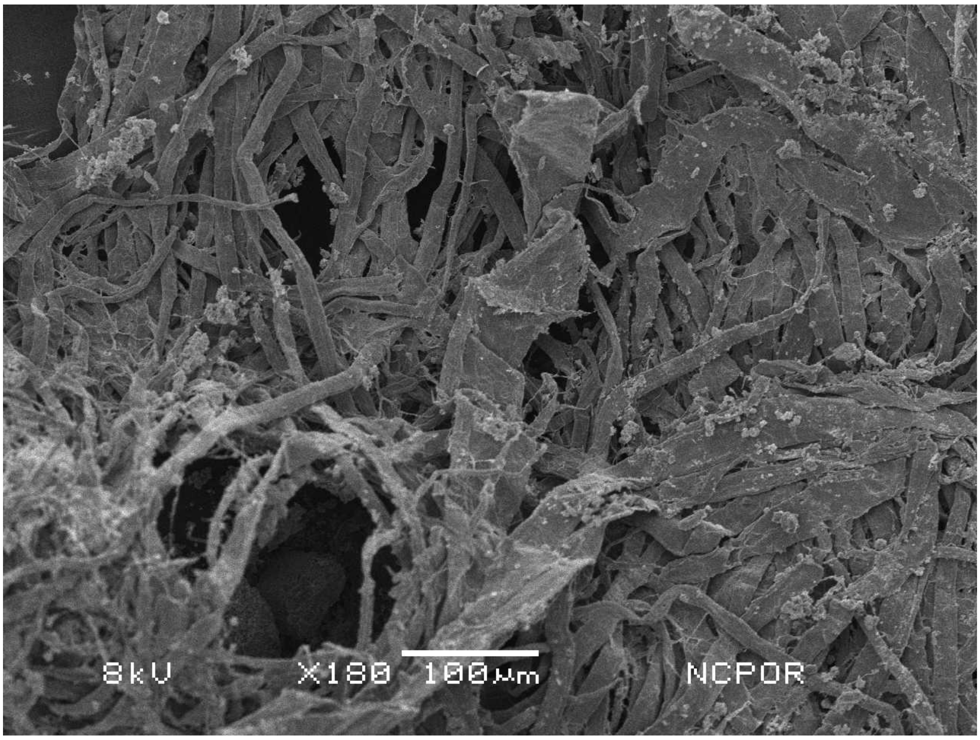


Fig 4.26: Strands of fibres visible in 180x magnification

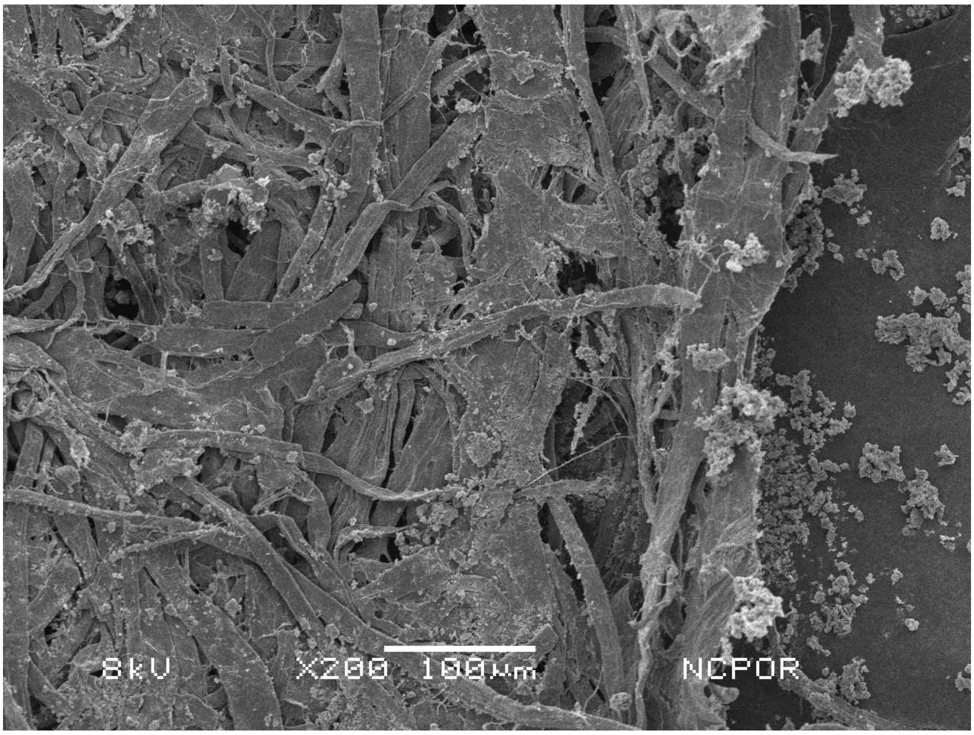


Fig 4.27: Zoomed in image on the threads of fibre, 200x

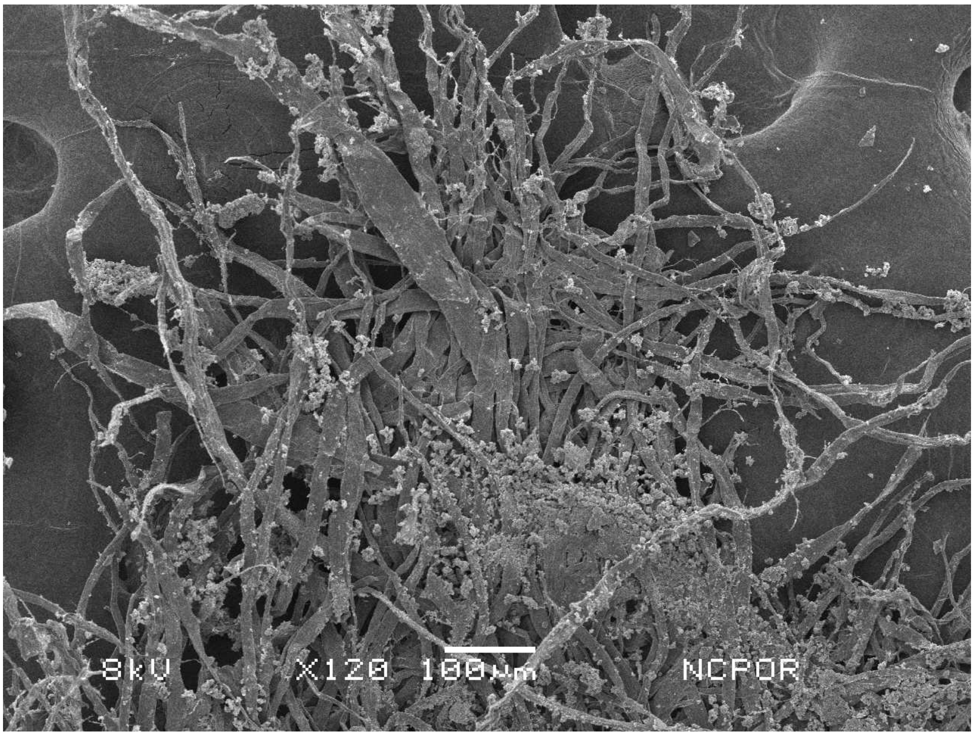


Fig 4.28: Image showing entangled fibres making a cluster

II)   Blue Fibre

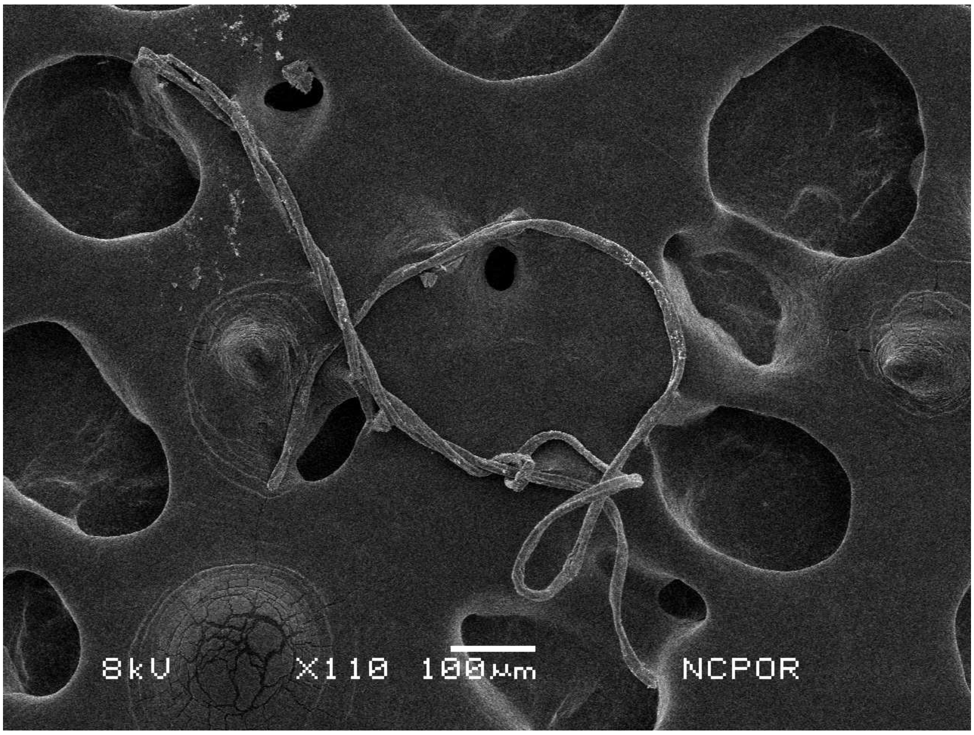


Fig 4.29 : Zoomed out image; blue fibre, 110x

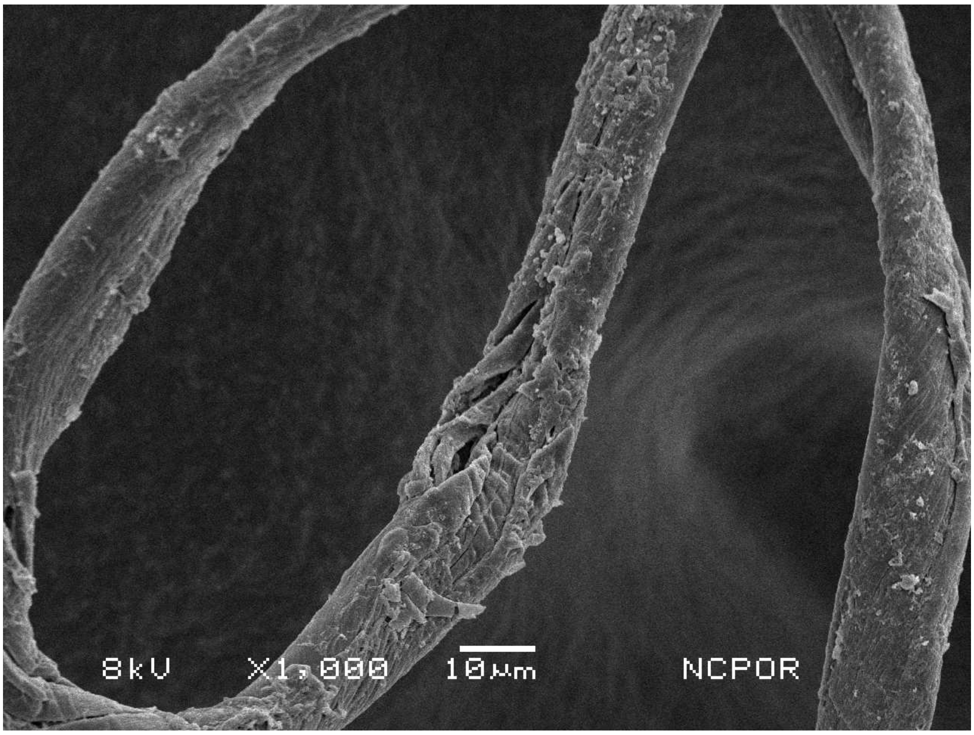


Fig 4.30 : Zoomed in image on the strand of fibre showing brittleness

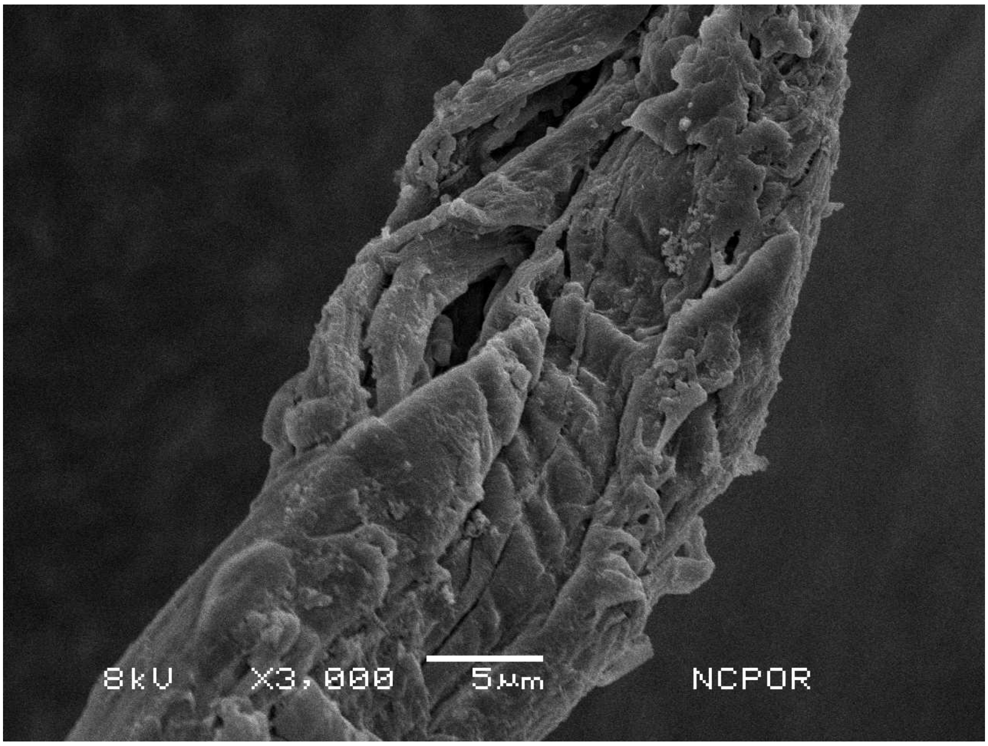


Fig 4.31: More zoomed in image of the same fibre showing brittle texture, 3000x

III) White Film

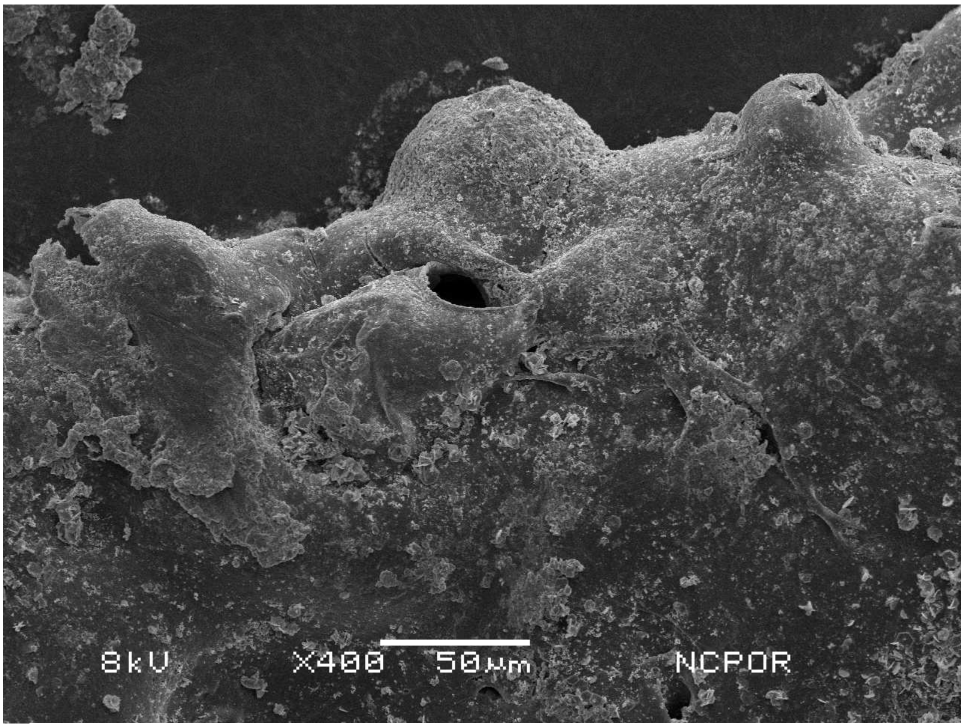


Fig 4.32: SEM image of film is developing bulbous nature

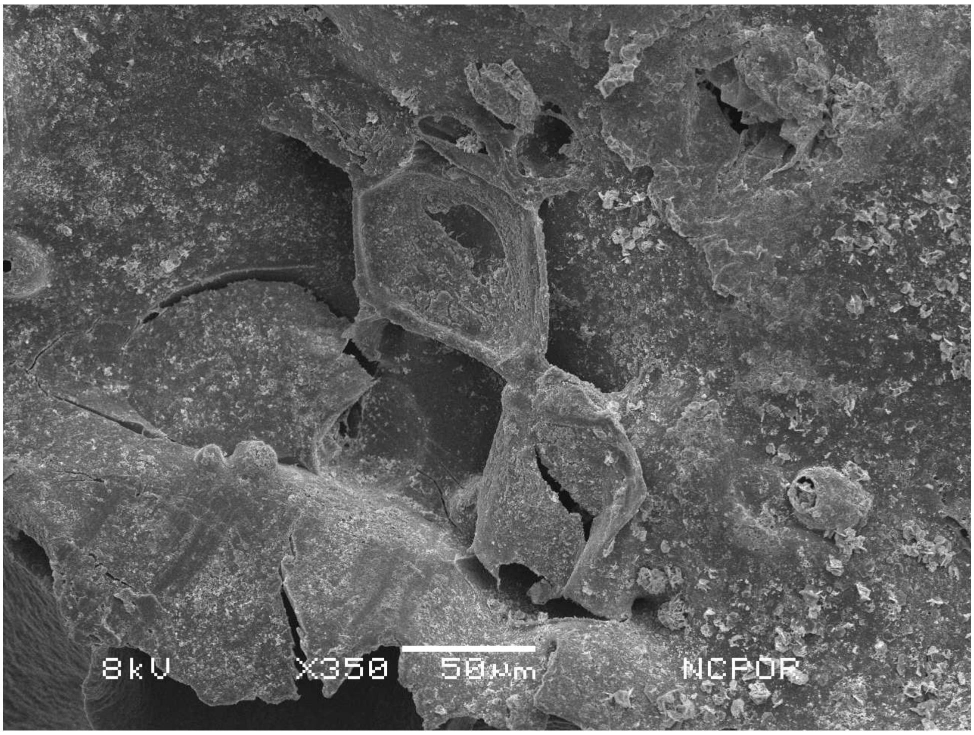


Fig 4.33: Image showing abrasion due to more exposure to UV in the environment

IV) Red Fibre

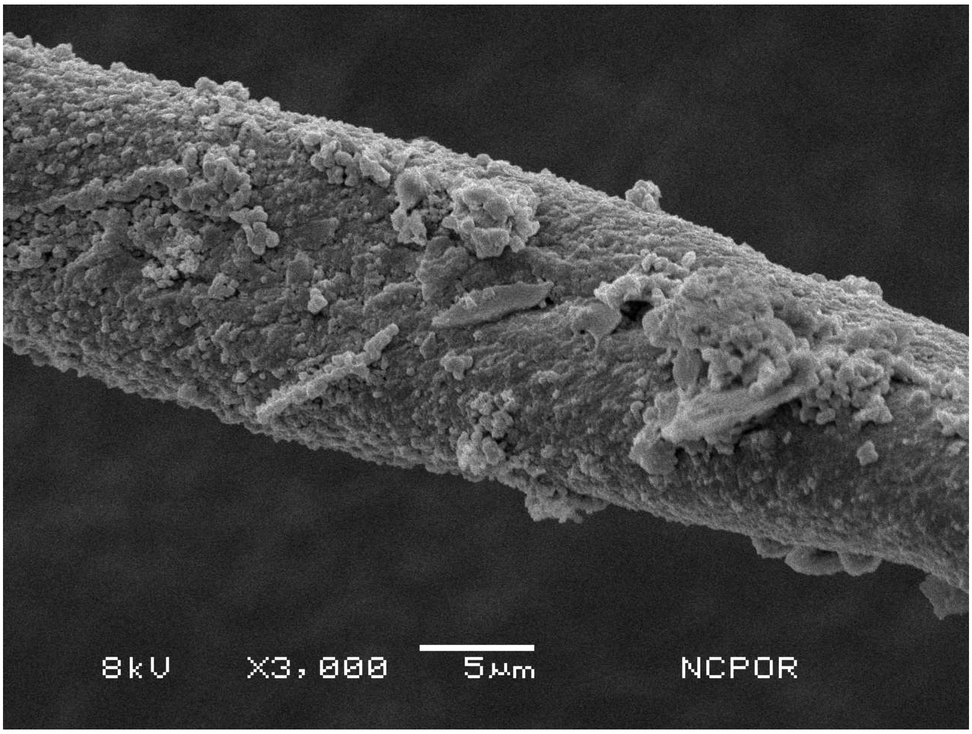


Fig 4.34 : Surface of fibre is smooth suggesting less exposure to UV rays

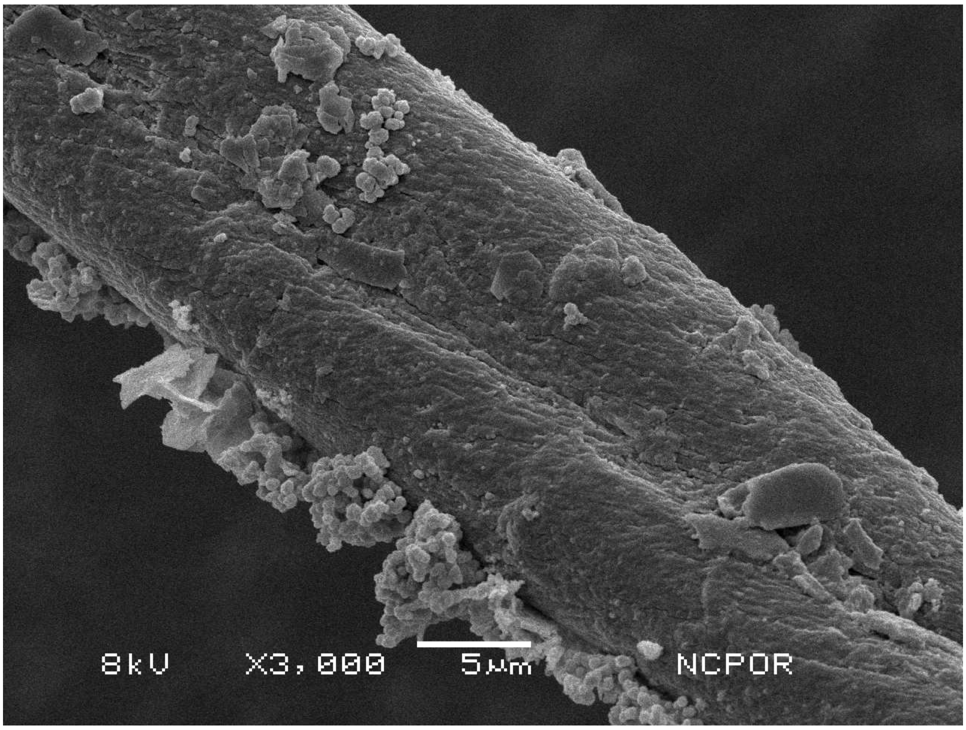


Fig 4.35: Zoomed in image of fibre showing less alteration

V) Green fragment

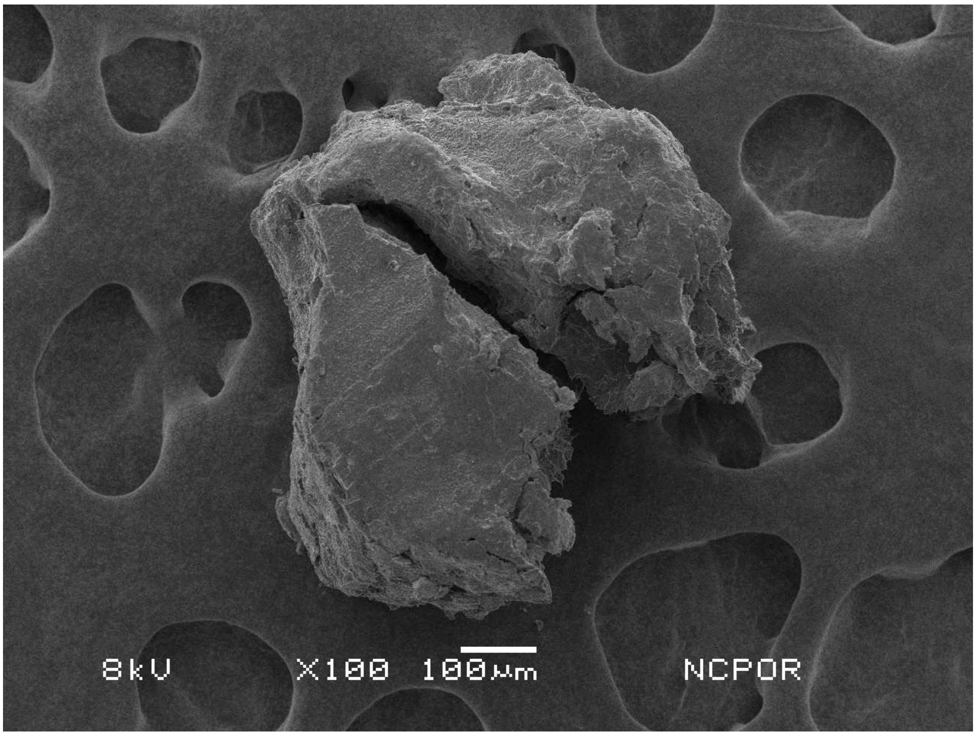


Fig 4.36: Zoomed out image ;Green fragment ,100 x

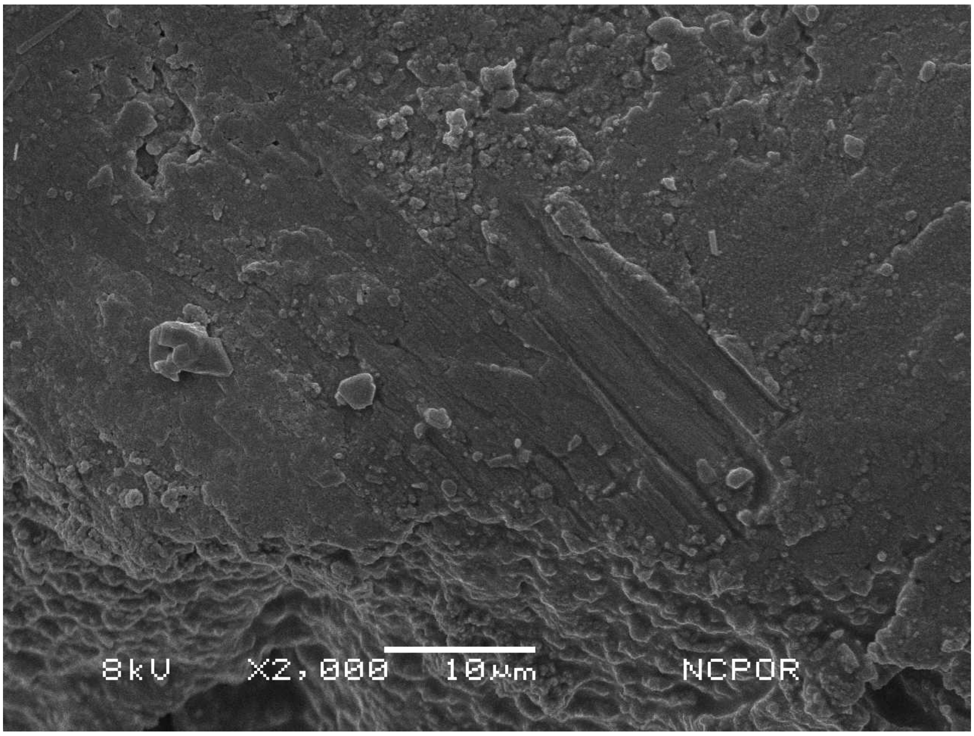


Fig 4.37: SEM image of fragment with visible groove marks on surface

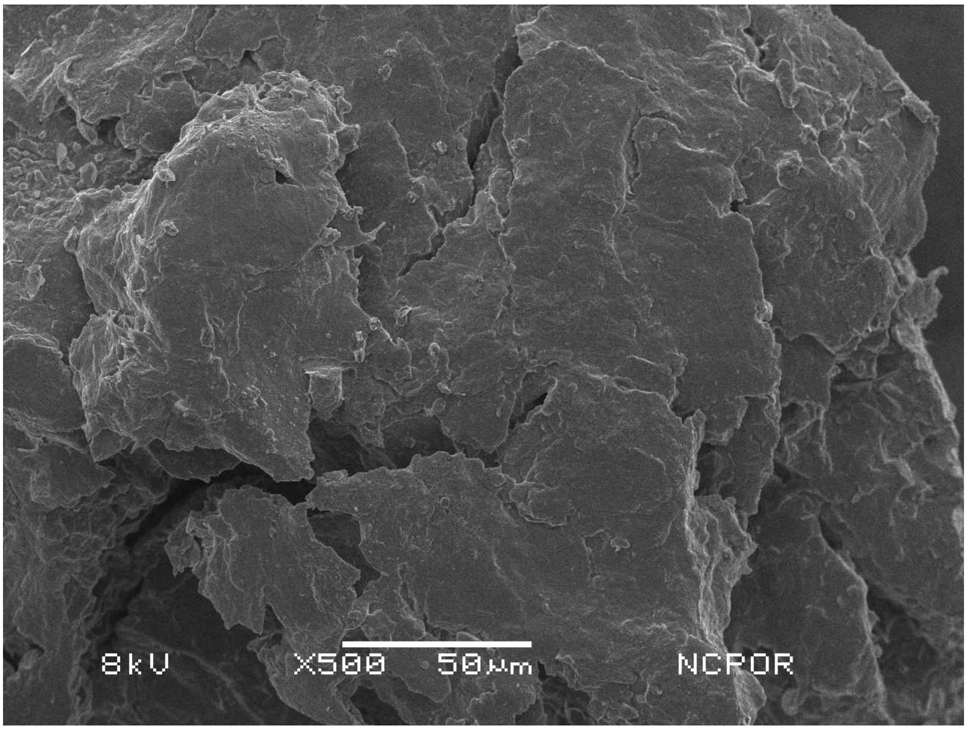


Fig 4.38: Flaky nature of fragment initiating disintegration of microplastic

VI) Green fibre

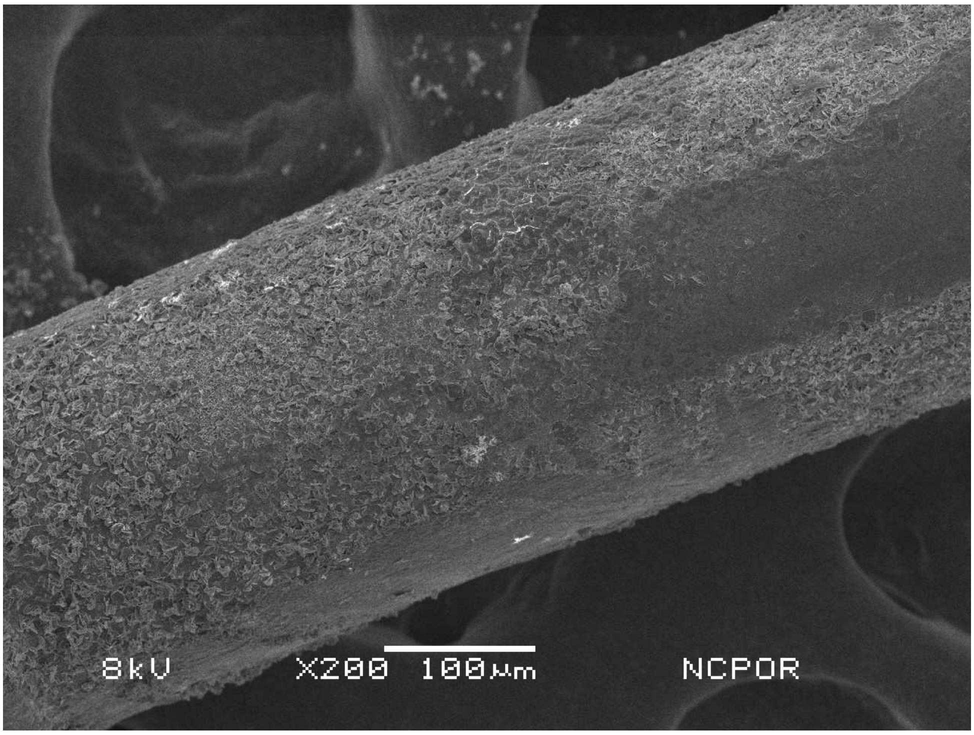


Fig 4.39 : Zoomed out image of green fibre, 200x

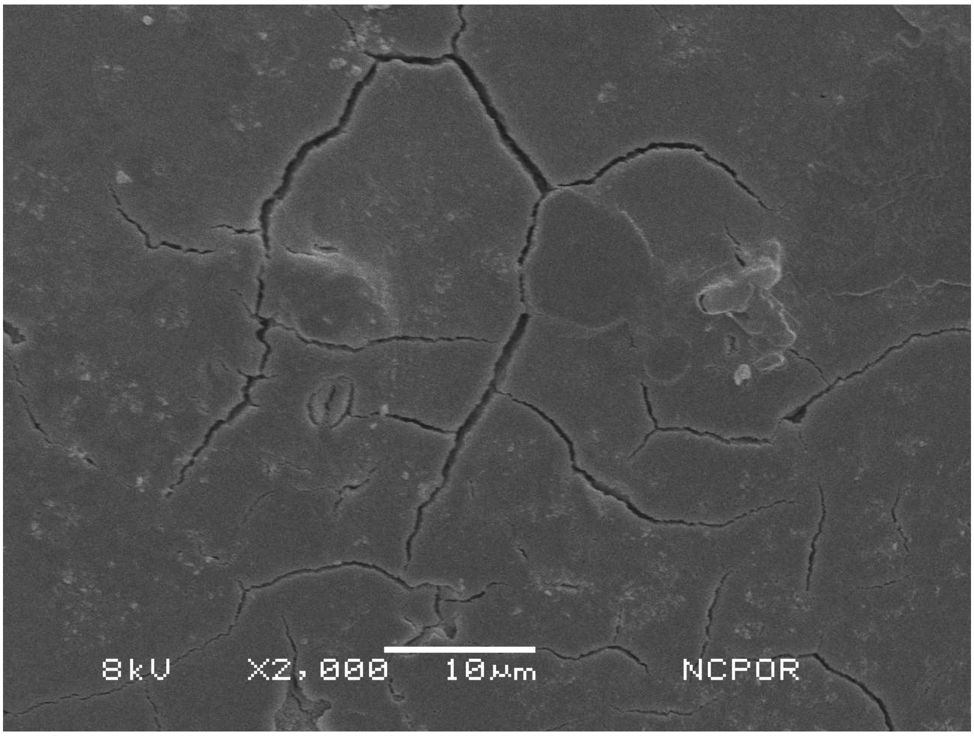


Fig 4.40: SEM image showing cracks on surface of fibre, 2000x

VII) Foam

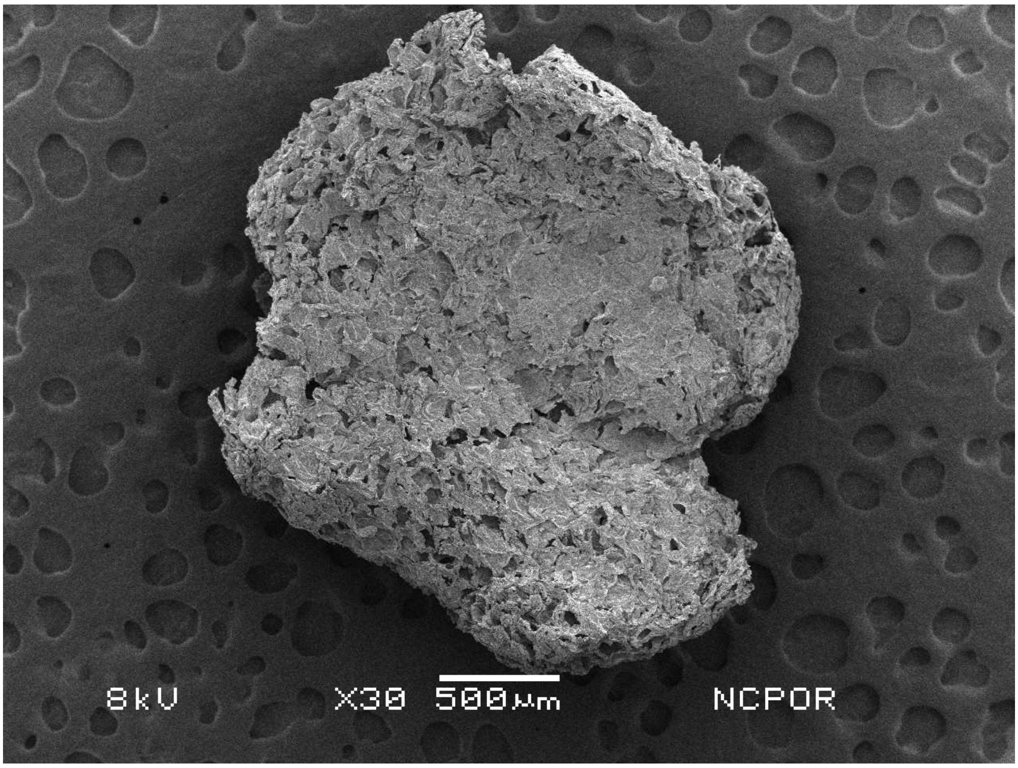


Fig 4.41: Zoomed out SEM image of Foam, 30x

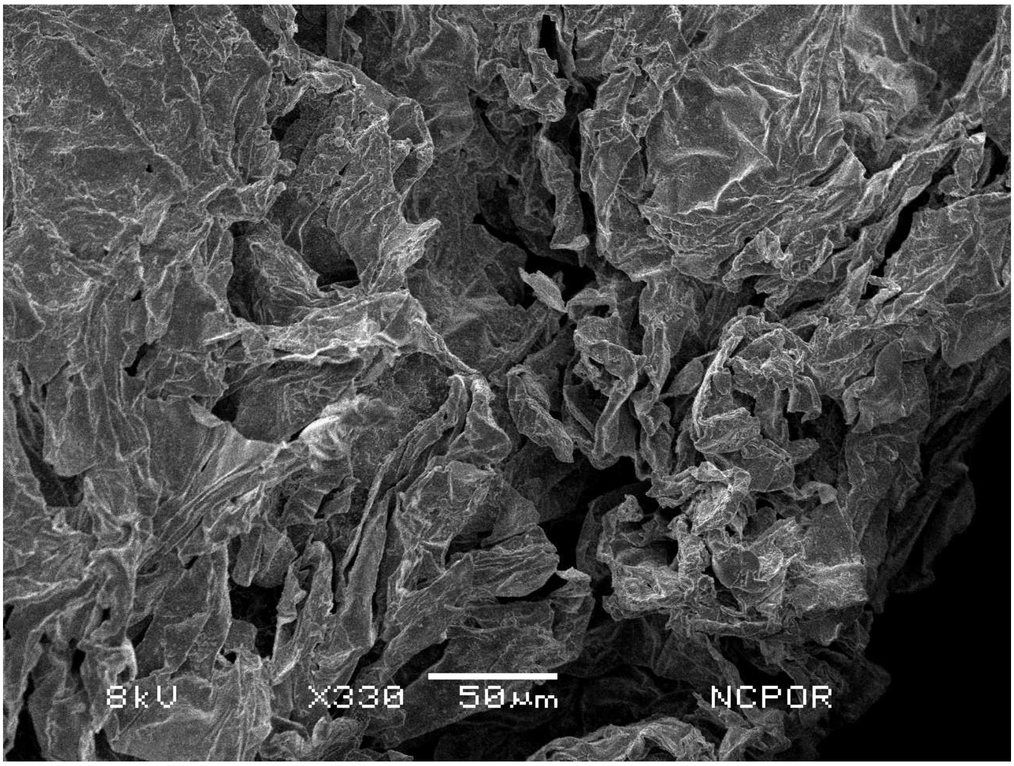
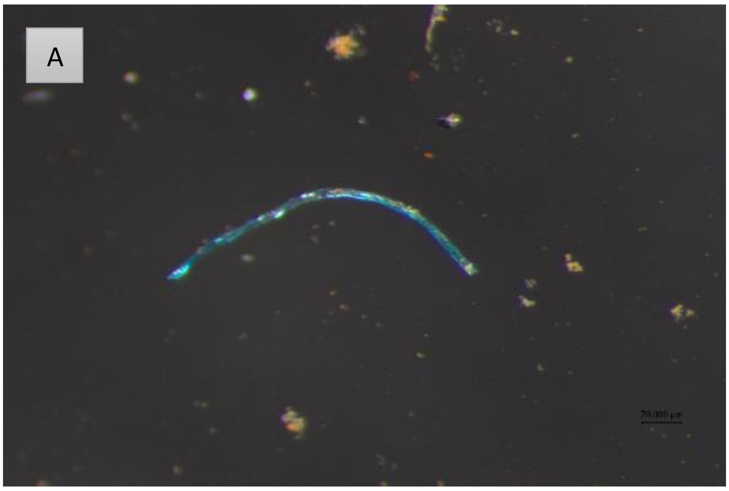


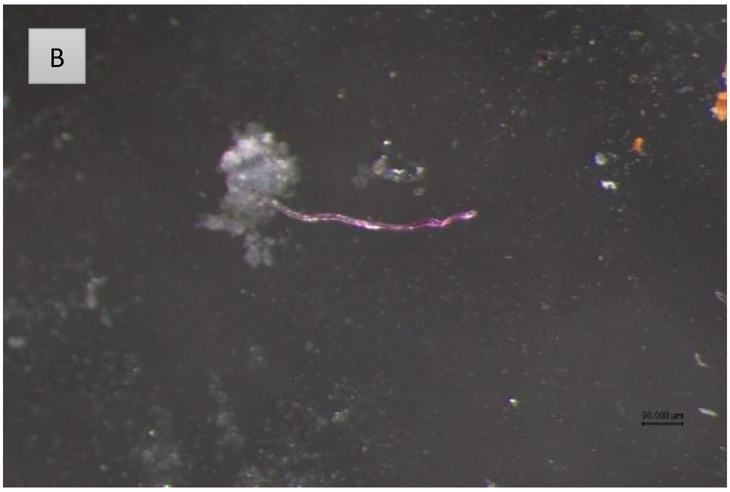
Fig 4.42 : Image taken at 330 x, displaying typical texture of foam with less alteration

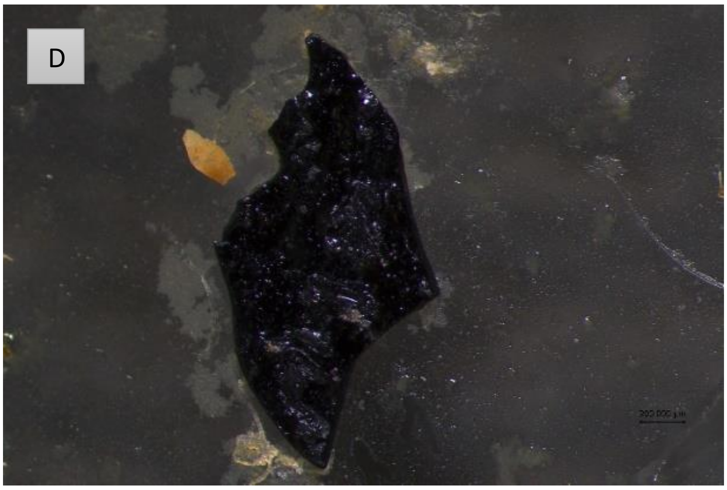
SEM facilitates the comparison of surface roughness, which is a crucial parameter for understanding the accumulation of persistent organic pollutants or trace metals on the microplastic surface, as well as the likelihood of plastisphere development.

Larger the surface area of material, more significant influence is expected on its interaction with organic compound. The potential binding sites for the adsorption of compounds onto microplastics also increases and greater adsorption is expected. SEM provides detailed insights into microplastic characteristics, interactions, and potential environmental impacts. Potential binding sites for heavy metals on the surface of microplastics can be viewed with the help of SEM images.

STEREOZOOM IMAGES



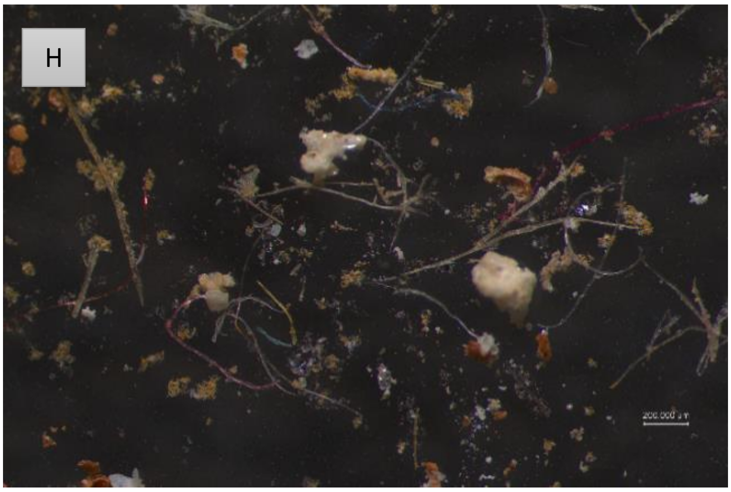


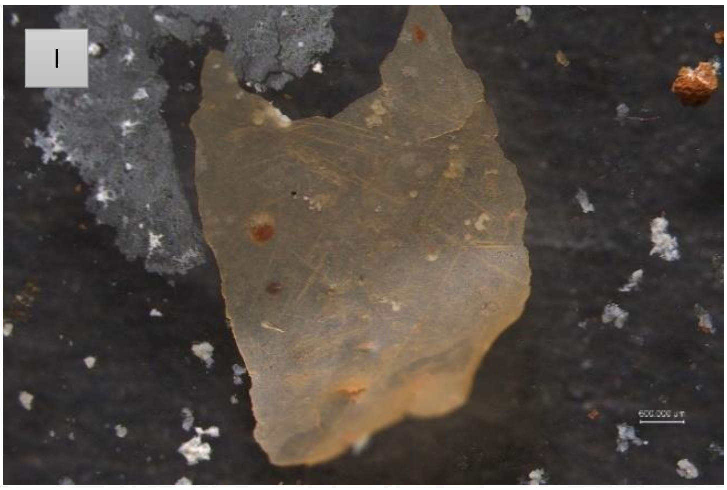

D


E


F


G


H


I

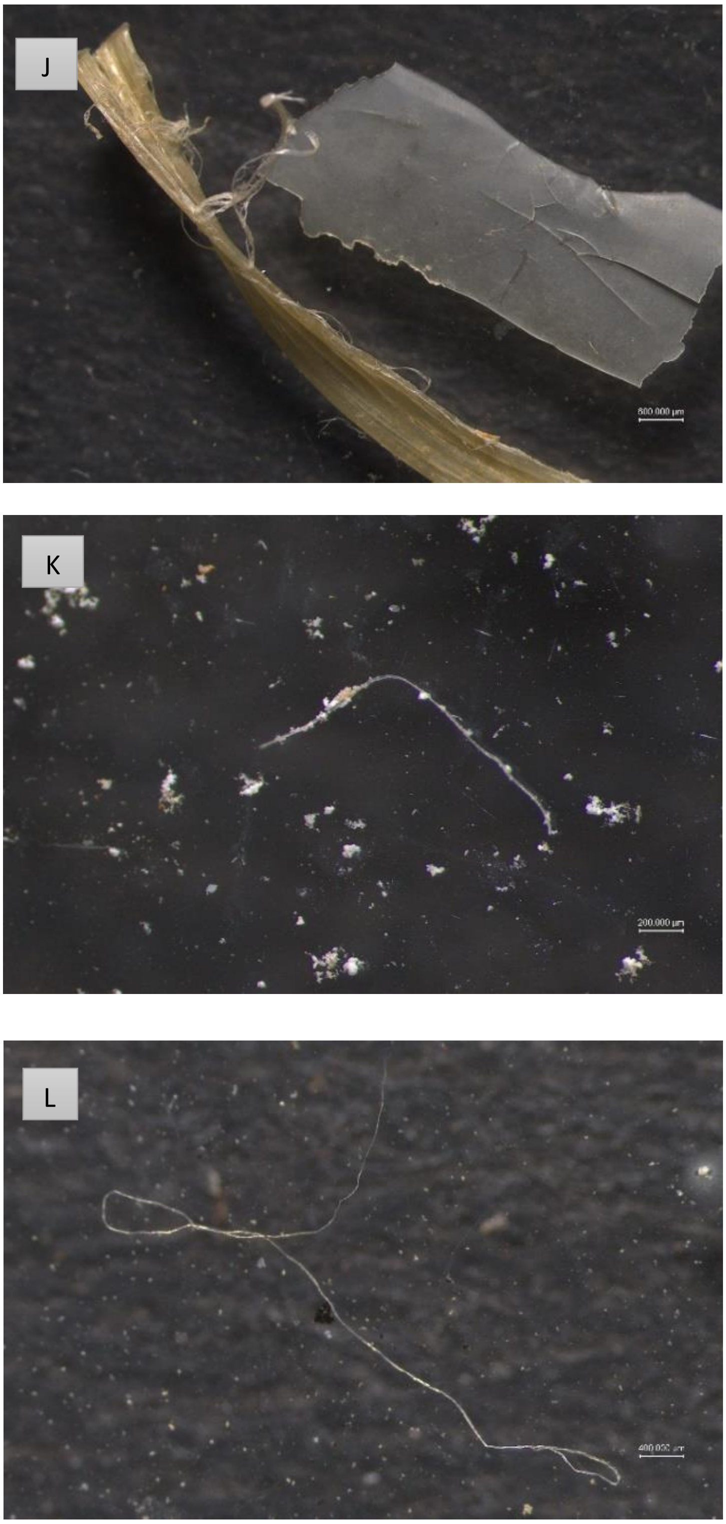


Fig 4.43: The photographs of different types/forms of MPs taken with the help of NIKON SMZ745T Stereozoom microscope. A(blue fibre), B(pink fibre), C(green fragment), D(black fragment), E & F (foam), G & H(cluster of fibres), I & J (film) , K(white fibre) & L(transparent fibre).

CHAPTER V

CONCLUSION

The abundance and characteristics of MPs investigated in this study showed the presence in all surface water samples indicating that the coastal water is contaminated with Microplastics. All the stations show variation with respect to abundance and types of microplastics found. Most prominent type of MP found in this study was fibres (94%), followed by film (1%), foam (1%) and fragments (0.4%). The MP values ranging 0.49 particles/litre to 2.05 particles/litre with an average of 0.508 particles/litre.

With respect to the microplastics, transparent constituted the most common colour (57%), followed by white(32%), blue (4%), red (2%), pink (1%), black (1%),green(1%) and yellow (1%). Polyketone and polystyrene was the commonly occurring polymers in this study. Size variation consideration revealed that fibres and films dominated the 5-1mm size range whereas foam, fragment dominate the 1-0.3mm size range.

Among all beaches studied, Colva beach was found to have the highest contamination (2.05 particles/l), followed by Bogmalo (1.13 particles/l), Utorda (0.99particles/l), Velsao (0.49 particles/l) and Cansaulim (0.46 particles/l).

The sources attributed to the pollution occurring in this area is mostly derived from anthropogenic means such as local fishing sector making use of fishing nets, boats, tourism sector constituting of tourists, vendors, water sport activities, beach side shacks, stays and restaurants in the vicinity.

The SEM analysis performed gave an overview on the surface morphology and resistant time of microplastic in the environment. The visible cracks, pitted appearance and embrittlement observed on the surface of MP confirms that it sustained in the environment for a greater period of time.

In conclusion, the presence of microplastics in our environment demands urgent attention. As we navigate the intricate web of ecological interactions, it becomes evident that mitigating microplastic pollution requires multiple strategies. From prevention to waste management, collaborative efforts across disciplines are essential. As we move forward, let us remain steadfast in our commitment to safeguarding our planet from the long-lasting legacy of plastic pollution.

REFERENCES

- Amrutha, K., & Warrier, A. K. (2020). The first report on the source-to-sink characterization of microplastic pollution from a riverine environment in tropical India. Science of the Total Environment, 739, 140377.
- Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1977-1984.
- Barnes, D. K., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical transactions of the royal society B: biological sciences, 364(1526), 1985-1998.
- Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: a review. Marine pollution bulletin, 62(12), 2588-2597.
- Desai, A., Srimuruganandam, B., Nanajkar, M., Kumar, M., Saha, M., Rathore, C., ... & Naik, A. (2019, December). Abundance and quantification of microplastics in water and sediments of Sal River and an approach to study the degradation of microplastics. In Proceedings of the Ocean Society of India Conference (OSICON–19), Kochi, India (pp. 12-14).
- do Sul, J. A. I., & Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. Environmental pollution, 185, 352-364.
- E. van Sebille et al., A global inventory of small floating plastic debris, IOP Publishing, 2015
- Godoy, V., Blázquez, G., Calero, M., Quesada, L., & Martín-Lara, M. A. (2019). The potential of microplastics as carriers of metals. Environmental Pollution, 255, 113363.

- Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. Journal of hazardous materials, 344, 179-199.
- Jayasiri, H. B., Purushothaman, C. S., & Vennila, A. (2013). Quantitative analysis of plastic debris on recreational beaches in Mumbai, India. *Marine pollution bulletin*, *77*(1-2), 107-112.
- Jeong, C. B., Kang, H. M., Lee, M. C., Kim, D. H., Han, J., Hwang, D. S., Souissi, S., Lee, S. J., Shin, K. H., Park, H. G., & Lee, J. S. (2017). Adverse effects of microplastics and oxidative stress-induced MAPK/Nrf2 pathway-mediated defense mechanisms in the marine copepod Paracyclopina nana. Scientific Reports, 7, 41323
- Kalangutkar, N., Mhapsekar, S., Redkar, P., Valsan, G., & Warrier, A. K. (2024). Microplastic pollution in the Chapora River, Goa, Southwest India: spatial distribution and risk assessment. Environmental Monitoring and Assessment, 196(5), 1-17.
- Karthik, R., Robin, R. S., Purvaja, R., Ganguly, D., Anandavelu, I., Raghuraman, R., & Ramesh, R. (2018). Microplastics along the beaches of southeast coast of India. Science of the Total Environment, 645, 1388-1399.
- Karthikeyan, P., & Subagunasekar, M. (2023). Microplastics pollution studies in India: A recent review of sources, abundances and research perspectives. Regional Studies in Marine Science, 61, 102863.
- Khaleel, R., Valsan, G., Rangel-Buitrago, N., & Warrier, A. K. (2022). Hidden problems in geological heritage sites: The microplastic issue on Saint Mary's Island, India, Southeast Arabian Sea. Marine Pollution Bulletin, 182, 114043.

- Li, J., Qu, X., Su, L., Zhang, W., Yang, D., Kolandhasamy, P., ... & Shi, H. (2016). Microplastics in mussels along the coastal waters of China. Environmental pollution, 214, 177-184.
- Masura, J., Baker, J. E., Foster, G. D., Arthur, C., & Herring, C. (2015). Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments.
- Ranjani, M., Veerasingam, S., Venkatachalapathy, R., Mugilarasan, M., Bagaev, A., Mukhanov, V., & Vethamony, P. J. M. P. B. (2021). Assessment Of Potential Ecological Risk Of Microplastics In The Coastal Sediments Of India: A Meta-analysis. Marine Pollution Bulletin, 163, 111969.
- Saha, M., Naik, A., Desai, A., Nanajkar, M., Rathore, C., Kumar, M., & Gupta, P. (2021). Microplastics In Seafood As An Emerging Threat To Marine Environment: A Case Study In Goa, West Coast Of India. Chemosphere, 270, 129359.
- Smith, S. D., & Markic, A. (2013). Estimates of marine debris accumulation on beaches are strongly affected by the temporal scale of sampling. PloS one, 8(12), e83694.
- Sreelakshmi, T., & Chitra, K. C. (2021). Microplastics contamination in the environment: An ecotoxicological concern. Intern. J. Zool. Invest, 7(1), 230-258.
- Sridharan, S., Kumar, M., Singh, L., Bolan, N. S., & Saha, M. (2021). Microplastics as an emerging source of particulate air pollution: A critical review. Journal of Hazardous Materials, 418, 126245.
- Sruthy, S., & Ramasamy, E. V. (2017). Microplastic pollution in Vembanad Lake, Kerala, India: the first report of microplastics in lake and estuarine sediments in India. Environmental pollution, 222, 315-322.

- Sunitha, T. G., Monisha, V., Sivanesan, S., Vasanthy, M., Prabhakaran, M., Omine, K., ... & Darchen, A. (2021). Micro-plastic pollution along the Bay of Bengal coastal stretch of Tamil Nadu, South India. Science of the Total Environment, 756, 144073.
- Van Cauwenberghe, L., & Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. Environmental pollution, 193, 65-70.
- Veerasingam, S., Mugilarasan, M., Venkatachalapathy, R., & Vethamony, P. (2016). Influence of 2015 flood on the distribution and occurrence of microplastic pellets along the Chennai coast, India. Marine pollution bulletin, 109(1), 196-204.
- Veerasingam, S., Ranjani, M., Venkatachalapathy, R., Bagaev, A., Mukhanov, V., Litvinyuk, D., ... & Vethamony, P. (2020). Microplastics in different environmental compartments in India: Analytical methods, distribution, associated contaminants and research needs. TrAC Trends in Analytical Chemistry, 133, 116071.
- Veerasingam, S., Saha, M., Suneel, V., Vethamony, P., Rodrigues, A. C., Bhattacharyya, S., & Naik, B. G. (2016). Characteristics, Seasonal Distribution And Surface Degradation Features Of Microplastic Pellets Along The Goa Coast, India. Chemosphere, 159, 496-505.
- Wu, C., Zhang, K., & Xiong, X. (2018). Microplastic pollution in inland waters focusing on Asia. *Freshwater microplastics: emerging environmental contaminants?*, 85-99.
- Xu, P., Peng, G., Su, L., Gao, Y., Gao, L., & Li, D. (2018). Microplastic risk assessment in surface waters: A case study in the Changjiang Estuary, China. Marine pollution bulletin, 133, 647-654.
- Yi, Y. Z., Azman, S., Primus, A., Said, M. I. M., & Abideen, M. Z. (2021). Microplastic ingestion by crabs. *The 6th proceeding of Civil Engineering. School of Civil Engineering*, 363-375.

- Zalasiewicz, J., Waters, C. N., Do Sul, J. A. I., Corcoran, P. L., Barnosky, A. D., Cearreta, A., ... & Yonan, Y. (2016). The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene, 13, 4-17.
- Zhang, T., Sun, Y., Song, K., Du, W., Huang, W., Gu, Z., & Feng, Z. (2021). Microplastics in different tissues of wild crabs at three important fishing grounds in China. Chemosphere, 271, 129479.