Survey of Abundance and Types of Microplastic on Goan Beaches

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Survey of Abundance and Types of Microplastic On Goan Beaches" is based on the results of investigations carried out by me in the M.Sc. Environment Science at the School of Earth, Ocean and Atmospheric Sciences, Goa University under the supervision of Dr. Nikita P. Lotlikar, 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.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "Survey of Abundance and Types of Microplastic on Goan Beaches" Is a bonafide work carried out by Ms. Renuka Amrut Naik under my supervision in partial fulfillment of the requirements for the award of the degree of Masters of Science in the Discipline Environmental Science at the School of Earth, Ocean and Atmospheric Sciences, Goa University.

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PREFACE

The sun-drenched shores of Colva and Sernabatim beaches in Goa are facing a silent menace - microplastic pollution. This survey has delved into the intricate dynamics of microplastic abundance, and types in these coastal havens from November to February. The study has focused on sediment and surface water and has unveiled that tourism and fishing are the primary contributors to microplastic contamination. Through meticulous analysis, the study has uncovered a pervasive presence of microplastics in all samples, predominantly originating from the degradation of larger plastic items. Sieve analysis has revealed concentrations peaking in the 250 µm and 100 µm fractions, with fibers emerging as the dominant shape across sand and water samples. The study's findings highlight the accumulation of microplastics in beach sediment, underscoring the urgent need for mitigation strategies. It suggests potential connections between fishing, tourism, and tidal patterns and their potential impact on the distribution of microplastics. These revelations reinforce the imperative to combat microplastic contamination in coastal environments. While challenging, proactive measures such as banning single-use plastics, enforcing littering penalties, and raising public awareness can mitigate this issue. The study hopes to catalyze positive change, prompting concerted efforts to protect and conserve the natural beauty of Goa's coastal treasure.

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LIST OF ABBREVIATIONS, ACRONYMS, SYMBOLS, AND UNITS

Abbreviation	Full-form
MP	Microplastics
OCED	Organization for Economic Cooperation and Development
UNEP	United Nations Environment Programme
g	Grams
L	Liters
µm	Micrometer
mm	Millimeter
ml	Milliliter
HCl	Hydrochloric Acid
H_2O_2	Hydrogen Peroxide
CO_2	Carbon Dioxide

ABSTRACT

The study aimed to analyze microplastics' occurrence, distribution, and characteristics in Colva and Sernabatim beaches. The study focused on monthly observations of microplastics in sand and surface seawater on both beaches with a focus on their shape, sieve size, and color. The monthly data revealed that February had the highest concentration of microplastics on both beaches. The analysis based on sieve size throughout all months indicated that the 250 µm and 100 µm sieves exhibited the highest concentrations of microplastics, whereas the 500 µm sieve showed the lowest levels From November to December, fibers emerged as the predominant shape found in both sand and water across both locations. Notably, colorless microplastics were more prevalent in sand, whereas black-colored microplastics were more commonly observed in water. Sand samples showed a higher abundance of microplastics than water samples. The notable increase in microplastic levels during February can be attributed to peak tourism and fishing activities, suggesting that both tourism and fishing may significantly contribute to microplastic pollution on both beaches.

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Keywords: Microplastic, Colva Beach, Sernabatim Beach, HCl, Sieves, Sand, Water, Fishing, and Tourism Activity.

CHAPTER 1: INTRODUCTION

1.1 Background

Plastic pollution has increased significantly due to rising demand and low-cost production. According to a recent report by the Organisation for Economic Cooperation and Development (OECD, 2022), global plastics production doubled between 2000 and 2019, reaching 460 million tonnes mainly in emerging economies (https://shorturl.at/qHKMR). Unfortunately, poor waste management practices have led to plastic waste seeping into various environments, including the ocean (Jambeck et al., 2015). Global plastic waste generation has doubled since 2000, with nearly two-thirds of plastic waste coming from short-lived plastics, 40% from packaging, 12% from consumer goods, and 11% from clothing and textiles. Only 9% is recycled, while 19% is incinerated, 50% goes to landfill, and 22% ends up in uncontrolled dumpsites or terrestrial or aquatic environments (OECD, 2022). There is a global concern regarding the extensive presence of plastic pollution in aquatic environments. According to the OECD report, around 6.1 million tonnes of plastic waste leaked into aquatic environments, including 1.7 Mt that directly reached the oceans. Plastic pollution in the marine environment mainly originates from land-based sources (80%), while the remainder originates from ocean-based (20%) activities like industrial fishing, shipping, etc (https://shorturl.at/cstTZ). Plastics can enter the environment through various pathways, such as littering, runoff, sewage overflow, wind-blown debris, accidental spills, and more (Golam Kibria et al., 2023.

Plastic takes centuries to degrade and forms garbage patches in the ocean. The ocean is estimated to contain 50-75 trillion pieces of plastic, which break down into microplastics (https://shorturl.at/mrBQ3). Approximately 12% of plastic waste in the ocean consists of microplastics. Based on the recent OECD report, both macroplastics (88%) and microplastics (12%) can be found in the ocean, (OECD, 2022) and an estimated 15 trillion microplastic particles float on the ocean surface (van Sebille et al., 2015). Both primary and secondary sources are accountable for the presence of microplastic in the ocean (https://shorturl.at/eGLQ4).

1.2 Plastic

Plastic is a flexible and versatile material made of synthetic polymer, commonly derived from petrochemicals, natural gas, and coal Moore 2008, Shah et al. 2008). Different chemical additives and colors are mixed with plastic, which determines their specific properties. Examples of additives are colorants, foaming agents, plasticizers, antimicrobials, and flame retardants (Shah et al. 2008) following which small molecules are converted into long-chain polymers using synthesis techniques (Moore 2008). Plastic can be molded into various shapes and has properties such as a high strength-to-weight ratio, chemical resistance, and flexibility (Thompson et al. 2009). There are two types of plastic: Thermoplastics are polymers that soften when heated and solidify upon cooling. They are flexible, lightweight, can be easily molded multiple times, and are recyclable on the other hand thermostable plastic once exposed to heat, becomes permanently hardened and rigid. They cannot be remolded or reshaped, and have limited options for recycling. These plastics are known for their high heat resistance (https://shorturl.at/drGHZ).

1.2.1 Types of Polymers

Polymers are complex organic compounds formed through polymerization; where small molecules join together to create extensive chainlike structures. These materials offer versatility as they can be molded, extruded, cast into diverse shapes and films, or drawn into filaments for use as textile fibers (https://shorturl.at/gmER7). The most dominant types of polymers in global plastic manufacture are PE, PP, PVC, PS, and PET, (Lithner et al., 2011). According to Andrady and Neal (2009), these plastic materials make up about 90% of the world's total production. The most abundant types of polymers are:

Polyethylene (PE): PE stands out as a versatile material employed in various products, distinguished by its different densities, including Low-Density Polyethylene (LDPE) and High-Density Polyethylene (HDPE). LDPE is super bendy and used for things like shopping bags, food containers, and packaging. HDPE is a bit tougher and used for plastic bottles, pipes, boats, and chairs. LDPE also works as a liner in beverage cartons and for surfaces that need to resist rust (https://shorturl.at/coY45).

Polypropylene (PP): Polypropylene (PP) is a widely used thermoplastic polymer known for its strength and durability. It is utilized in the production of various items like Tupperware, car parts, diapers, and yogurt containers. PP is highly resistant to fatigue, heat, and acid, making it versatile and useful in many industries, including medical, automotive, and food packaging (https://shorturl.at/bfIT0)

Polyvinyl chloride (PVC): PVC can be either rigid or flexible and is used in a variety of industries. Rigid PVC is commonly found in building materials and pipes, while flexible PVC is used in plumbing, wiring, insulation, and flooring. Due to its lightness, durability, and ease of processing, PVC is increasingly being used as a substitute for traditional materials in many applications (https://shorturl.at/bfIT0)

Polyethylene Terephthalate (PET): PET is a versatile thermoplastic resin that is widely used due to its excellent chemical resistance and recyclability. It is lightweight, shatterproof, and has a high strength-to-weight ratio. PET is used in a variety of products, including clothing fibers, engineering resins, and food containers. It is commonly used in polyester fabrics, beverage containers, and food packaging (https://shorturl.at/bfIT0)

Polycarbonate (PC): PC is a plastic material that is both strong and transparent. This material is preferred for various applications because it is 250 times stronger than glass. In addition, polycarbonate is easy to mold and work with, which offers more design flexibility. It is commonly used in products like DVDs, greenhouses, sunglasses, and police riot gear (https://shorturl.at/uPWX7).

Polystyrene (PS): PS also known as Styrofoam, is a cheap, effective insulating plastic used in food packaging, construction, cups, shipping and product packaging, egg cartons, cutlery, and building insulation. However, it poses dangers as it can release toxins and is non-biodegradable. It harms wildlife and is not easily recycled (https://shorturl.at/krJMX)

Acrylonitrile-Butadiene-Styrene (ABS): ABS, a plastic polymer made by combining styrene, acrylonitrile, and polybutadiene, is highly known for its strength, flexibility, and resistance to impact. It is widely used in various industries, including automotive, refrigeration, and consumer goods, such as luggage, toys, and gauges, due to its glossy appearance and ease of processing (https://shorturl.at/).

1.2.2 Types of Plastic

Plastic can be classified based on the type of degradation it undergoes resulting into categories: Biodegradable, conventional, oxo-degradable plastic, and bio-based plastic. Plastics are a common material used in various industries, but conventional plastics are derived from non-renewable resources like petroleum and do not contain any additives to accelerate their degradation (Sinan, 2020). However, other types of plastics have additives specifically designed to accelerate their degradation. Oxo-degradable plastics break down into smaller pieces over time when exposed to oxygen and heat due to these additives (Thomas et al., 2012). Biodegradable plastics are another type of plastic that contains an additive to make them break down quickly. Biodegradable plastics are designed to be more environmentally friendly and differ from traditional plastics made from petroleum-based materials that can take hundreds of years to break down. Despite being more sustainable, biodegradable plastics have their limitations. Bioplastics, on the other hand, are made from renewable resources such as corn starch, sugarcane, or vegetable fats and are becoming more popular as a sustainable alternative to conventional plastics (Sinan, 2020). Breaking down these plastics through biodegradation is possible, but it poses a significant challenge due to the necessity of favorable environmental conditions and specific microorganisms, which aren't consistently available across different environmental settings (Paco et al, 2018; Rivas et al., 2016). It's essential to understand that not all biodegradable plastics are entirely bio-based, but all biobased plastics are biodegradable.

1.3 Possible Sources of Plastic in Marine Ecosystems

The presence of plastic pollution in aquatic ecosystems is a problem that arises from various sources, both on land and at sea. Over 70% of land-based sources are the main contributors to plastic pollution in marine environments (Andrady, 2011). Inadequate waste management, tourism, littering, urban runoff, industrial discharges, and sewage outflows are among the factors that lead to plastic waste in marine environments (Thushari et al. 2017; Browne et al. 2007). This plastic waste enters aquatic ecosystems like rivers and streams and eventually ends up in the ocean (as a riverine outlet) (Rech et al., 2014; Zhao et al., 2015). In addition to land-based sources, there are also sea-based sources of plastic pollution in marine environments. For instance, fishing, shipping, and maritime operations release plastic waste directly into the ocean (Cole et al., 2011; Derraik, 2002; Thushari et al., 2017). Fishing fleets, in particular, are known to be persistent sources of plastic pollutants (Derraik, 2002). Furthermore, operational activities at port facilities can also contaminate coastal areas. In addition to human activities, climatic conditions like storms, hurricanes, and flooding, as well as natural phenomena such as tidal action and wind, play a role in carriers of plastic waste and contribute significantly to pollution in marine environments (Thompson et al., 2005; Moore et al., 2002). In Zhanjiang Bay, South China, Peng Zhang et al. (2022) found more plastic litter in summer than in winter, attributing the difference to seasonal factors and increased human activity.

1.4 Degradation of Plastic

Plastic debris accumulates in terrestrial and marine ecosystems due to its extensive production and long-lasting nature (Barnes et al., 2009; Rillig et al., 2012). Plastics can last for hundreds or thousands of years depending on their characteristics and environmental conditions (Plastics Europe 2019). Despite slow degradation, environmental factors contribute to the breakdown of plastics, leading to changes in polymer properties through biotic or abiotic processes. Plastics can break down due to both living and non-living factors. Abiotic degradation happens when plastics break down due to non-living factors such as temperature, light, and physical forces (Andrady, 2015). Biotic degradation on the other hand, happens when living organisms break down plastics through physical and biochemical processes (Cade, 2002; Dawson et al., 2018; Jang et al., 2018; Porter et al., 2019; Danso et al., 2019; Cau et al., 2020; Mateos-Cardenas et al., 2020). Microorganisms, including bacteria, fungi, and insects, are major contributors to the biodegradation of plastics (Crawford and Quinn 2017). These plastics break down into fragments of different sizes and shapes through mechanical and thermal degradation (Barnes et al., 2009: Pirsaheb et al., 2020). In the ocean, larger plastic items undergo abiotic and biotic defragmentation processes such as UV radiation, mechanical weathering, oxidative properties of the atmosphere, hydrolytic properties of seawater, biofilm formation, etc., and eventually form microplastics, which are particles measuring between 0.1 μm and 5 mm (Hidalgo-Ruz et al., 2012; Law; Andrady 2011; Webb et al., 2013; Thompson, 2014).

1.5 Microplastic

In 2004, the term "microplastics" was introduced to describe tiny particles of plastic. However, there is no consensus on the exact size of these particles that would classify them as microplastics. Some experts have suggested that particles smaller than 5mm should be considered microplastics (Hidalgo-Ruz et al., 2012; Thompson, 2014). Microplastics are a growing concern. Based on their origin microplastics are differentiated, into primary microplastics and secondary microplastics (Cole et al, 2011). Microplastics can occur in various sizes, colors, and shapes (Hidalgo-Ruz et al., 2012).

1.5.1 Classification of Microplastic Based on Their Shape

Microplastics have diverse shapes and forms that influence their interactions with the environment and organisms. Some common shapes of microplastics include:

1. **Fragments**: Fragments are small plastic pieces with jagged edges and irregular shapes, primarily formed from the breakdown of larger plastic items including bottles, packaging materials, and other forms of plastic waste. (Hidalgo-Ruz et al., 2012; Prapanchan et al., 2023; Kaviarasan, T., 2022).
2. **Filament**: Filament microplastics are elongated plastic particles resembling fibers or threads, originating from various sources such as synthetic textiles, ropes, fishing nets, and other plastic materials that degrade into smaller pieces (Prapanchan, et al., 2023; Kaviarasan, T., 2022)
3. **Films**: Microplastic films are thin, flat sheet-like plastic structures that form through the degradation and amalgamation of plastic bags, packaging films, plastic sheets, and various other plastic items (Prapanchan et al., 2023; Kaviarasan, T., 2022).
4. **Microbeads:** Microbeads are tiny plastic particles typically less than 5mm in size, commonly found in personal care and cosmetic products like exfoliating scrubs, toothpaste, and body wash (Gregory 1996; Fendall and Sewell 2009; Cluzard et al. 2015; Napper et al. 2015; (Prapanchan et al., 2023).
5. **Fibers:** Microplastic fibers are elongated thin structures resulting from synthetic textiles, ropes, fishing gear, nets, lines, discarded nets, etc. (Salvador Cesa et al., 2017; Cesa et al., 2020; De Falco et al., 2020; (Prapanchan et al., 2023).
6. **Microfibers**: Microplastic microfibers are ultra-fine strands, flat and thin of plastic material, and are smaller than fibers mostly shaded from synthetic textiles, ropes, fishing gear, nets, lines, discarded nets, etc (Prapanchan et al., 2023).
7. **Irregular shapes Microplastics**: Microplastics can also take on diverse irregular shapes, such as flakes, irregular fragments, and amorphous particles. These irregularly shaped

microplastics are typically formed through the gradual degradation and weathering of larger plastic items over time (Prapanchan, et al., 2023).

1.5.2 Classification of Microplastics Based on Their Size

Plastic can be differentiated based on its size or form in various ways. One study done by Kaviarasan, T., (2022) quantified and characterized macro, meso, and microplastic litter across six sandy beaches along the southeast coast of India. Some common sizes of microplastics include the standardized size categories of pieces of plastic (Veeasingam et al., 2022; Kai Zhang et al, 2021; Prapanchan et al., 2023).

1. **Macroplastics**: plastic debris or pieces that have sizes greater or equal to 25 mm.
2. **Mesoplastic**: plastic debris or pieces that have sizes less than 25 mm but more than 5 mm
3. **Microplastic:** plastic debris or pieces that have sizes less than 5 mm but more than 1mm.
4. **Mini- Microplastics:** plastic debris or pieces that have sizes less than 1 mm but more than 1 μm
5. **Nanoplastic**: plastic debris or pieces that have sizes less than 1 μm

1.5.2 Microplastics Based on Their Origin/ Sources

Microplastics, as classified by the United Nations Environment Programme (UNEP) in 2016, can be categorized as either primary or secondary. The classification of Primary Microplastics and Secondary Microplastics is compiled on the studies done by Thushari & Senevirathna, (2020), Kai Zhang et al. (2021), and Prapanchan et al. (2023).

1. **Primary Microplastics**

Definition: Primary microplastics are small plastic particles intentionally manufactured for use in various products such as cosmetics, personal care items, industrial abrasives, and microbeads. They are produced directly as microplastics and are not the result of larger plastic items breaking down (Cole et al. 2011).

Sources: These microplastics enter the environment through human activities, including product disposal, industrial processes, wastewater discharge, runoff, and direct release, as well as intentional use in certain applications.

Characteristics: primary microplastics are designed to be small in size and typically exhibit spherical or irregular shapes, ranging from nanometers to millimeters in diameter.

Examples: Common examples of primary microplastics include microbeads in exfoliating scrubs, synthetic fibers in clothing, and pellets used in industrial processes. These examples illustrate how primary microplastics are integrated into various products and industries, contributing to environmental pollution.

2. Secondary Microplastics

Definition: Secondary Microplastics are plastic particles that form as a result of the degradation of larger plastic objects such as bottles, bags, and packaging, due to environmental deterioration and fragmentation processes.

Sources: These microplastics are created through the breaking down and degradation of macroplastics like plastic waste, fishing equipment, deteriorated plastic debris, etc in the environment, predominantly through physical, chemical, and biological processes.

Characteristics: They exhibit varying sizes, shapes, and compositions, which depend on the original plastic material and the degradation mechanisms.

Examples: include fragmented portions of plastic bottles, deteriorated plastic bags, and weathered plastic debris found along coastlines, all arising from the disintegration of larger plastic objects.

1.6 Effect of Microplastic

1.6.1 In Marine Ecosystems

The presence of microplastics in marine environments has significantly impacted the ecosystem's health and biodiversity, affecting most of the organisms and overall environmental well-being. Here are some key effects reported by Yokota et al. (2017), Schwarz (2019), Thushari & Senevirathna (2020), and Prapanchan et al. (2023).

1. **Ingestion by Marine Organisms:** Microplastics are frequently mistaken for food by marine organisms, leading to ingestion at various levels of the food chain (Nelms et al., 2021). A study conducted, by Anbumani et al. (2018) and Prata et al. (2020), highlights the widespread ingestion of microplastics by marine organisms across different trophic levels. This ingestion leads to physical harm, reduced feeding efficiency, and issues with nutrient absorption, posing risks such as digestive blockages, respiratory issues, reduced reproductive success, and internal injuries (Goswami et al., 2023). Additionally, microplastics can adhere to the outer surfaces of fish, causing abrasions, inflammation, and potential exposure to harmful chemicals. The bioaccumulation of microplastics within organisms can lead to the transfer of plastic particles up the food chain, potentially impacting organisms8 across all levels of the trophic levels, spanning from phytoplankton to apex predators.
2. **Transfer of Toxic Chemicals**: Microplastics can absorb and concentrate toxic pollutants like polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals from the surrounding water. Upon ingestion by marine organisms, these microplastics can release these absorbed contaminants into their tissues, potentially causing toxicological effects, bioaccumulation, and biomagnification in the food chain. Additionally, it can act as a carrier for persistent organic pollutants (POPs) and heavy metals from the surrounding water (Prapanchan et al. 2023; Thushari & Senevirathna

(2020). Smaller plastic particles tend to accumulate more toxic substances (Andrady, 2011).

3. **Habitat Degradation and Ecosystem Impacts**: The accumulation of microplastics in marine environments alters habitat structure and biodiversity, impacting benthic organisms and sediment processes and leading to long-term ecological consequences.
4. **Disruption of Trophic Interactions:** Microplastics disrupt trophic interaction in marine ecosystems by altering feeding behavior, growth rates, and reproductive success of organisms, causing cascading effects on food webs and ecosystem dynamics. These changes can impact the stability and resilience of marine ecosystems, potentially altering species abundance and distribution.
5. **Disruption of Feeding and Nutrition:** Microplastics interfere with the feeding behavior of marine organisms by impairing their ability to distinguish between plastic particles and natural prey. The presence of microplastics in the digestive tract can lead to malnutrition, reduced energy reserves, and impaired growth and reproduction.
6. **Spread of Invasive Species:** Microplastics act as vectors for transporting invasive species, pathogens, and harmful microorganisms across marine environments. Colonization of microplastic surfaces by biofouling organisms facilitates the spread of non-native species, disrupting native ecosystems through competition and predation.
7. **Overall Environmental Impact**: Cumulative effects of microplastics contribute to ecosystem degradation, biodiversity loss, and negative impacts on ecosystem services. Additionally, the microplastic contamination at nesting sites poses further threats to egg viability, hatchling survival, and overall population health.
8. **In Coastal/ Beach Ecosystems**

1. **Habitat Alteration**: Accumulation of microplastics on beaches alters sediment composition, microbial communities, and coastal ecosystem health.

2. **Microplastic Transport and Persistence:** Microplastics deposited on beaches can be transported by wind, waves, and tides when they disperse plastic particles across coastal regions and marine ecosystems. Due to their small size and buoyancy, microplastics persist in beach sediments, posing long-term environmental challenges and contributing to the global microplastic pollution problem.

1.6.2 Effect of Microplastic in Humans

Humans are exposed to microplastics through various means, such as consuming contaminated food and water, inhaling airborne particles, and directly interacting with consumer products (Toussant et al., 2019; Silva-Cavalcanti et al., 2017). An emerging concern about microplastics is their potential entry into the human food chain through the consumption of seafood and terrestrial food products, which can pose potential health risks to humans (Rist et al., 2018; Wright and Kelly, 2017; Smith et al., 2018; Enyoh et al., 2019). Studies done by Karbalaei et al. (2018) and Campanale et al. (2022) have reported that microplastics may accumulate in the gastrointestinal tract, potentially affecting digestive health, nutrient absorption, and immune system function (Hwang et al., 2019). These microplastics can translocate from the gastrointestinal tract to other tissues and organs due to their small size, potentially entering the bloodstream and eventually reaching all body parts from cell to organ, raising concerns about long-term accumulation (Lehner et al., 2018; Campanale et al., 2022; Karbalaei et al., 2018). Inhalation of airborne microplastics, especially in urban or indoor environments, raises concerns about respiratory health (Campanale et al., 2022). Microplastics can absorb and transport toxic chemicals like POP and heavy metals, posing health risks when ingested. Additionally, the release of additives and plasticizers from microplastics may disrupt endocrine, liver, and thyroid functions, alter insulin resistance, reproductive activities and systems, affect immune responses, cause inflammatory reactions, and even cause cancer in the long run (Karbalaei et al., 2022). Concerns also exist about microplastics acting as carriers for pathogens and bacteria, increasing the risk of infections and other long-term health impacts. One study conducted by Barboza et al. (2018) found the presence of microplastics in the blood, brain, and placenta, while another study reported by Smith et al. (2018) found the presence of more than 90% microplastics in human stool.

Aim: To study the abundance of different types of microplastics found on Colva and Sernabatim beaches

Objective: To identify and enumerate types of microplastics found on Colva and Sernabatim beaches based on their shape, size, and color.

Hypothesis:

The distribution of microplastics significantly depends on factors such as fishing activity, tourist seasons, and tidal action, both in sediment and water.

CHAPTER 2: LITERATURE REVIEW

A study by Peng Zhang et al. 2022 examined plastic waste presence and characteristics at Yugang Park Beach and found that white plastic waste, particularly foam, was the most common, with a correlation noted between litter frequency and sediment characteristics. Plastic waste sources encompass tourism, domestic activities, shipping, aquaculture, and climate change. Waste distribution is influenced by rainfall, typhoons, wind, runoff, and river currents. A study by Jarin Tasnim et al. (2023) assessed microplastic pollution in surface beach sediments across seven coastal beaches in Bangladesh during the monsoon and winter seasons. The study aimed to evaluate spatiotemporal variations of microplastic debris and provide baseline data for better management. Significant quantities of microplastics were found in all sampled beaches, a total of 340 particles from 1.4 kg of sand samples. Predominant microplastics were in white and fiber form, indicating the influence of anthropogenic sources such as urbanization, industrialization, and tourism on the study site. Where one study done by Markic, A., et al (2023) studied microplastic levels in sediments of Vava'u, Tonga, both in intertidal and subtidal areas. The researchers discovered that intertidal regions had the highest concentrations of microplastics. The most prevalent colors found were blue, black, and colorless, with blue and black fibers being the most common. Fibers were also the dominant shape observed, making up more than 60% of identified microplastics in both zones.

In a study conducted by Sunitha, T. G., et al (2021) on the abundance and composition of microplastics in seawater, wet sand, and dry sand samples from an urban sandy beach Marina, the composition of the microplastic particles on the sand was predominantly filamentous, with blue and pink colors being the most common. The study showed more microplastics in wet sand than in water. Another study done by Kaviarasan, T., (2022) found that filaments were the predominant shape, with white being the most common color in both backshore and intertidal zones. This difference was mostly due to a combination of land-based and fishing activities. A study done by Karthik, R., (2018) examined the distribution of microplastics on the beaches of Tamil Nadu, particularly looking at sources such as riverine outlets on beaches, tourism, and fishing activities. The samples taken from the high tide line had more microplastics than those from the low tide line. Beaches located near river outlets tend to have higher levels of microplastics compared to those impacted by tourism and fishing activities. The most common types of microplastic debris were fragments, fibers, and foam. Overall, human activities like river pollution, tourism, and fishing had a noticeable impact on the amount of microplastics present on the beaches. The study done by Suresh, A., et al (2018) looked into the presence of microplastic pollution in water, sediment, and fish samples from various sites in the Cochin estuary and nearby coastal areas in Kochi. The levels of microplastics were higher in the estuarine water and sediment compared to the beaches, with average amounts of 751.7 ± 452.21 particles/m3 and 1340 ± 575.22 particles/kg, respectively. Stations close to urban areas had notably higher concentrations of microplastics. Examination of dissected fish samples identified nine microplastics, mostly fibers, all categorized as secondary microplastics. The most commonly seen colors of microplastics were white and black. Another study was conducted by Rabari, V., et al (2022). evaluate the levels of microplastics on 20 beaches along the Gujarat coast, and they were categorized based on human activities. The contamination of microplastics varied from 1.4 to 26 MPs/kg of sediment, with fibers being the most prevalent at 89.98%, followed by films (4.75%), fragments (3.36%), and foam (1.89%). Transparent microplastics were found to be the most common, accounting for 52.90% of the total. Sites with high levels of anthropogenic pressure from fishing or tourism exhibited higher levels of contamination, whereas sites with lower impacts had lesser contamination possibly due to reduced industrialization and tourism. The study done by Nithin, A., et al (2022) examined the spatial and seasonal distribution of microplastics in the Vellar estuary, focusing on both water and sediment samples. Over two years, the summer season consistently exhibited the highest microplastic abundances in both surface water and sediment samples. Fibers were prevalent year-round in surface water, while fragments dominated sediment. Blue and black emerged as the most abundant microplastic colors. The differences observed between 2018 and 2019 in the Vellar estuary may be attributed to various factors, including rainfall patterns, human activities, and sediment dynamics, underscoring the temporal variability in microplastic pollution levels in the estuarine environment. The study done by Ranjani, M., et al., (2022) explored the seasonal variation and factors influencing microplastics at six prominent beaches along the southeast coast of India in Chennai. Spatial variation of MPs during the northeast (NE) monsoon showed a higher range (76–720 items/kg) compared to the southwest (SW) monsoon (range: 84–498 items/kg). The high tide (HT) zone showed a higher no of MPs than the low tide (LT) zone in all seasons. Fibers, along with blue and red-colored microplastics, were dominant during both SW and NE monsoons suggesting sources from fishing, textile, riverine outflow, and urban activities. Nagarajan Manimozhi et al. (2022) investigated spatiotemporal variations in microplastic in water, sediment, and salt in Thoothukudi's coastal salt pans. The study analyzed microplastic fluctuations across seasons, noting the highest occurrence during the monsoon season: 52 MPs/kg in salt, whereas in sediments (45 MPs/kg) and surface water (42 MPs/liter) during the in post-southwest monsoon. white-colored microplastics with fragments and irregular shapes were found to be dominant in all the samples. Polyethylene and polypropylene were the predominant microplastics found in all samples. Kaushik Dowarah and Suja P. Devipriya (2019) conducted a study on microplastic levels in beach sediments in Puducherry, India, examining their association with fishing, tourism, and recreational activities. Through observational methods, they analyzed microplastic abundance, finding an average of 72.03 ± 19.16 particles per 100 g of dry sediment across six beaches. Fishing emerged as a significant contributor to microplastic pollution, with a strong correlation between fishing activities and microplastic abundance, underscoring the impact of human actions on coastal contamination. The study identified common polymers such as Polypropylene, HDPE, LDPE, Polystyrene, and Polyurethane in beach sediments. M.

Tiwari et al. (2019) investigated the presence of microplastic particles on Indian beaches, focusing on Girgaon, Mumbai, Tuticorin, and Dhanushkodi. They found that Mumbai exhibited the highest microplastic concentration (220 ± 50 # MP kg^{-1}), followed by Tuticorin (181 ± 60 # MP kg^{-1}) and Dhanushkodi (45 ± 12 # MP kg^{-1}). They observed that Fibrous microplastics dominated across all sites, followed by granules and films, and results found in Mumbai displayed the most advanced polymer aging and weathering, indicating heightened degradation. Polyethylene and polystyrene microplastics dominated across all sites. The fluctuations in microplastic levels were attributed to land-based waste and urban stormwater runoff, aligning with previous literature on microplastic pollution and its environmental drivers.

A study done by Mahua Saha et al. (2021) investigated the presence of microplastics in water, sediment, and biota samples from the Sal estuary in Goa, India, during the post-monsoon season. They observed that fiber and black and blue color microplastics were predominant in all three matrices. The water had an average MP concentration of 48 - 19.4 MPs/L, while sediment samples had 3950 - 933 MPs/kg and the Biota samples had smaller MPs (10-300 mm). The study identified polyacrylamide, polyacetylene, and ethylene vinyl alcohol as primary polymers. The study conducted by Veerasingam et al. (2016) examined the presence and distribution of microplastic pellets (MPPs) along the Goa coast, focusing on six sandy beaches. Their research revealed that MPPs, predominantly white and composed of PE and PP, were present in varying quantities across the sampled beaches. They highlighted spatial and seasonal variations in MPP distribution, attributing these differences to factors like wind, currents, weathering processes, polymer types, and hydrodynamics.

CHAPTER 3: METHODOLOGY

3.1 Study Area

Two south Goan beaches namely Colva and Senarbatim located in the Salcate Taluka, South Goa District, were selected for microplastic sampling.

Colva Beach lies 39 km away from Panaji and is one of the most famous tourist sites. The beach stretches about 2.4 km along the Arabian Sea, with pristine white sand, and coconut palm trees lined along its shoreline. This beach is lined with resorts, holiday homes, and various food stalls along its length. Colva Beach is known for its various types of water sports activities. There is also a river discharge present on the beach. Senarbatim Beach lies 1 km further from Colva Beach and is one of the fewer explored beaches of South Goa.

Colva and Senarbatim beaches are prime locations for fishing, with many motor trawlers anchored off the coast along the beaches. When selecting the sampling sites, factors such as popular tourist locations and areas with fishing activities were taken into account.

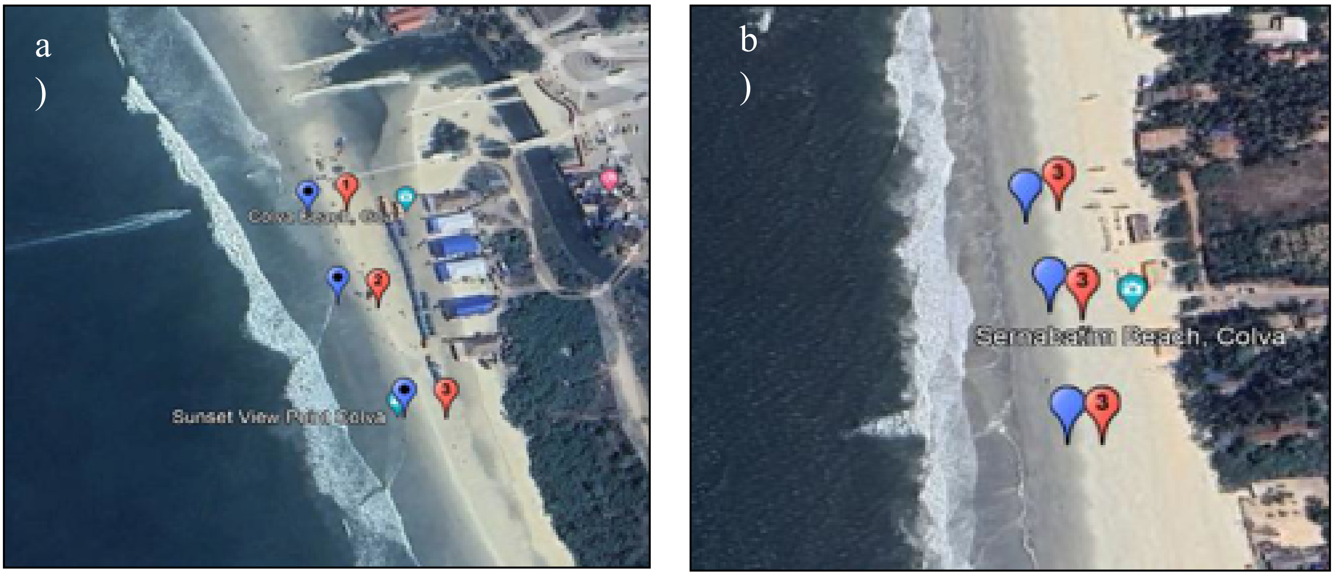


Figure 3.1: Maps of Study Area Showing Sampling Points (a) Colva Beach, (b) Sernabatim Beach

Table 3.1: The Location of Sampling Sites Across the Beach of Goa

Station	Matrices	Colva Beach		Sernabatim Beach	
		Latitude	Longitude	Latitude	Longitude
Station 1	Sand	15°16’32.87"N	73°54’47.38" N	15°15’51.93"N	73°55’59.78" N
	Water	15°16’32.69"N	73°54’46.70" N	15°15’51.66"N	73°54’59.30" N
Station 2	Sand	15°16’30.16"N	73°54’48.31" N	15°15’49.57"N	73°54’0.51" N
	Water	15°16’30.17"N	73°54’48.63" N	15°15’49.75"N	73°54’59.98" N
Station 3	Sand	15°16’27.86"N	73°54’48.85" N	15°15’47.16"N	73°54’1.15" N
	Water	15°16’27.82"N	73°54’48.38" N	15°15’47.17"N	73°54’0.64" N

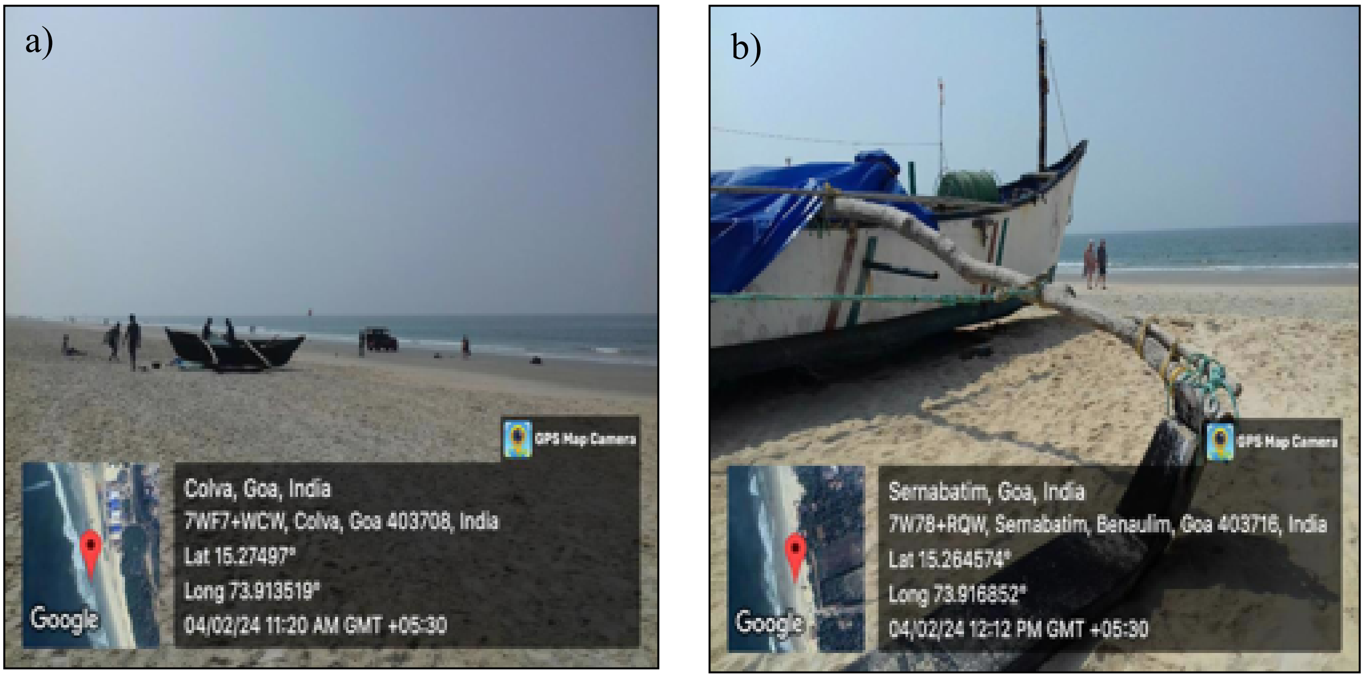


Figure 3.2: GPS Photo of Both Locations (a) Colva Beach, (b) Sernabatim Beach

3.2 Methodology

3.2.1 Step 1: Water and Sand Sampling

A total of three locations (Figure 3.1 a and 3.1.b), 50 meters apart were selected for seawater and sand sampling on both beaches, monthly during the post-monsoon season from November to February. A total of 6 sand samples and 6 water samples were collected per sampling per month. Sampling locations on each beach are shown in Table 1.

For water sampling, 10 liters of water samples were directly collected from the surface zone of the beach as depicted in (Figure 3.3.b). For sand sampling, a quadrant 1 x1 meter was constructed using sticks, and approximately 50 g of sand was collected for five regions within the quadrant (Fig 3.3. a). The samples were collected in pre-label bags and this process was repeated for the remaining two locations on the beach. Large and mesoplastic debris on top of the sands was removed (Coppock et al., 2017; Karkanorachaki et al., 2018). Finally, a total of 24 surface sand samples were obtained for further analysis.

3.2.2 Step 2: Treatment and Extraction of Microplastic from Water and Sand Samples

I. Water Sample Analysis

After the water sample was brought to the laboratory, the entire 10 Liters of each water sample was filtered using a vacuum filtration unit (figure 3.5. a) using a filter paper with a diameter of 47 mm and pore size of 10 mm and then dried in the oven at 40°C. The Filter paper was exposed to the H_2O_2 to remove organic matter (modified from Mahua Saha et al. 2021). This method was also followed for other water samples.

II. Sand Sample Analysis

b. Sample Preparation

After the sand sample was brought to the laboratory, the bulk sample was dried in an oven at 60°C till a constant weight was achieved. Then 30 g samples were separated from the total sample and were used for further analysis. This method was followed for further samples too.

c. The Purification Method

To extract organic matter from the samples, 45 mL of 30% H_2O_2 was added to the sand in a glass beaker covered with aluminum foil (figure 3.4 a). The samples were continually stirred on the first day and thereafter were kept undisturbed for 2-3 days (Mahua Saha et al., 2021). After treatment, the samples were washed and dried in an oven at 70°C.

Following this, 25 ml of 4.5% HCl was used on the dried sample to remove the calcareous fragments such as shells (Vidyasagar et al., 2018; M. Zobkov et al., 2020, S. Venkataramana et al., 2022). Calcareous fragments produce bubbles when they come into contact with the HCl solution due to the formation of CO_2 (figure 3.4. a and 3.4. b) This test was repeated until no more bubbles could be seen in the sample. The effect of HCl on plastic was also checked by subjecting different types of plastics to 5% HCl. After treatment, the samples were washed and dried in an oven until completely dry. This method was followed for further samples.

d. Sieving

The dried samples devoid of organic matter and calcium carbonate were sieved through an array of 500 µm, 250 µm, and 100 µm sieves stacked on top of each other by shaking the sieves together (figure 3.4.c). The particles retained on each sieve were transferred to a Petri plate and covered with aluminum foil.

3.2.3 Step 3: Enumeration of the microplastic

The collected samples on the Petri plate were examined using SZ X16 Stereo Microscope (Figure 3.5. b). Pictures were clicked using Mag Version Software. The identified microplastic samples were then divided according to their color, shape, and size (according to their sieve size).

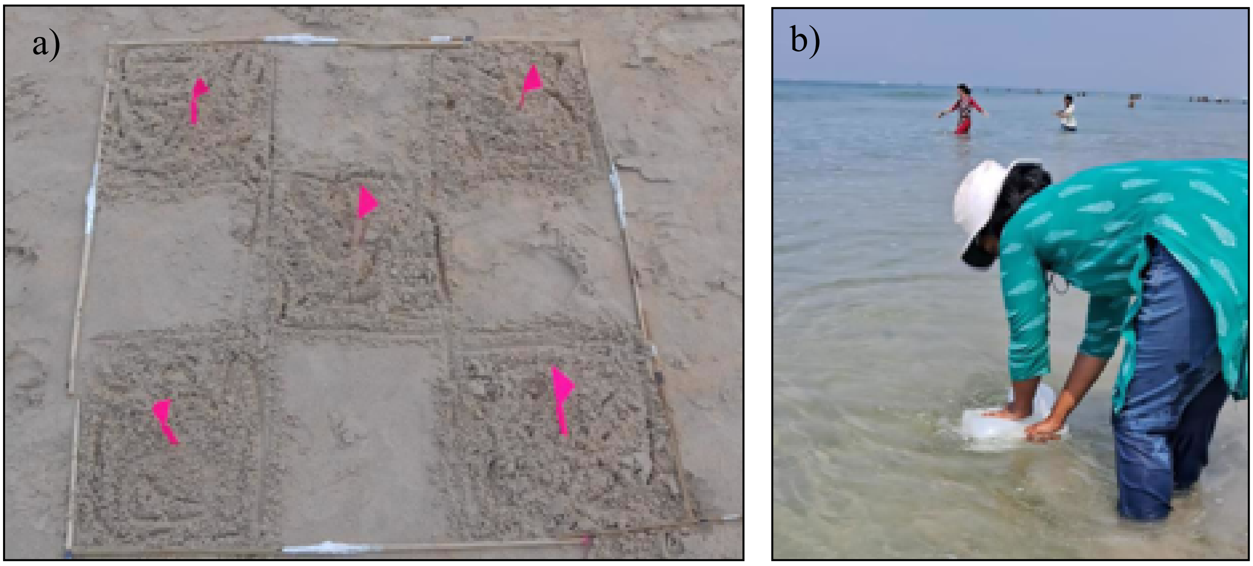


Figure 3.3: Photos During the Collection of Samples (a) 1X1 Quadrant Divided into 5 Sub Samples, (b) Water sampling collection

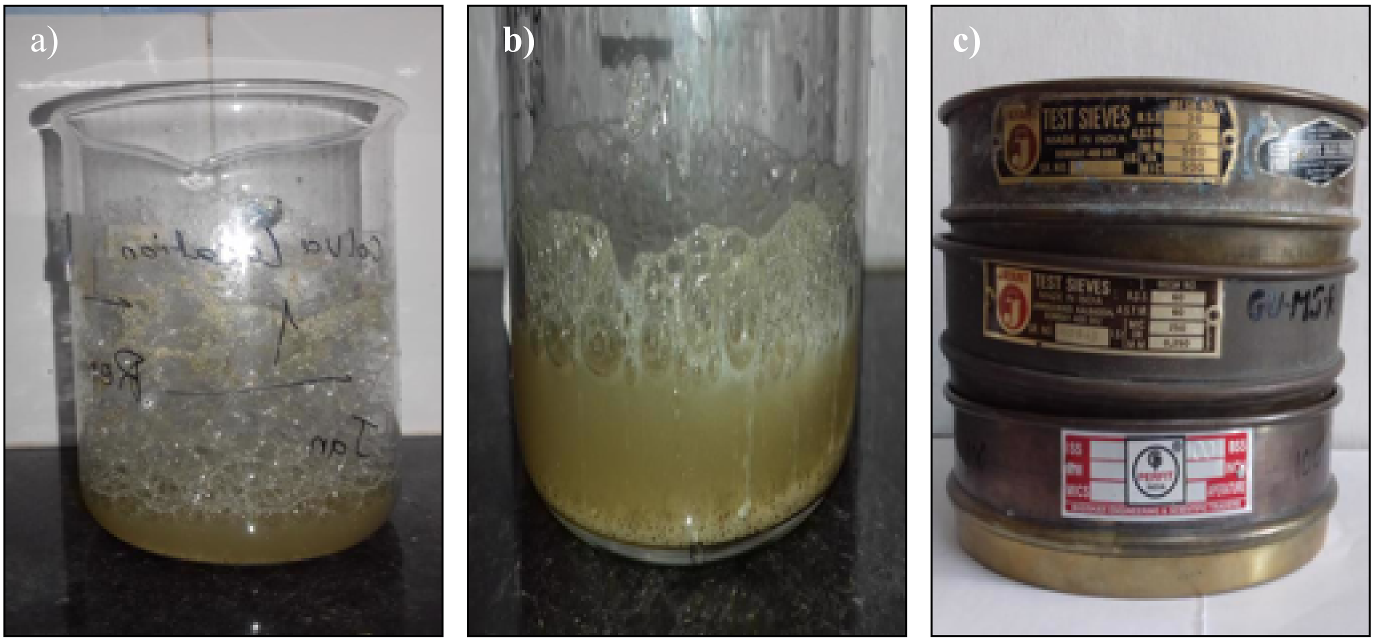


Figure 3.4: Photos During the Experiment (a) Samples Submerge with 30% Hydrogen Peroxide Solution, (b) Sample Submerge with 4.5 % HCL Solution Reacting with Shell Fragments, (c) Different Sizes of Sieves Used for Sand

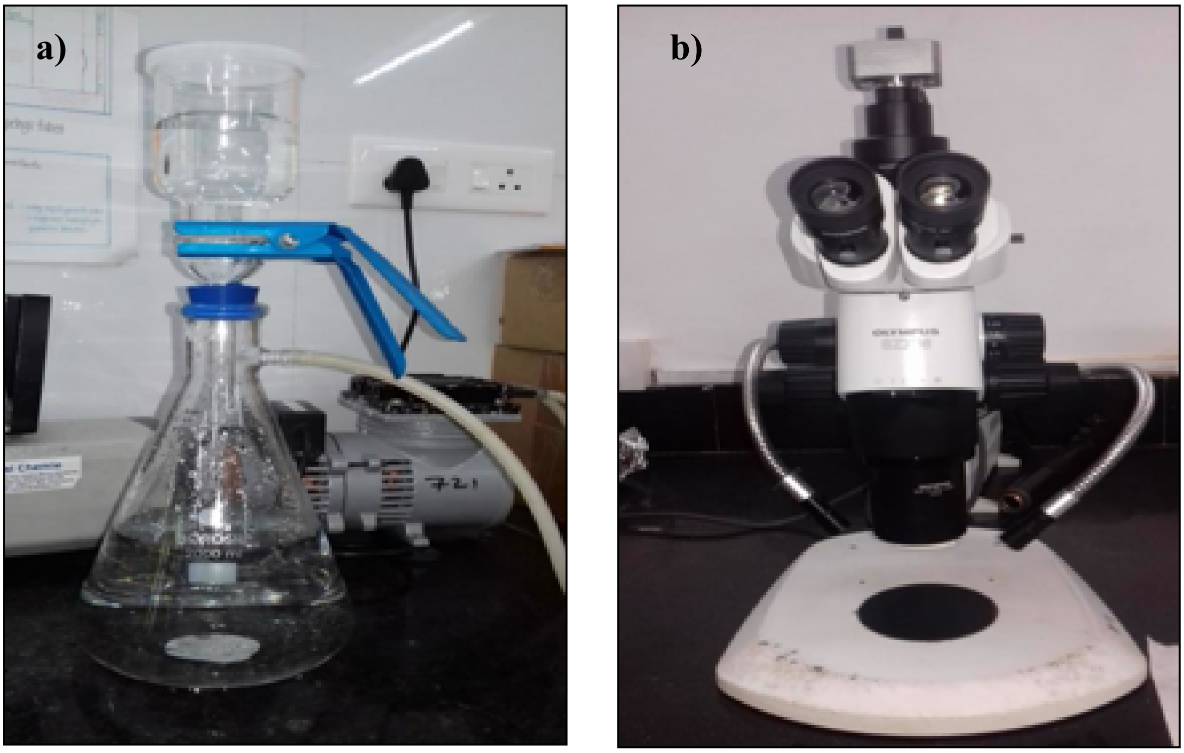


Figure 3.5: Instrument Used During Experiment (a) Water analysis: Vacuum Filtration Unit, (b) Olympus SZ X16 Stereo Microscopic with Mag Vision Camera

CHAPTER 4: RESULT, ANALYSIS, AND DISCUSSION

Samples were gathered from the sediment and surface water of Colva and Sernabatim beaches and subsequently categorized according to their shape, size, and color.

4.1 Microplastic Found in the Sediment of Colva Beach and Sernabatim

The sediment samples taken from the Colva and Sernabatim beaches were categorized according to their shape, size, and color.

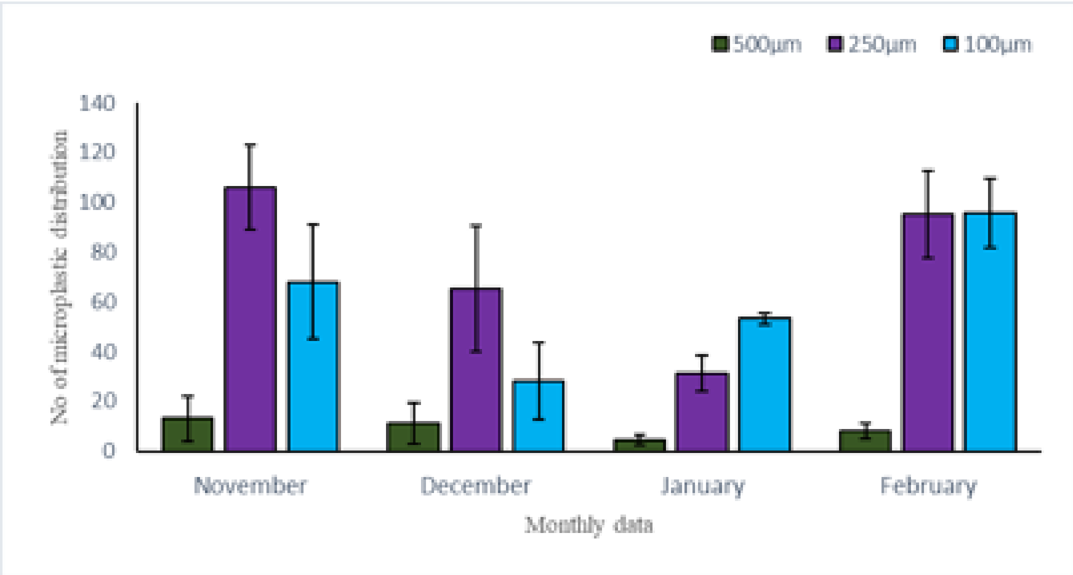
4.1.1 Classification of Microplastics Based on Their Sieve Size

The analysis of microplastic distribution at Sernabatim and Colva beaches was classified based on sieve size, with monthly samples collected and analyzed. In graphs (Figures 4.1 a and b), the X-axis represents the months of sample collection, while the Y-axis indicates the number of microplastics found in each sieve size. The average level of microplastics per month is represented by each bar on the graph, with error bars denoting standard deviation to illustrate variability. Based on the monthly data, it was found that the highest concentrations of microplastics were recorded in February at Colva Beach. Similarly, Sernabatim Beach also showed similar results in terms of microplastic abundance.

The analysis reveals that the maximum microplastics were observed in the 250 µm sieve in November in Colva, while in Sernabatim, in December. The 500 µm sieve consistently had the least number of microplastics at both locations each month. Furthermore, the data show that in November, the maximum number of microplastics was found in the 250 µm sieve followed by the 100 µm sieve at Colva Beach, while at Sernabatim Beach, the 100 µm sieve showed the highest number of microplastics followed by 250 µm sieve. In December and January, both locations exhibited a nearly identical pattern of microplastic distribution. However, by February, the trend began to show an increase, with the counts of microplastics in the 250 µm and 100 µm sieves, demonstrating a similar pattern between the two beaches.

As depicted in the bar graph, a discernible trend emerges in microplastic levels at Colva Beach from November to February, showing fluctuations, Conversely, in Sernabatim, the data reveal a consistent upward trajectory in microplastic levels over the same period.

a)



b)

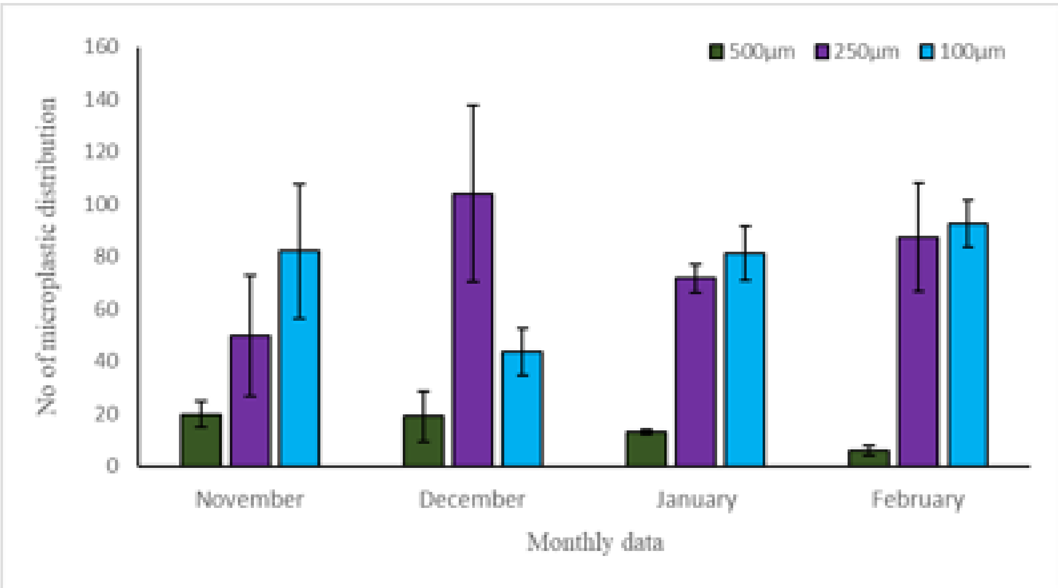


Figure 4.1: Bar Graph Interpreting Overall Microplastic Size On (a) Colva Beach, (b) Sernabatim Beach

The coastline of Goa is facing an increasing problem with microplastic pollution due to tourism and fishing activities. Tourism and fishing activities contribute to the generation of plastic waste, which reaches the shoreline directly or indirectly through coastal waters (H.B. Jayasiri, 2013; Wright et al., 2021). Various factors such as wave action, tides, wind patterns, seawater density, and ocean dynamics govern the distribution and abundance of microplastics in sediment (Rayan, 2015; Fazey and Ryan, 2016; Liubartseva et al., 2016). Additionally, the composition of microplastics on beaches can also be influenced by seawater (Sunitha, T. G., et al., 2021). Both primary and secondary microplastics contribute to the microplastic content in beach sediment, with in-situ weathering of plastic litter in the beach environment being a significant mechanism for the generation of microplastics (Andrady, 2011). The sources of microplastics on the beach may include the degradation of macroplastics (as previously mentioned). Furthermore, Seasonal variations can also play a role in the distribution and abundance of microplastics on the beach (Veerasingam et al., 2016; Nithin, A., et al., 2022; Jarin Tasnim et al., 2023)

The sieving method, as described by Nabi et al. (2022), was utilized to separate microplastics from sediments. Microplastic particles ranging from 500 μm to 100 μm were categorized as both primary and secondary microplastics. The analysis revealed that the highest concentrations of microplastics were observed in February at both locations, possibly due to an increase in tourism activities like water sports, shacks, more plastic litter, etc, fishing activities, tidal action, wind, and the influence of seawater, along with seasonal variations. This finding aligns with previous studies which identified land-based like tourism and fishing activities as could be significant sources of microplastic distribution (Browne et al., 2010; Andrady, 2011; Karthik, 2018; Dowarah and Devipriya, 2019; Kaviarasan, 2022; Markic, A., et al., 2023). Additionally, factors such as riverine outlets, seawater impact, tidal action, wind, and currents were found to contribute to the microplastic presence on beaches (Thiel et al., 2013; Kim et al., 2015; Veerasingam et al. 2016; Sunitha, T. G., et al., 2021). Furthermore, the degradation of macroplastics due to UV radiation was identified as another contributing factor (Endo et al., 2005).

High microplastic abundance was also observed in November after February in both locations could be attributed to the impact of the monsoon season on coastal microplastic distribution (Ranjani, M., et al., 2022; Nagarajan Manimozhi et al., 2022). During the monsoon season, increased river discharges result in a higher influx of plastics and microplastics into the marine environment (Ashwini S. K. & George K. Varghese, 2020). Additionally, sieve size variations seen in 500 µm had the least microplastics in each month, possibly due to the small amount of sediment sampled and the inverse relationship between particle size and abundance (Lots et al., 2017). This trend may explain the increasing number of microplastics in the 250 µm and 100 µm sieves over time.

Another reason could be due to the fragmentation of macroplastics like discarded nets, fragmented nets, ropes, and fishing gear, from fishing activity and tourism, synthetic cloths, single-use plastic bags, fragmented plastic sheets, plastic fragments, bottles, cans, and bottle caps fishing nets was seen on the beach which can lead to secondary sources of microplastic (Arthur et al., 2009), Microplastics in the sand fragment more when exposed to UV radiation from the sun during low tides on the beach (Ronda, A. C, et al.,2023) this could be the probable reason for the MP abundance in the sediments in sand. Similar findings were reported in former studies (Wu et al., 2019; Han et al., 2019; H.B. Jayasiri2013; Kumar et al., 2016; Ribeiro et al., 2021; Acosta-Coley and Olivero-Verbel, 2015). Lee et al. (2013) observed a positive correlation between macro and mesoplastics, as well as between macro litter and micro litter across all beaches studied.

4.1.2 Classification of Microplastics Based on Their Shape

The microplastic distribution at Sernabatim and Colva beaches was analyzed based on shape, with monthly samples collected and examined. A variety of microplastic shapes like fibers (figure 4.2 a, b, g, j), Filaments (figure 4.2 f,), fragments (figure l), and films (figure j, k, n) were observed along with a 'line' shaped microplastic was also found (figure 4.2 o).

It was observed that amongst all the shapes that were found on sieving the sediment samples, more than 70% of MPs found were fibers, followed by the filament (20%), fragment (10%), and films (5%) in Colva Beach whereas, in Sernabatim, 80% MPs found were fibers followed by filament 10%, fragment 5%, films %, and lines 2% during February.

Further, it is seen that from November and December, it was seen that fiber (<85%), filament (>12%), and fragments (5%) were common at both locations with slight variations in the percentage of each shape. However, from January and February, it showed more variations in shape. In January, besides fibers, filaments, and fragments, film (>5%) was found at both locations. In February, along with fibers, filaments, and fragments, films also found at Colva Beach, whereas in Sernabatim similar results were but one more shape was were found lines (>2%).

Figures 4.3 illustrate the different shapes found from November to February, on both beaches, with fibers being the most abundant shape. The only difference that was observed in February was that films were found in Colva, whereas lines were observed in Sernabatim. Overall, similar trends in microplastic distribution were seen, with some variations in shapes found during certain months.

The analysis conducted during the period from November to February revealed a diverse array of microplastic shapes across different locations, with notable influences from both local fishing activities and tourism (Ribo et al., 2021). Coastal areas like Colva and Senarbatim beaches are particularly vulnerable to microplastic pollution due to their proximity to fishing activity, fishing vessels, and related activities. Moreover, tourism can also contribute significantly to microplastic pollution through the use of synthetic clothing, plastic litter, and beach elements (Ribo et al., 2021).

Figure 4.2. Various Shapes of Microplastics are Found on Colva and Sernabatim Beaches in Sediment

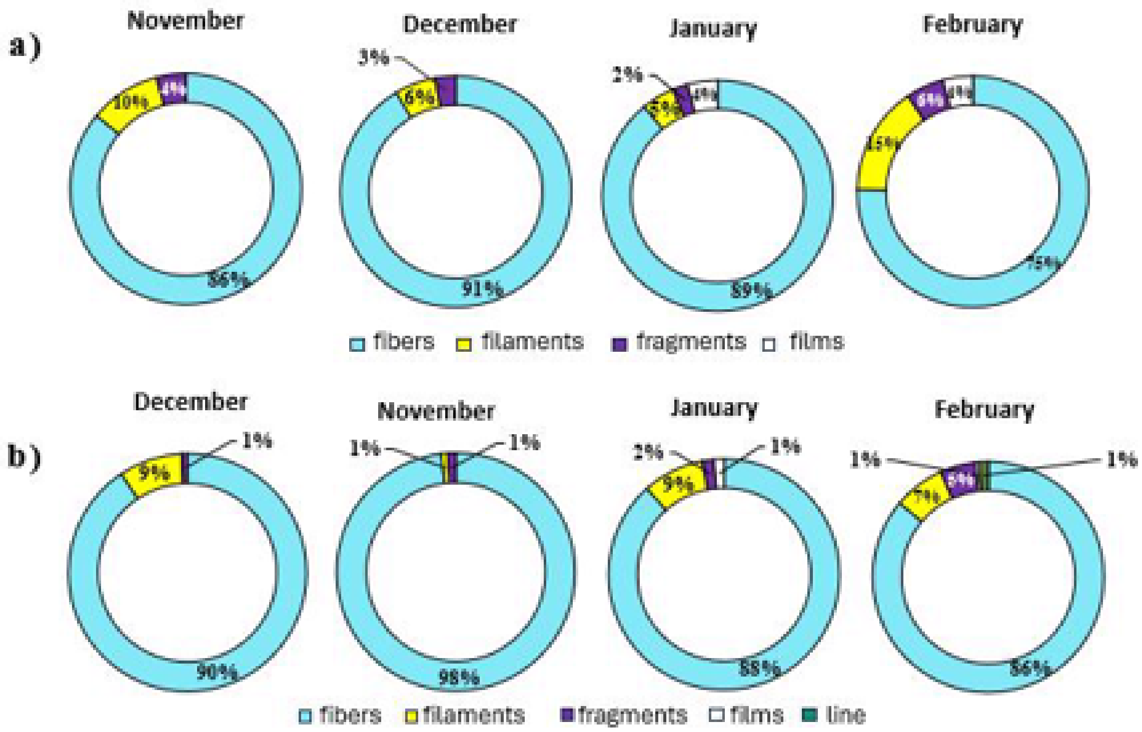


Figure 4.3. Distribution of Variable Microplastic Shapes in the Sediments of (a) Colva and (b) Sernabatim Beaches

Notably, the most frequently occurring litter consists of single-use plastics, as reported by Kaladharan et al. (2017), highlighting items such as carry bags, sachets for beverages, and PET bottles as dominant on Goa beaches. The presence of various shapes of microplastics observed between November and February, alongside variations in location, suggests a multitude of potential sources contributing to their presence as explained in shape distribution. Analysis of monthly data shows that fibers are the most abundant form of microplastics in the sediments, potentially attributed to fishing and tourism activity activities. A similar result was seen in the (Saha 2021). Some of the studies done by Aytan et al. (2016), Karthik et al. (2018), and Pinon-Colin et al. (2018) support this, citing fishing nets as a major source. Textiles also contribute to fiber pollution, as noted by Zhao et al. (2014); Yu et al. (2018); Napper and Thompson (2016). Browne et al. (2011) highlight fishing gear and wastewater effluents as significant fiber sources. Kim et al. (2015) the role of winds and currents in microplastic distribution along beaches. another Silva and Nanny (2020) identified fibers originating from fishing lines, nets, clothing, and non-woven textiles. Additionally, fragments and films originating from the degradation of macroplastic pieces such as plastic bags, plastic sheets, and plastic bottles are also present in lower proportions (Goswami et al., 2023; Ronda et al., 2023). Filaments may arise from primary or secondary sources like fishing nets, ropes, or synthetic materials. Fiber clusters and filament clusters were identified during the study, and according to other studies, these fiber clusters (4.2 d, e) were categorized as part of the overall fiber observations.

Research by Paul and Mark (2020) showed microplastic fibers in water and sediment samples contained PE, PP, Nylon, and PS, suggesting a common source from plastic and textiles. Similarly, Karthik et al. (2018) and Purca and Henostroza (2017) found PE and PP, widely used in items like bags and bottles, to be predominant microplastics. This indicates the complex origin of microplastics from both plastic and textile degradation

4.1.3 Classification of Microplastics Based on Their Colors

The bar graphs depicted in Figure 4.4, show the distribution of microplastics by color at Colva and Sernabatim beaches. The Y-axis displays the months when the samples were collected, while the X-axis represents the number of microplastics found. The graph illustrates fluctuations in the color of microplastics in sediment samples from November to February on both beaches. Based on the monthly data from Figure 4.4, it is evident that colorless microplastics (> 50%) exhibited the highest abundance on both beaches, followed by black, blue, and red.

Upon analyzing the graph, it is seen that from November to February, colorless, black, blue, and red are the predominant microplastic colors found at both Colva and Sernabatim beaches. However, there are variations in additional colors between the two locations across the months. In November, Colva Beach notably presents white, pink, and orange alongside the common colors, while Sernabatim Beach shows pink and yellow. Moving to December, both beaches share pink and orange, but Colva Beach additionally features yellow, while Sernabatim Beach displays sky blue and purple. As January approaches, pink remains prominent at both locations. Colva Beach introduces green and maroon, whereas Sernabatim Beach maintains orange. Finally, in February, Colva Beach showcases a diverse range of colors including pink, orange, yellow, sky blue, and maroon, while Sernabatim Beach presents yellow, pink, sky blue, green, and maroon.

As depicted from the bar graph, it is observed that colorless microplastics have the highest abundance, followed by black, blue, and red microplastics from November to February, in both locations. Additionally, pink and orange are consistently prevalent across all months and locations. February exhibits increased color variation in microplastics at both sites.

It is also crucial in identifying the potential to be swallowed by a visual predator and provides information on chemical composition, potential sources, and the level of degradation (Imhof et al., 2016; Castro et al., 2016; Blettler et al., 2017). Some study refers to colorless microplastics as "pale microplastics" (Alvarez-Zeferino et al., 2020), while other transparent colored microplastics (Dowarah and Devipriya 2019; Saha et al., 202; Rabari et al., 2022). In this study, colorless microplastics were the most abundant in sediments and accounted for more than 50%., followed by black blue, and red. The colorless microplastic can mostly be possibly due to its original color or due to the bleaching from weathering (Kalogerakis et al., 2017). This trend is consistent with studies conducted in India, where transparent colors microplastics are commonly found (Dowarah and Devipriya 2019; Saha et al., 202; Rabari et al., 2022; Markic, A., et al (2023; Alvarez-Zeferino et al., 2020). However, some studies have noted blue, black, and red microplastics as prevalent (Lots et al., 2017; Karthik et al., 2018; Frias et al., 2016), suggesting that pale coloration may indicate prolonged weathering and degradation. Moreover, translucent particles suggest degradation by UV light and subsequent bleaching (Karthik et al., 2018).

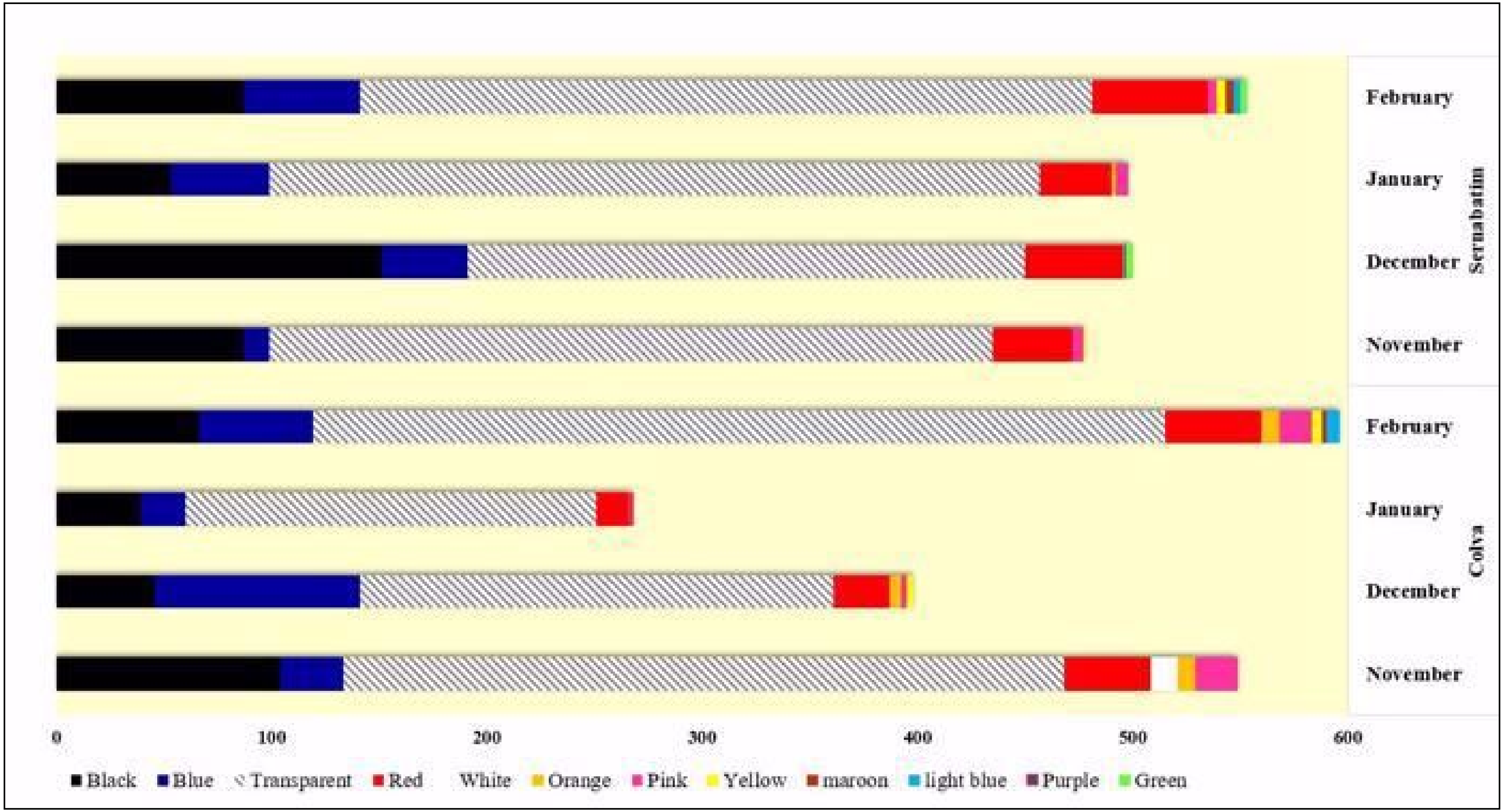


Figure 4.4: Microplastic Differentiation Based on Color in the Sediments of Sernabatrim and Colva Beach

The presence of black-colored microplastics may originate from synthetic fibers, particularly those associated with tourists' clothing, bags, etc. This is supported by studies such as Turner et al. (2019) and Wright et al. (2019), which found that the higher abundance of blue and black particles in beach sand could be attributed to detached synthetic fibers from clothing worn by tourists. These fibers often contain dyes like indigo blue or phthalocyanine, which are commonly found in semi-synthetic textile fibers. The elevated presence of transparent particles in seawater could be attributed to the over-oxidation of phenolic compounds in polymers lacking additives, influenced by the seawater's physicochemical conditions the phenomenon may cause discoloration of plastic particles (Arpia et al. (2021). Furthermore, colors such as blue, red, sky blue, and yellow may originate from fragments of nets or ropes. Other potential sources include the fragmentation of PET bottles, plastic toys used on beaches, fishing vessels, and plastic debris. The highest variety of polymers was seen in the study, with the most commonly found ones being PE, PET, and PP (Ronda et al. 2023)

4.2 Microplastic found in the waters of Colva Beach and Sernabatim

Water samples collected from Colva and Sernabatim beaches were classified based on their shape (Figure 4.5) and color (Figure 4.6). Different types of microplastics were identified in 10-liter samples.

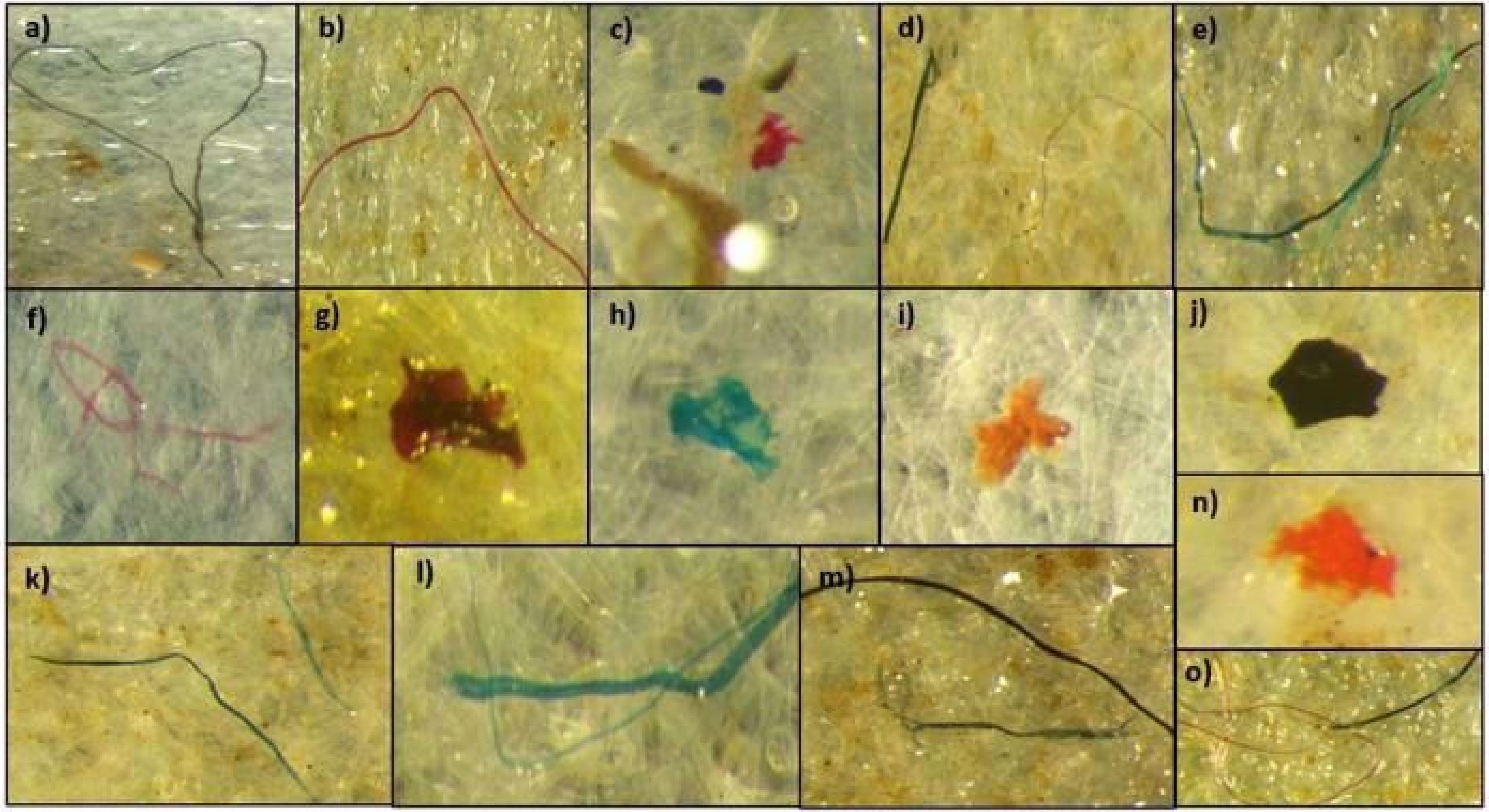


Figure 4.5: Various Shapes of Microplastics are Found on Colva and Sernabatim Beaches in Water

4.2.1 Classification of Microplastics Based on Their Shape

The analysis of microplastic distribution at Sernabatim and Colva beaches was conducted based on the shape of microplastics, with monthly samples collected and analyzed from water samples. Figures 4.6 illustrate the various shapes of microplastics found throughout the study.

It is observed that fibers accounted for more than 75% of the total, followed by filament (less than 20%) and fragments (less than 10%) at both Sernabatim and Colva beaches from November to February. The data indicates that from November to December, fibers, filaments, and fragments were the common shapes of microplastics found at both locations. However, in January, in addition to fibers, filaments, and fragments, films were also found at Colva Beach, which was not observed at Sernabatim. Similarly, in February, along with fibers, filaments, and fragments, films were also found at Colva Beach, while films were also observed at Sernabatim during this month.

The analysis of microplastic distribution at Sernabatim and Colva beaches revealed that fibers dominated (>75%), followed by filament and fragments from November to February. Notably, while common shapes persisted across months, films were exclusively detected at Colva Beach in January and were observed at both locations in February.

The analysis conducted during the period from November to February revealed a diverse array of microplastic shapes at both locations, with notable influences from both local fishing activities and tourism (Ribo et al., 2021). The presence of various shapes of microplastics observed between November and February in the water, alongside variations in location, suggests a multitude of potential sources contributing to their presence as explained in shape distribution. Analysis of monthly data shows that fibers are the most abundant form of microplastics in the sediments, which could be due to tourism like synthetic clothing, plastic litter, fishing activities like fragmentation of fishing nets during fishing, fishing vessels, etc, and other possible sources can be riverine discharge, sewage outlet, influences waves, tidal movement, wind flow, seawater density, and oceanic processes regulate the dispersion. Analysis of monthly data shows that fibers are the most abundant shape of microplastics in the water, potentially attributed to fishing and tourism activity activities. A similar result was seen in the (Saha 2021). Additional shapes such as filaments, fragments, and films were observed in water, likely originating from either primary or secondary sources.

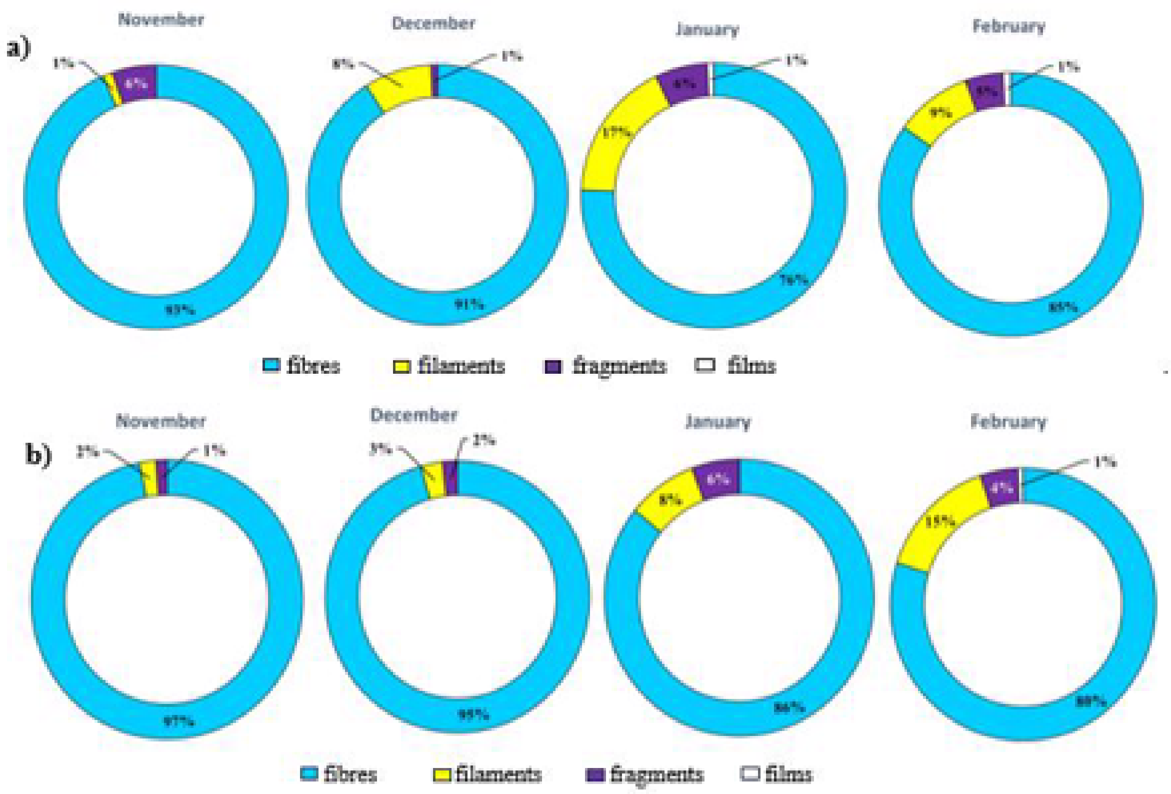


Figure 4.6: Distribution of Variable Microplastic Shapes in the Water of (a) Colva and (b) Sernabatim Beaches

Various physical, biological, and chemical processes, including UV radiation, contribute to the breakdown of larger plastic particles over time, leading to their fragmentation and the production of secondary microplastics (Moore, 2008; Andrady, 2011). While plastic particles in water are protected from solar UV radiation and high temperatures, slowing degradation rates (Gregory and Andrady, 2003; Barnes and Milner, 2005; Corcoran et al., 2009), however due to mechanical degradation by the swash and surf zones, influenced by the forceful action of breaking waves and sediment movement, is vital in generating microplastics from larger plastic objects (Chubarenko et al., 2018). Additionally, fragmentation in aquatic environments is induced by abrasion, wave action, and turbulence (Barnes et al., 2009). The absence of pellets or microbead microplastics in the study suggests that the predominant sources of microplastics can be secondary. (Barnes et al., 2009).

4.2.2 Classification of microplastics based on color

Figure 4.7 bar graph delineates the distribution of microplastics based on color at Colva and Sernabatim beaches in water samples. The X-axis represents the quantity of microplastics detected, while the Y-axis denotes the months when samples were collected.

The bar graph clearly shows that the highest abundance of black-colored microplastics was found in both locations from November to February. As per the analysis of the graph, it appears that the most common microplastic colors at Colva and Sernabatim beaches from November to February are black, blue, red, and white. However, there are variations in the prevalence of additional colors between the two locations across the months. In November, both beaches share the presence of purple-colored microplastics, but Colva Beach displays more variety with colors such as pink, orange, purple, and green, alongside the common colors. Moving to December, orange is observed at both locations, but Colva Beach displays green, while Sernabatim Beach exhibits pink and purple. As January progresses, pink and orange remain prevalent at both locations, yet Colva Beach introduces maroon, whereas Sernabatim Beach maintains the presence of purple. Lastly, in February, Colva Beach presents a diverse palette including pink, orange, yellow, gray, and sky blue, while Sernabatim Beach offers a more limited selection of orange, pink, sky blue, gray, and maroon. The bar graph illustrates that black-colored microplastics are the most abundant, followed by blue, red, and white microplastics from November to February at both Colva and Sernabatim beaches. Moreover, February exhibits more color variation in microplastics at both locations, with Colva Beach showing a higher abundance of color variations compared to Sernabatim Beach.

In this study, it is seen that black microplastics were the most abundant in water and accounted for more than 50%., followed by blue, red, and white. The presence of black-colored microplastics may originate from synthetic fibers, particularly those associated with tourists' clothing, bags, etc. This is supported by studies such as Turner et al. (2019) and Wright et al. (2019), which found that the higher abundance of blue and black particles in beach sand could be attributed to detached synthetic fibers from clothing worn by tourists. Another possible source can be fibers from the fishing nets. Another explanation for the high presence of black-colored microplastics in my study area may stem from the white background of the filter paper. Additionally, white-colored microplastics were observed, mainly because they were often intertwined with other microplastics

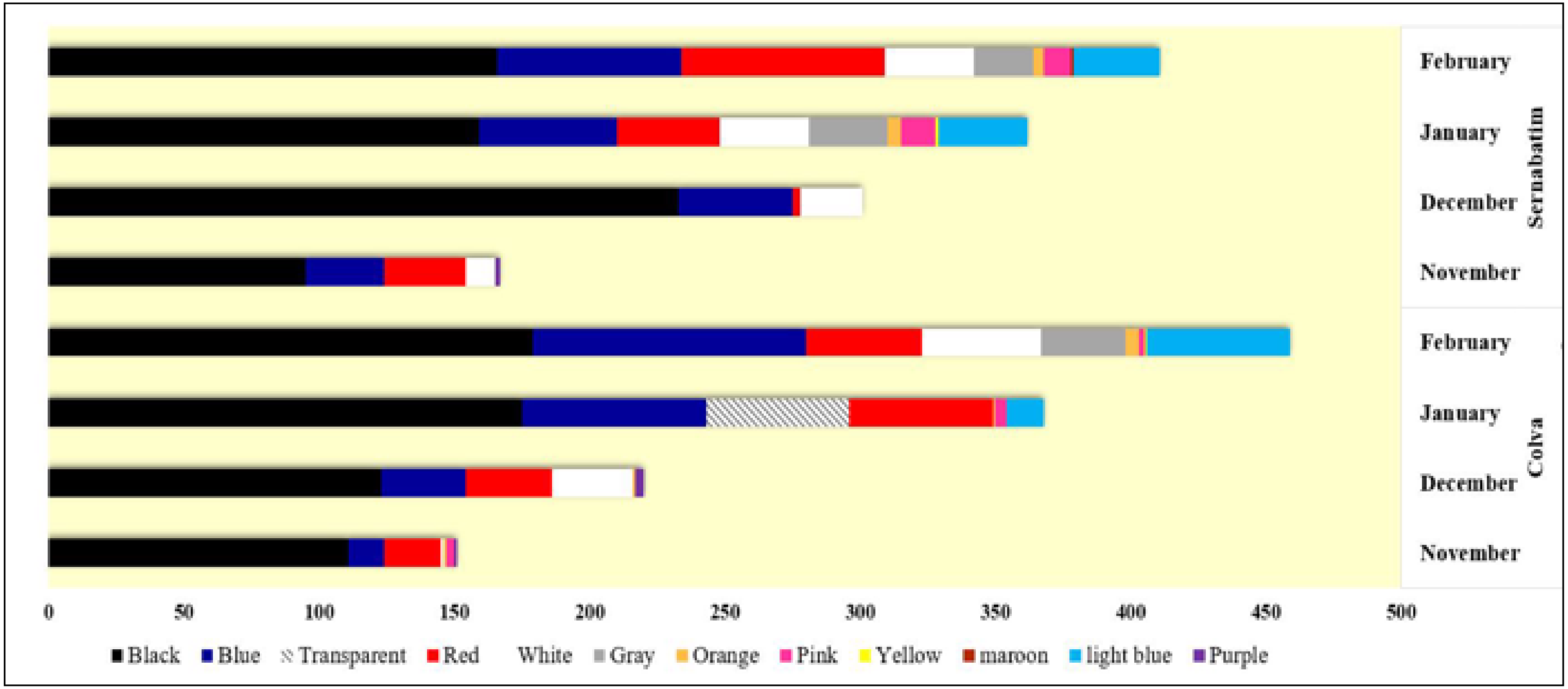


Figure 4.7: Microplastic Differentiation Based on Color in the Waters of Sernabatrim and Colva Beach

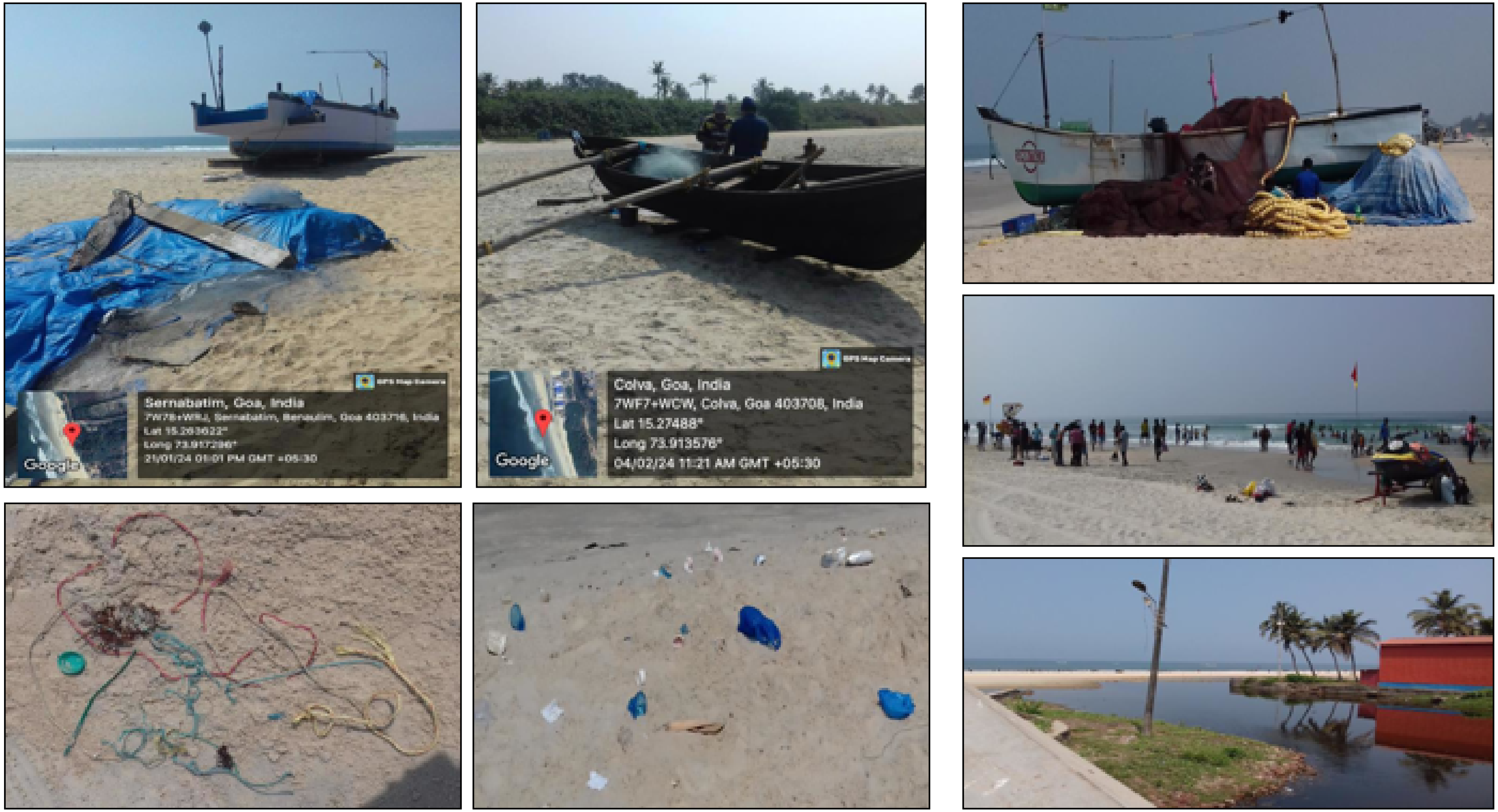


Figure 4.8: Photos of the Study Areas

Conclusions

The study investigated the distribution of microplastics in Sernabatim and Colva beaches in Goa from November to February. The analysis focused on microplastic presence in sediment and surface water and identified tourism and fishing as major causes of microplastic pollution in these areas. The study found that microplastics were present in all samples from both beaches and mostly originated from the breakdown of larger plastic items, a secondary source. According to the results of the sieve analysis, the microplastics were most concentrated in the 250 µm and 100 µm sieves, whereas the lowest concentration was found in the 500 µm sieve. The most common shapes found were fibers, filaments, and fragments, with fibers being the most dominant shape in both sand and water in both locations and all months. The study also found that microplastics were more abundant in sand than in water, indicating a potential accumulation of microplastics in beach sediment. Based on these findings, we can hypothesize that the distribution of microplastics is greatly impacted by various factors such as fishing, tourism, and tides in both sediment and water samples. These findings underscore the need to address microplastic contamination in coastal areas and the importance of monitoring all potential sources of microplastics entering beaches within a specific region. It is necessary to take action to tackle the issue of microplastic contamination in coastal areas and marine ecosystems. Although it is challenging to remove microplastics from the environment, we can prevent their pollution by implementing several measures such as prohibiting single-use plastics and microbeads in cosmetics, imposing penalties for littering, organizing cleanup campaigns for beaches and rivers, and regulating the release of industrial wastewater to prevent its direct discharge into the water without treatment, particularly from textile industries, raising public awareness about the formation of microplastics that occur when plastic enters the environment and the impact it has on both humans and the ecosystem.

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