DETERMINATON OF MICRO PLASTIC FROM FRESHWATER ENVIRONMENT: LENTIC ENVIRONMENT

A dissertation

Submitted for the partial fulfillment of the requirement for the award of the degree of

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In

CIVIL ENGINEERING

By

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DECLARATION

This Dissertation titled "**Determination of Micro Plastic from Freshwater Environment: Lentic Environment**" is prepared and submitted for the partial fulfilment of the of the requirements for the award of the degree of Master of Engineering in Civil Engineering course of Jadavpur University for the session 2020-2022.

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RECOMMENDATION CERTIFICATE

*This is to certify that the thesis entitled "**Determination of Micro Plastic from Freshwater Environment: Lentic Environment**' 'is prepared and submitted by **Gora Chand Tudu**, who got his name registered on for the session 2020-2022, for the fulfilment of the requirements for the award of Master of Engineering in Civil Engineering degree of Jadavpur University is absolutely based upon his work under the supervision of **Dr. Tumpa Hazra** and that neither his thesis nor any part of this thesis has been submitted for any degree or other academic award anywhere before.*

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ABSTRACT:

"**Micro plastics**", defined as plastics with a diameter of less than 5 mmwhether originating directly from industrial and household products or from the degradation of larger plastics, can have extremely negative effects on the public health and ecosystem and are now frequently found in various water bodies.An additional concern is the ability of microplastics to adsorb inorganic and organic pollutants and subsequently liberate them into marine and freshwater systems. Therefore, the aim of the present study is to estimate microplastic concentration of different urban lentic fresh waterbodies and determine the correlation between different water quality parameters with microplastic concentrations. The present study has been carried out for two seasons (i.e., post-monsoon and pre-monsoon) from 2021-2022. The water bodies identified for the present study are situated within the municipal boundary of Kolkata, West Bengal. In this study, different ponds within the Kolkata Municipal Corporation area were evaluated for the presence of micro plastics in terms of their characterization of water samples, correlation of micro plastics concentration with other water quality parameters, and classification of micro plastics using machine learning technique.

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Microplastic abundance in water is measured as items/m^3.For determining Pearson correlation coefficient, SPSS-2025 has been used. For morphological classification of microplastic support vector machine (SVM) and MATLAB R-2020a has been used.

The highest percentage for microplastic based on the shape were obtained as fibres (58 %), followed by films (11 %), fragments (5.0%), others (22%) and pellets (3.0 %) in post monsoon season.For pre-monsoon seasons out of total 419 microplastic particles collected the main type of plastics observed were fibres (59 %), followed by films (14 %), fragments (9.0%), others (14%), foam (2%) and pellets (2.0 %). No significant differences were found between the post monsoon and pre monsoon seasons based on the abundance, but significantly varied based on size and shape. To study correlation between water quality parameters and microplastics six water quality parameters were considered viz. pH, turbidity, TDS, DO, BOD_5 and total coliform count. All the water quality parameters are obtained significantly correlated with microplastic concentration at 90% or 95% significance level. DO concentration is negatively correlated with microplastic where BOD_5 and total coliform count are positively correlated with microplastic. Microorganisms are attached with microplastics and consume more DO therefore BOD_5 increases while DO decreases with microplastic concentration.The overall accuracy of support vector machine (SVM) for morphological classification is 89 %.

Keywords: Micro plastics, lentic environment, water quality

CONTENTS

Chapter – 1

INTRODUCTION:

1.1 Preamble: Due to their addition to products that are used almost daily, micro plastics particles have grown to be a global concern. Washing liquids, body and facial scrubs, soaps, toothpaste, and lotions are just a few of the cosmetic and personal care products that contain micro plastics. The distribution and impact of plastic waste, including micro plastics, on various natural ecosystems have received a lot of attention in India over the last few years. Micro plastics, which are plastic particles with a diameter of 1 mm to 5 mm or less, are pervasive human-made pollutants that have infiltrated the atmosphere, water, and land. Micro plastics are released into the environment through a variety of sources and entry points, either as primary Micro plastics that are already smaller than 5 mm in size or as secondary Micro plastics that are degrading.

One of the greatest environmental threats is the presence of micro plastics in the environment. Because of their generally smaller size, micro plastics are ingested by a variety of aquatic organisms, from zooplanktons to fish, suggesting the possibility of their accumulation in lentic environments. Therefore, micro plastics may also have an effect on human health and food safety. Micro plastics' hydrophobic nature also makes them an active site for the sorption of a variety of hazardous persistent organic and inorganic contaminants, which further increases their toxicity.

Fig.1. Plastic pollution in aquatic body(Image Credits: Rich Carey/shutterstock.com).

Microplastics which are also known as plastic micro beads, are small, often microscopic particles of plastic which make their way into our environment regularly via cosmetic products and generally when larger plastics are broken down into smaller pieces

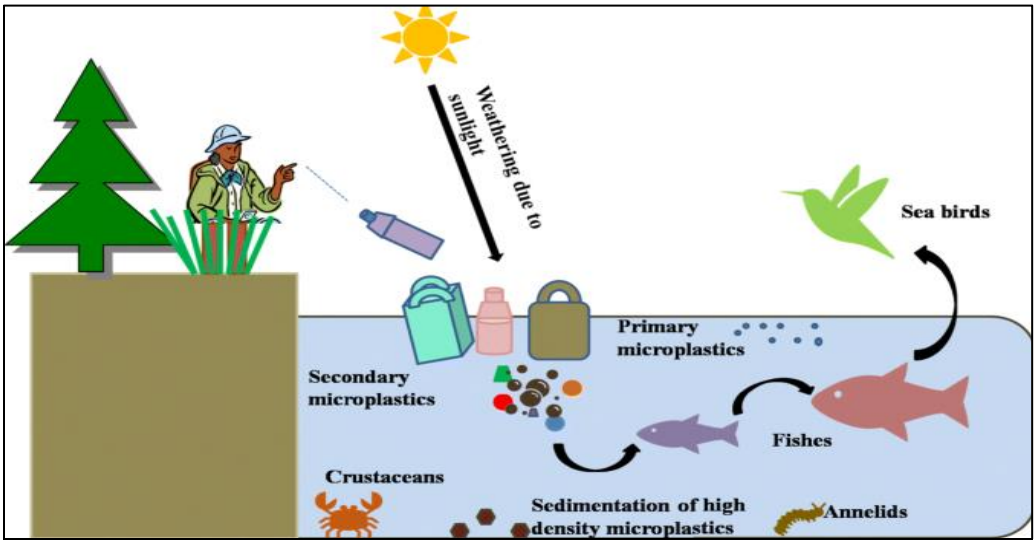


Fig.2. The effect of micro plastics in water and aquatic systems ((Espinosa et al. 2016).

Freshwater systems provide key pathways for micro plastics pollutions. Headwater streams serve as an important vector for the transport of material which can extend into the downstream reaches of rivers, lakes and estuaries. Plastics litter is of serious concern for economic and ecological reasons: while diminishing the aesthetic value of water environments. Plastic has immeasurable impacts to every aspect of daily life including technology, medicine and treatments, and domestic applications. Most of the plastics after used are thrown to away by consumers after single use and that has become a huge environmental problem as they will end up in landfill, oceans and other waterways. Plastics have become the ubiquitous propulsive force of modern society with their unparalleled functional properties at a relative cheaper cost. Secondary microplastics are formed by physical, chemical and biological degradation of microplastics parts and these are the main source of microplastics that are released into the environment. Microplastics either settle down at the sediments or float in the water. In the aquatic systems the microplastics concentration are higher than in the surface water because of their smaller size they can easily interact with aquatic biota or ingested by the plank tonic communities, invertebrates, and fishes. The presence of this microplastic is reported to adversely affect the growth of organisms and hence affect the ecological functions. Micro plastics can be even transfer to higher order food chain through consumption of contaminated water. Presences of microplastics in table salts and drinking water raises concern as these products are directly taken by human and can be source of microplastics to human beings. MPs can potentially impact food safety and human health through sea food. Micro plastics are also source of air pollution, occurring in dust and airborne fibrous particles.

1.2. Microplastics: Microplastics are any synthetic solid particles or polymeric matrix, with regular or irregular shape and with size ranging from 1 μm to 5 mm, of either primary orsecondary manufacturing origin, which are insoluble in water(Frias et al., 2019). Microplastics are the small plastic less than five millimeters long and which can be harmful to our aquatic life. Under Combined effects of environmental physiochemical and biotic factors (ultraviolet radiation, mechanical abrasion and microbial action), the plastic debris will continuously degrade into secondary plastic (less than 5mm in diameter). Plastic waste is major concern for environmental issue because of their world wide's effects on land and aquatic ecosystems.Microplastics commonly nowadays found in all environmental matrixes.

1.3. Micro plastic classification: Different methods can be used to categorize microplastics. They can be separated into primary and secondary microplastics based on their sources.

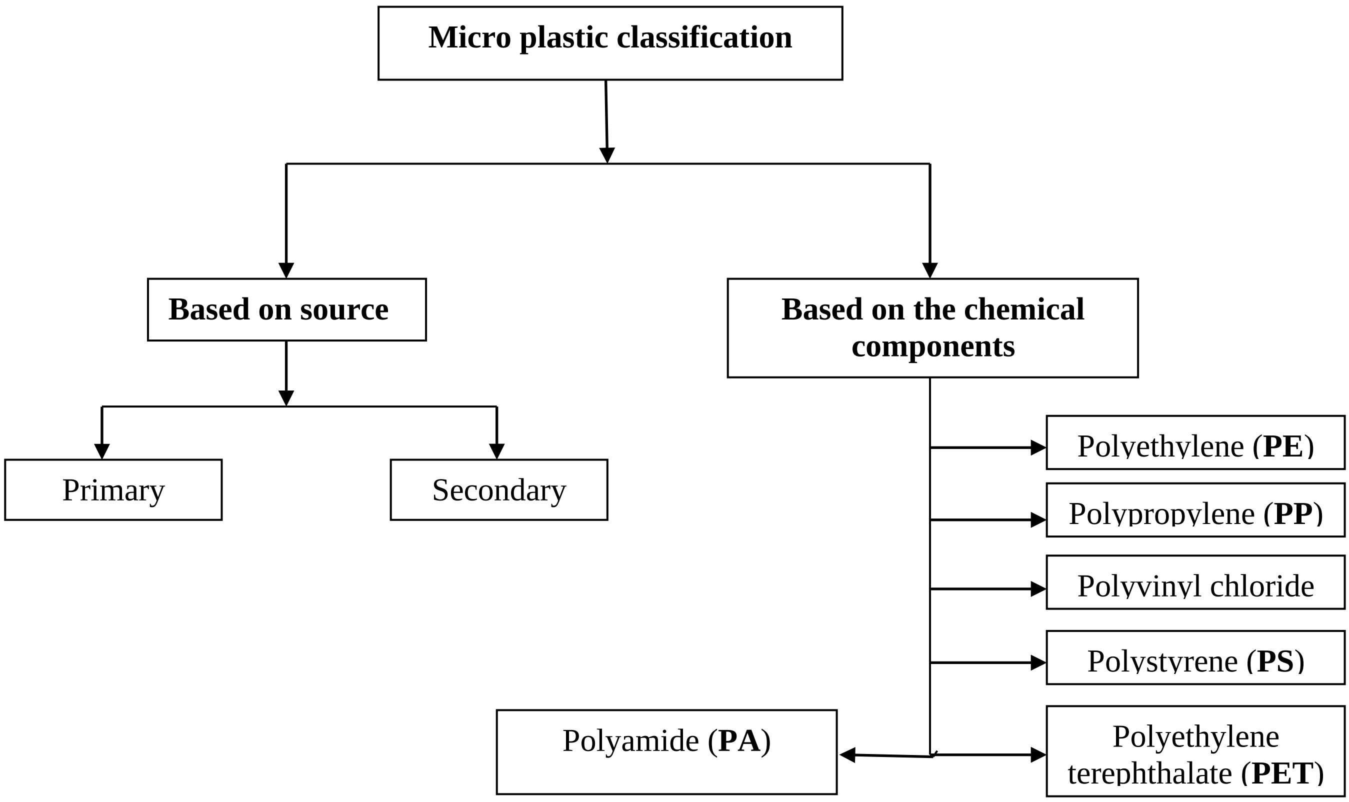


Fig.3. Classification of micro- plastics in water sample.

a) **Primary microplastic: Micro** plastics those have been intentionally produced, voluntarily added, produced as a byproduct of a process, or accidentally released. The three main types of micro plastics are plastic pellets used in industrial manufacturing, micro beads found in personal care products, and synthetic textiles (e.g., nylon). Various pathways allow primary plastics to enter the environment.

b) **Secondary Microplastics:**

Secondary microplastics are very small of plastic derived from breakdown of larger plastic debris both at sea and on land. This breakdown is caused by exposure to various environmental factors. Culmination of physical, biological, including progradation caused by sunlight, can reduce the structural integrity of plastic debris to a size of undetectable to the naked eye. Secondary microplastic can accumulate in the air terrestrial ecosystems. The secondary sources of microplastics are the larger plastics which break downs into smaller pieces through the process of photo degradation which are caused by ultraviolet rays from the sun and other mechanical forces. This happens to mismanaged waste like used large plastics bags and fishing nets (Boucher, J et al., 2017).

Another typical classification method for microplastics is based on its chemical components, such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET). The most important morphotypes of the plastic particles are found to be fibers (polyesters) and sheet or film. Microplastic pollution highlighting fibers is emphasized recently as compared to other morphotypes like film and beads (Rodrigues et al., 2019).

Chapter – 2

LITERATURE REVIEW

2.1. Source of Micro plastics: Both primary and secondary micro plastics can be found in countless places. When synthetic clothing is washed, micro plastic fibers are released into the environment. Depending on where they enter the water, land-based or marine sources of micro plastic can be distinguished. However, some primary micro plastics are directly transported into the aquatic system, and some larger pieces of land-based litter may ferment during or after transportation. On the other hand, secondary micro plastics in the aquatic environment are brought about by marine-based sources due to the breakdown of marine debris. Small streams and rivers have been found to be the main conduits for micro plastics (MPs) into aquatic ecosystems and environments. Fig.4 shows the pathways of microplastic in marine environment.

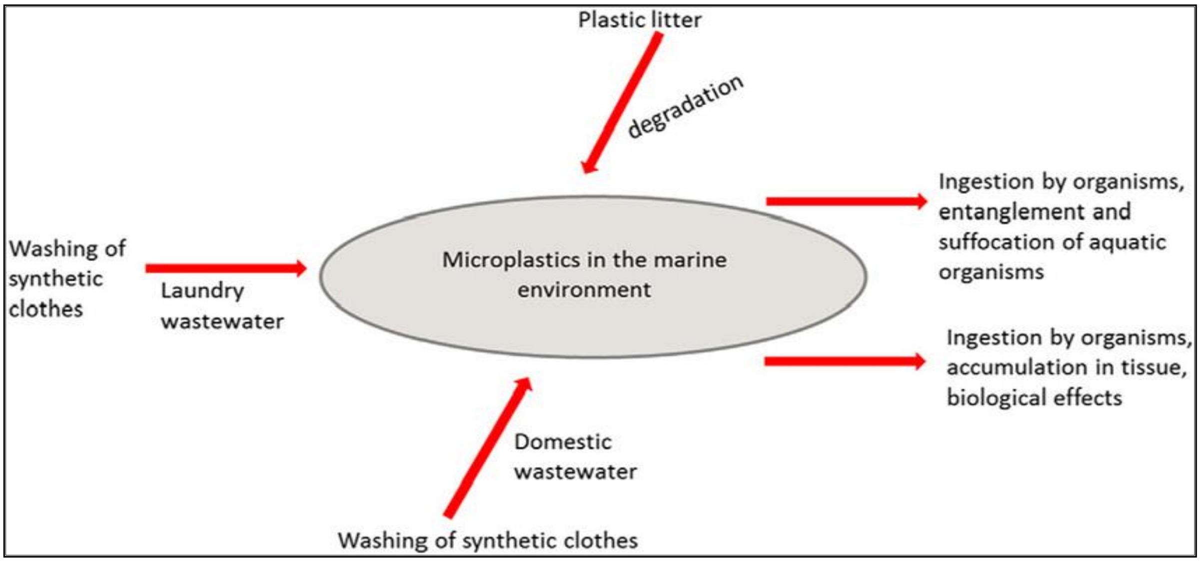


Figure.4. Ways of Microplastics ending up in marine environment (Stolte et al, 2014).

In India, pilgrimage centers are another important source of microplastic pollution. Apart from the single-use plastics packaging litter from the active population, pilgrims and tourists who prefer to bathe, wash their clothes, and frequently discard them along the river banks, are also a major source of single-use plastics packaging litter, according to (Kumar Raja et al 2020; Ajith K. Sarmah et al, 2020). According to reports from pilgrimage sites in that area, the Netravathi River in Karnataka is the main source of microfibers. Another aspect that is frequently studied and connected to the origin, existence of additives, and degradation of microplastics is colour. (Eriksen et al., 2014) claimed that plastic products invariably end up in the aquatic environment due to their mass production and use. (Duis et al; Corrs et al, 2014), has summarized the source of primary and secondary microplastics based on the various publish studied as shown in Table-1.

Table 1 Sources of primary and secondary microplastics in the environment

Type of Microplastics	**Primary and secondary microplastics found in the environment**
Primary Microplastics:	a) Exfoliants/abrasives are microplastic-containing personal care products; b) Specific medical applications e.g., dentist toot polish; c) Drilling fluids for oil and gas exploration; d) Industrial abrasives; e) Preproduction plastics, production scarp, plastic degranulate: unintentional losses, processing facility runoff.
Secondary Microplastics:	a) Littering and dumping of plastic waste in general; b) Waste losses during waste collection, at landfills, and at recycling facilities; c) Losses of plastics materials during natural disasters; d) Plastics mulching synthetics polymers particles used to improve quality and as composting additives; e) Abrasion/release of fibers from synthetic textiles and release of fibers from hygiene products; f) Paints based on synthetic polymers (ship paints, other paints, house paint, road paint): abrasion during use and paint removal, ships, illegal dumping; g) Plastics items in organic; h) Plastics coated or laminated paper: losses in paper recycling facilities; i) Material lost or discarded from various fishing vessels and aquatic facilities.

(Hammer et al., 2012, stated that microplastics are originate from both land and ocean-based source. (Magnusson and Noren et al. 2014) has found that waste water treatment is the dominant source of microplastics and waste water treatment plant can remove up to 95% of microplastics.According to (Arthur et al. 2009), there are two main ways for microplastics to enter a body of water: primary and secondary microplastics. According to (Lechner and Ramler et al, 2015), industrial emissions can result from the spillage of primary polymers in granular or pelleted form produced for the manufacture of plastics products.

Plastic is mainly used in many activities performed in business and by the households on land or at sea. the main known microplastics are reported and classified (Table-2), based on recently publish data from Denmark (Lassen et al,2015), Sweden (Magnuson et al ,2016) and Germany (Essel et al,2015) and losses and releases of microplastics are quantified at global scale for seven dominant sources are identified. The sources of microplastics are from household and commercial activities are presented in Table 2. **Fig.5.shows** the marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans.

Table 2Different sources of microplastics from household and commercial activities both on land and at sea

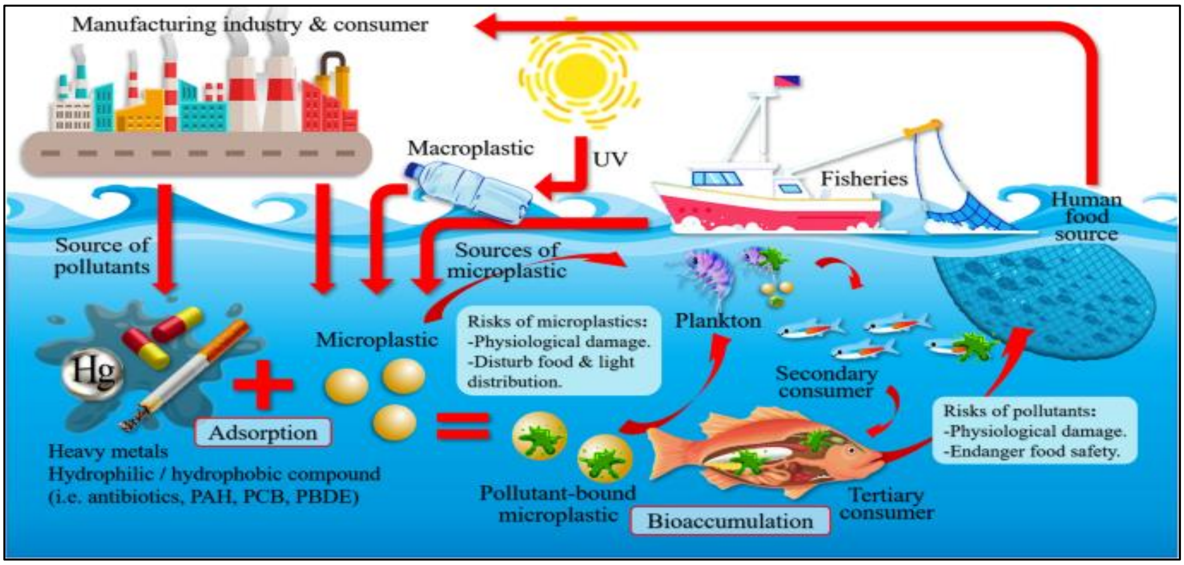


Fig.5. Marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans

(Browne *et al*., 2011; Magnusson and Norén, 2014), stated that urban waste water treatment plants (UWWTPs) are the receptors of microplastics and that are derived from incoming effluents and have been found to emit microplastics through effluent water and sewage sludge. (Browne et al.2007), stated Primary microplastics consist of manufactured raw plastic materials, such as plastics pellets, scrubbers, and microbes and that enter the ocean via runoff from land.

2.2. Microplastic weathering and fragmentation:

Microplastics may be abundant throughout their pollution pathway in the environment. Microplastics are primarily formed by improperly degraded domestic plastic waste, synthetic textile washing, and tire abrasion. Plastic debris will degrade continuously due to the combined effects of environmental physiochemical and biotic factors (ultraviolet radiation, mechanical abrasion, and microbial action).Microplastic degradation rates vary greatly and are influenced by inherent plastic properties such as crystallinity, molecular weight, functional groups, plastics and additives on physical forces (heating/cooling, wetting/drying). (Sruthy, and Ramasamy et al.,2019) studied the microplastics in the Vembanad lake and discovered that secondary microplastics are formed as a result of the breakdown of larger plastics. These microplastics are found in a degraded state, and fragmentation can reduce the size of microplastics, increasing their bioavailability to organisms.(Lorena M. Rios et al.2019) studied microplastics in freshwater environments and discovered that microplastics come in a variety of shapes and sizes and are classified as fragments, films, lines, spheres, filaments sheets, pellets microbeads, fishing lines, ropes, foams, or fibers. Fibers are found in much higher densities than the other microplastics in freshwater (lentic) Environments Fig. 6 depicts the effects of weathering and environmental behavior of microplastics.

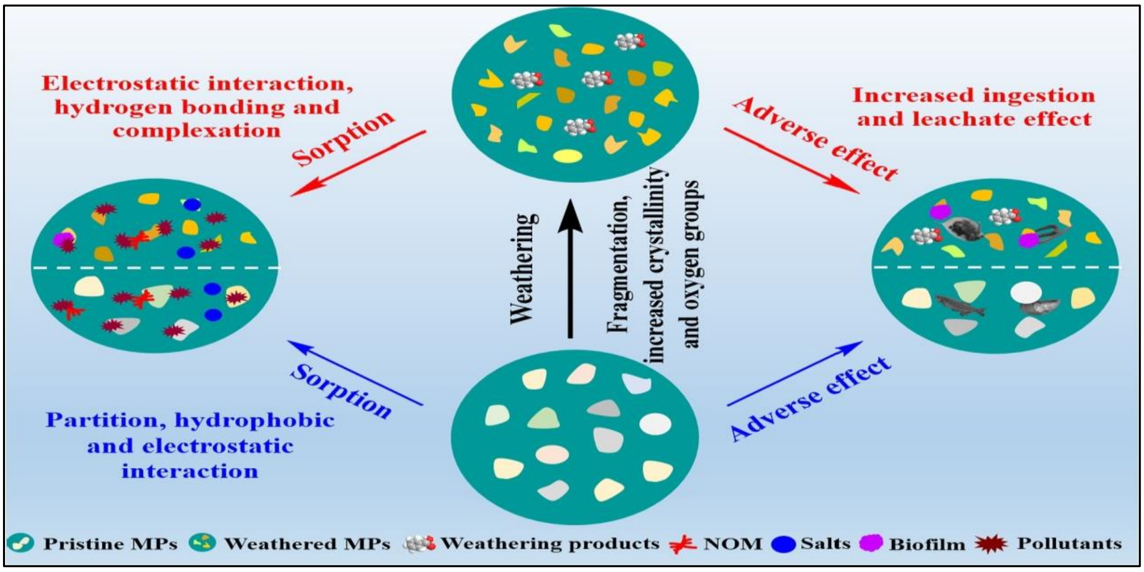


Fig.6. Effect of weathering of microplastics

2.3. Occurrence and Fate of Microplastics in Freshwater Environments:

According to (Eriksen et al., 2013; Imhof et al., 2013; Free et al., 2014; Hoellein et al., 2014; Lechner et al., 2014), the physical and chemical nature of microplastics influences their dispersal in aquatic environments. Physical forces are to blame for the dispersal of microplastics in marine environments, and wind-influenced surface currents are also to blame. (Lorena.M. Rios Mendoza et al, Mary Balcer et al,2018), studied the freshwater environment and stated microplastics occurs in a variety of forms and are generally classified as fragments, films, lines, spheres, filaments, sheets, pellets, microbeads, ropes, fishing lines, foams or fibres.According to (Law et al, and Thompson et al, 2014), physical, photo, and bio-degradation can fragment plastic waste into microplastics (debris 5 mm in diameter).

According to (Ferguson et al., 2010), the transport of microplastics (polypropylene, polyethylene, polystyrene, nylons, low density polyethylene (LDPE), and high-density polyethylene (HDPE) on the water's surface is subject to physical and biological forces.

2.4. Potential Human Health Consequences:

The possibility of microplastics migrating by microbes could be an important factor in determining the risks to humans. (Imran et al, 2016) identified microplastics as a vector for antibiotic resistance in human pathogenic microbes, posing a potential threat to living beings. (Keswani*et al*., 2016), stated that the physical properties of plastics provide unique habitants for microbial communities. (Vanapalli and Dubey et al.2020) recently published assessment of microplastics pollution in aquatic ecosystems -An Indian perspective and demonstrated that the disintegration of plastics waste into microplastics can further harm the health of aquatic biota and be ingested by humans via their food chain. The physical properties of microplastics and their impact are depicted in Figure 7.

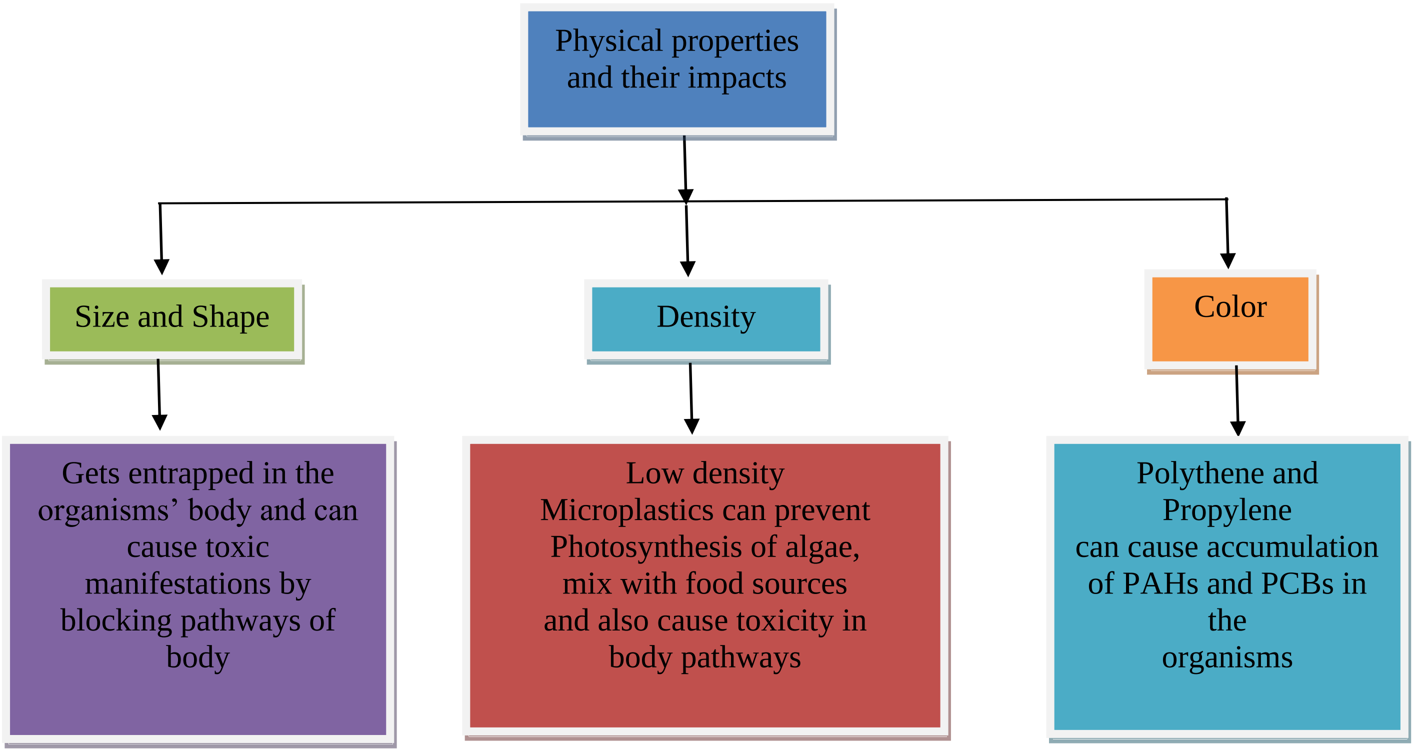


Figure 7. Impact of the physical properties of microplastics on living organisms.

Fenget al. (2020) stated that Pathogenic bacterium can travel the waters on MPs. (Feng et al. (2020) found that MP surfaces are enriched with Vibrio, Erythrobacteriaceae, and Xanthobacteriaceae, which can cause coral bleaching and tissue damage. (Sun et al. 2020, Wang J. et al., 2020; Xue et al., 2020, Laverty et al. 2020), stated that the bacterial communities that accumulated on the surface of MPs were more correlated with human disease than in the water column isolated three human pathogens from MPs, including Vibrio cholerae, Vibrio parahaemolyticus, and Vibrio traumatica, which may pose a risk to aquatic ecosystems and human health.(Imran et al., 2019), stated that microplastics act as effective carriers of both heavy metals and biofilms, thus pose a new health threat on a global scale (Imran et al., 2019).Impacts of the chemical properties of micro plastics on living organisms aredepicted in Figure 8.

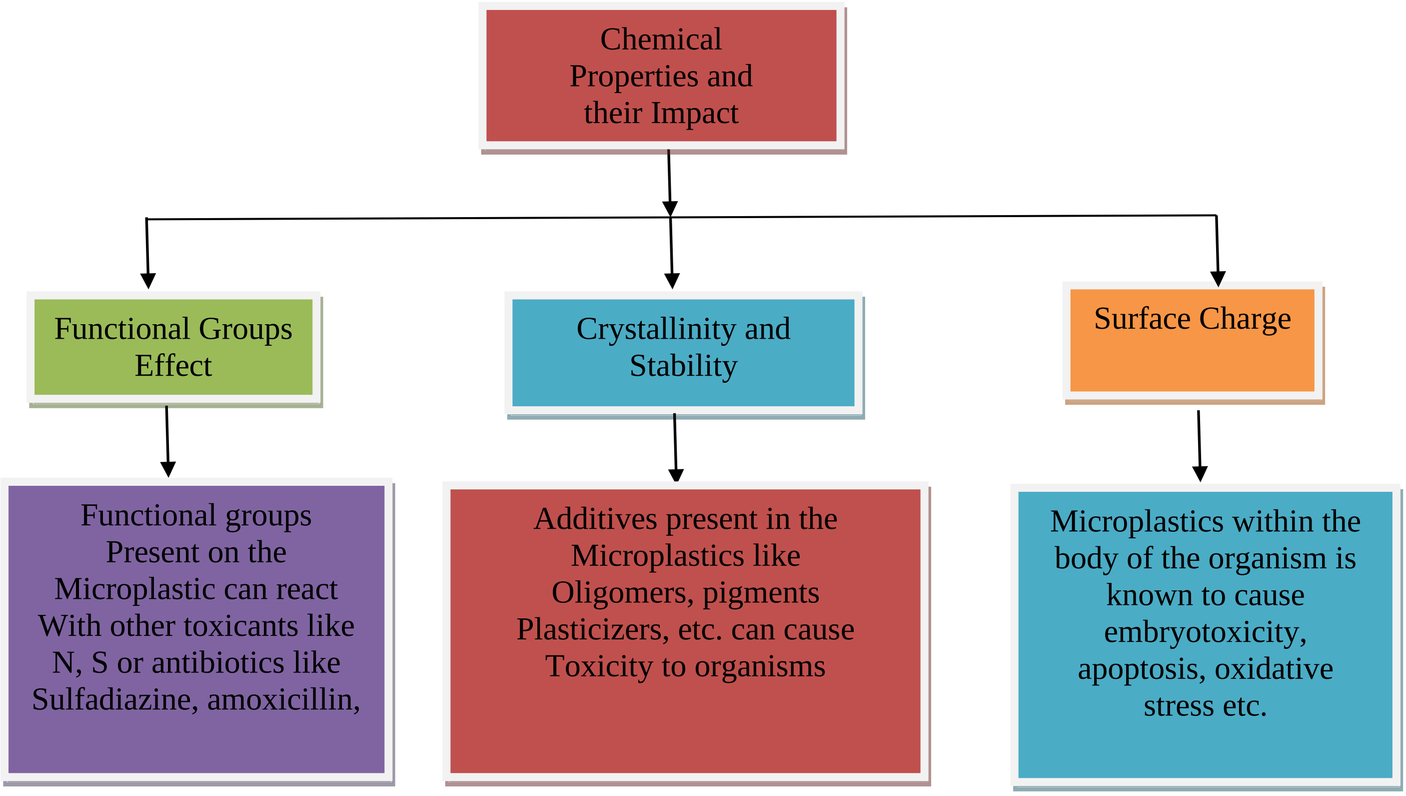


Figure 8**:** Impact of the chemical properties of microplastics on living organisms.

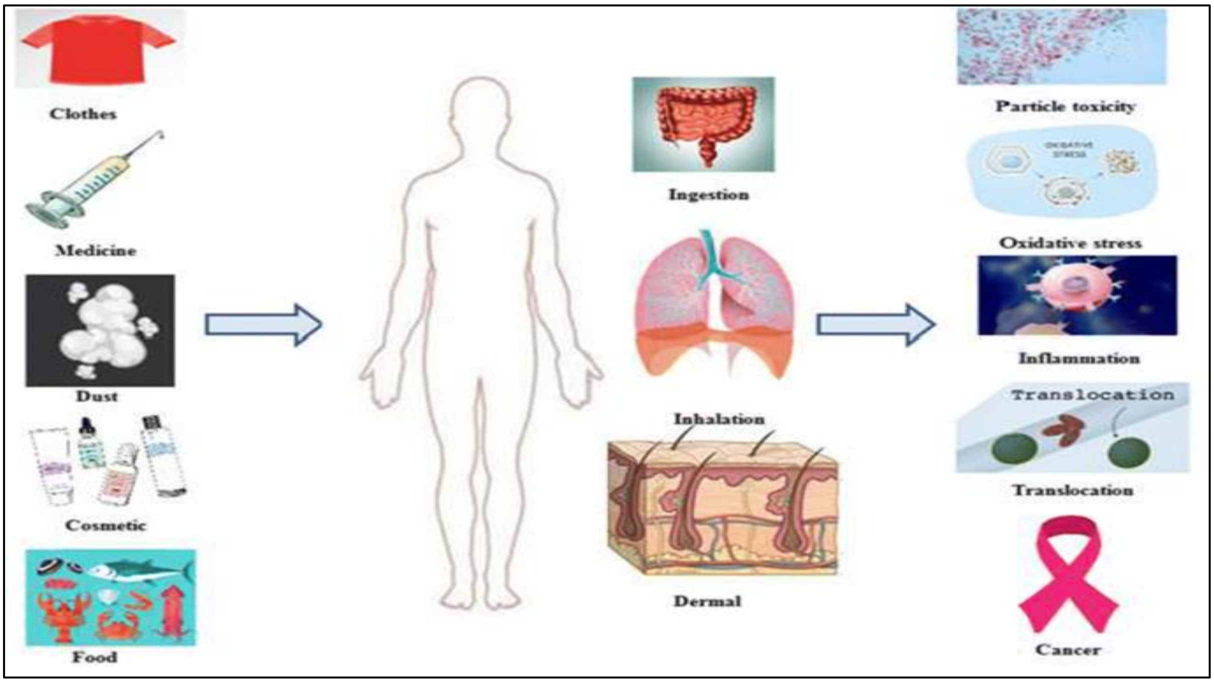


Fig.9.Effect of microplastic and neoplastic on human health.

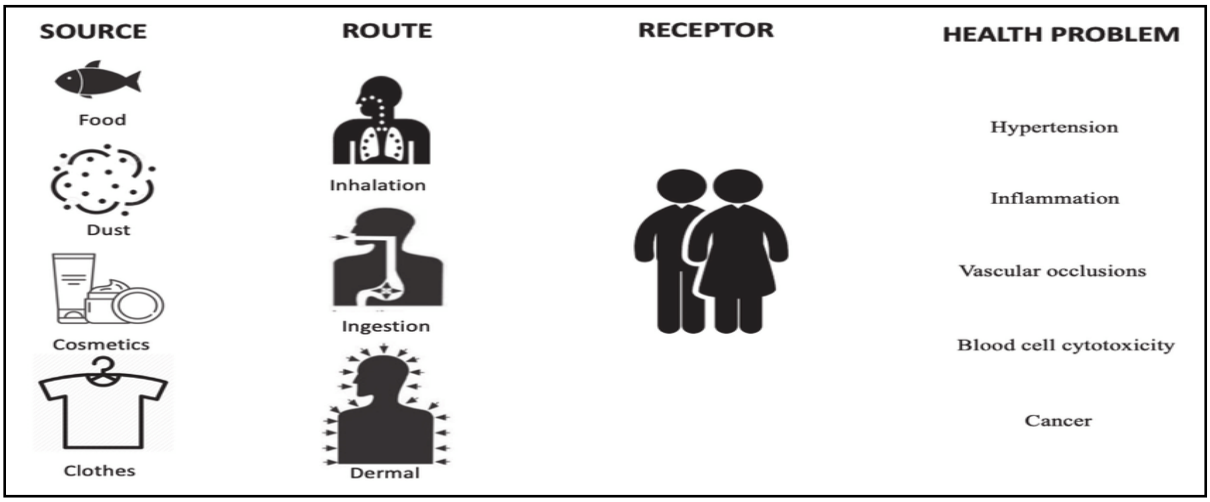


Fig.10.Effect of microplastic on human health (prata.et al., 2020)

Human health could be affected via food chain transmission of microplastics (Hollman et al., 2013) (Figure 9 and 10). Furthermore, the physical and chemical properties of microplastics have been found to facilitate contaminant sorption to their surfaces, that's why microplastics may serve as a vector of contaminants to organisms.

2.5. Microplastics' potential effects on species and habitats:

Impacts on biota have been observed in a range of taxa in laboratory conditions. (Bhattacharya et al, 2010), observed that microplastics affect photosynthesis in marine algae which resulting in reduced feeding of marine zooplankton. (Rebolledo et al,2013), has been found microplastics in the stomachs of harbour seals, Phocas, vitulina, which could occur through the direct consumption of contaminated fish or birds. Rochman et al. (2013), Fossi et al. (2016), Cole et al. (2013), Caron et al. (2016), and Rehse et al. (2016) Microplastics have been found to cause chemical and physical harm when consumed by marine organisms. According to (Clark et al., 2016), biological interactions of microplastics with marine biota are critical to understanding the movement, impact, and fate of microplastics in the marine environment.

According to (Ashton et al., 2010; Cole et al., 2011) and (Ng et al, and Obbard et al, 2006), the large surface area to volume ratio of microplastics makes them susceptible to contamination by water-borne contaminants such as persistent organic pollutants (POPs), metals, and endocrine disrupting chemicals. These chemicals are found in high concentrations in the sea surface micro layer, which also contains a large number of low densities microplastics (Teuten et al., 2009). The accumulation of microplastic waste could have an impact on the functioning of marine ecosystems. The bioaccumulation of microplastics and the substances they may carry appears to be a growing problem as a result of microplastics found from small fish species to the top of the food chain. Ingestion of microplastics can have a variety of effects on marine animals. Figure 11 depicts the main effects of microplastics in fish. Microplastics can have an impact on the immune system both chemically (due to the substances that microplastics may contain, absorb, or release that may be toxic) and physically (by blocking the digestive organs and preventing animals from feeding). Ecology and behaviour may also be impacted.

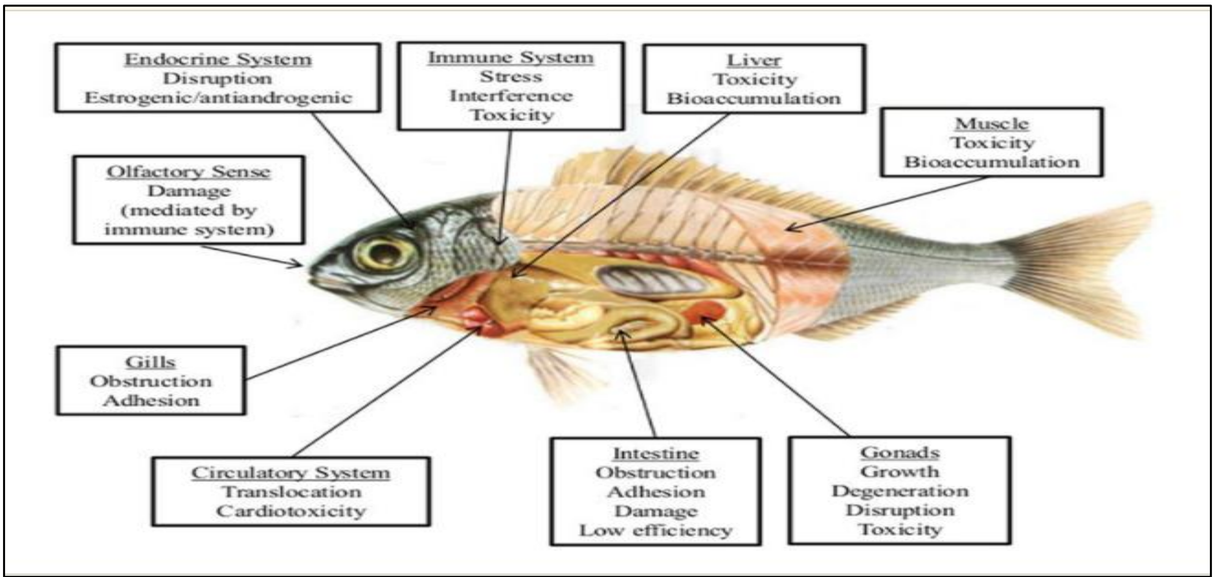


Fig.11. Principal Effects of micro plastics on fish (http://dx.doi.org/10.5772/64815)

2.6. Influence of Environmental Factors on Interactions between Micro plastics and Heavy Metals:

Metal pollution is common in harbours and marinas and is caused by a variety of factors, including the use of metal-based antifouling paints, industrial waste, and fuel combustion (Deheyn and Latz, 2006).

According to (Wang et al., 2019), various environmental factors influence the interactions between microplastics and heavy metals. Aging, temperature, ionic strength, contact time, particle size, weather with UV radiation or ageing agents (e.g.; H_2O_2) and Fenton are all factors that can increase the adsorption capacity of microplastics for heavy metals. According to (Bandow et al., 2017; Liu et al., 2019), photochemical can also break bonds on the surface of microplastics and form new carboxyl groups.

The aquatic ecosystem is highly complex, with dynamic interactions between biotic and abiotic compounds. (Schwabl et al,2019) discovered that microplastics can form complex contaminants with heavy metals, which can affect the immune system and cause various diseases when they enter the body. Heavy metals' effects on human health have been widely reported (Zahra et al,2017; Fu and Xi et al,2019). For example, Hg can cause chronic neurotoxicity in humans; Pb invasion damages the nervous and digestive systems, causing people to exhibit animacies, low immunity, and other symptoms. Cr is easily absorbed by human cells and causes DNA damage. For directly assess the risk to human health from combined contamination of heavy metals and MPs, (Godoy et al, 2020) used a dynamic gastrointestinal simulation device to study the biodiversity of ‘Cr’ and ‘Pb’ in microplastics in the human body and found that the release rate and content of ‘Cr’ and ‘Pb’ metals in microplastics were different. (Liao and Yang et al, 2020) stated that Cr was mainly released in the stomach, while Pb was released more in the duodenum. (Liao and Yang et al,2020), also conducted in vitro experiments on the whole digestive system for Cr-containing microplastics and found ‘Cr’ is mainly released into the body during gastric digestion, and ‘Cr’ has a higher bioavailability in degradable microplastics [such as polylactic acid (PLA)] compared to non-degradable micro plastics (PE, PP, PVC, and PS). Table 3 presents the interactions between microplastics and heavy metals.

Table-3 Characteristics of interaction between microplastics and heavy metals.

Type of MPs	Type of heavy metals	Factors	Results	References
1) PE, PP, PS, PVC.	Cd^{2+}	pH, Ionic strength: Humic acid (HA).	The sorption tendency increased as the pH increased, [PVC>PS>PP>PE]. The sorption decreased as the salinity increased, [PVC>PS>PP>PE]. The sorption tendency increased as the HA increased, [PVC>PS>PP>PE].	Guo et al,2020

Type of MPs	Type of heavy metals	Factors	Results	References
2) PA	Pb^{2+}	pH	Minimum adsorption efficiency found 3.37% @ PH 2.6, the max. adsorption efficiency (%) of 91.24% was required @ pH 6.	Tang et al., 2020
3) PE	Cr^{3+}	pH SDBS SDBS and pH	The adsorption capacity was increased when the dosage of PE MPs was increased. The addition of SDBS can improve the adsorption capacity of PE on $Cr^{2+}$the peak of the adsorption capacity was at SDBS concentration between 1 and 1.5mM. pH< 6, with the increase of SDBS, the adsorption efficiency increases. pH > 6, SDBS would compete with CrO4 2C for occupying the adsorption sites of PE microplastic.	(Zhang W. et al., 2020)
4) PET PA EVE	Pb^{2+}	pH	pH is the most significant factor; the maximum adsorption was acquired at pH 5.5.	(Oz et al., 2019)
5) PE	Cr	Concentration of chromium	The higher the initial concentration of chromium, the higher the adsorption Capacity.	(Zon et al., 2018)
6)PET	$Zn^{2+} + Cu^{2+}$	Aging	There is a positive correlation between the degree of aging and the adsorption capacity.	(Wang Q. et al., 2020)

Type of MPs	Type of heavy metals	Factors	Results	References
		Microplastic dosage Time pH Temperature	The more MP doses, the higher sorption capacity of metal ions was fully realized. The longer the adsorption time, the greater the adsorption capacity. The pH range is 3–7; the higher the pH, the greater the adsorption capacity. The temperature range is 288K–318K; the higher the temperature, the Greater the adsorption capacity.	

PA=Polyamide; PE= Polyethylene; PET= Polyethylene Terephthalate; PP= Polypropylene; PS= Polystyrene; PVC=Polyvinyl Chloride; EVA= Ethylene Vinyl Acetate Copolymer;

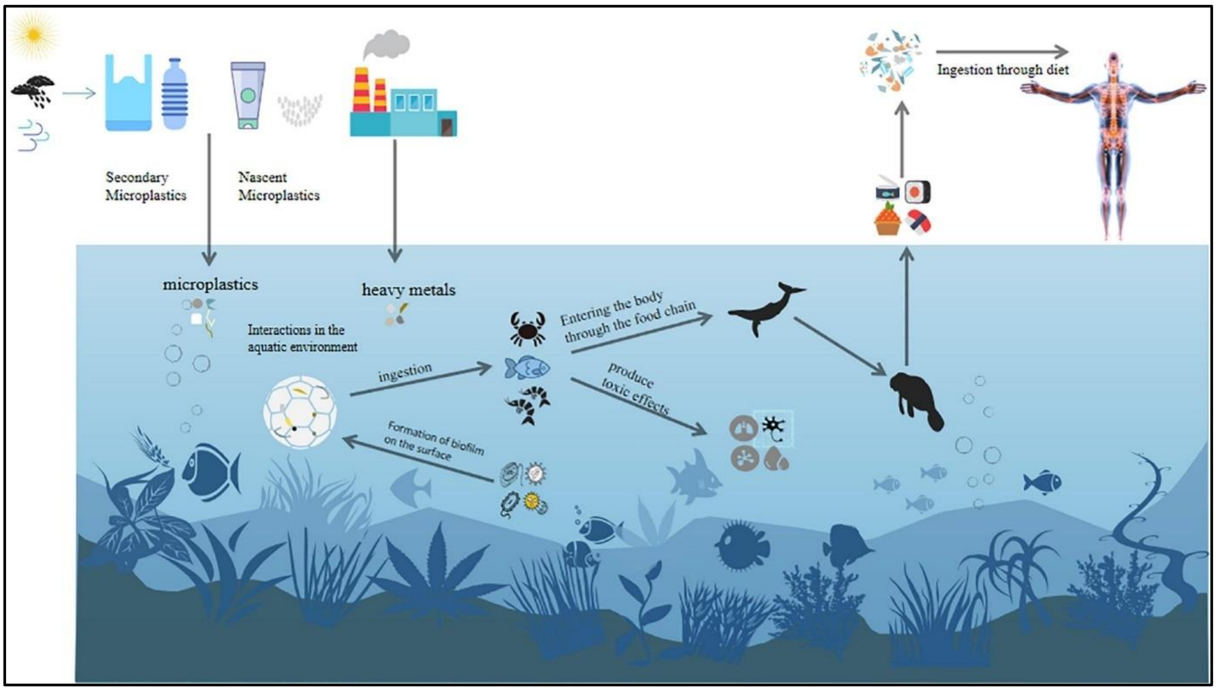


Fig.12.Ecological risk of microplastic and heavy metals (https://doi.org/10.3389/fmicb.2021.652520).

Figure 12 presents the ecological risk of microplastics and heavy metals. (Joana et al.2019), stated that organic matter from microplastic can be removed by sample processing and this sample processing are acid digestion, alkali digestion, oxidizing agents, enzymatic digestion. (Joana et al.2019), also recommended five new methods of chemical characterization methodology for reducing the cross-contaminations microplastics due to its importance in the validation of results and these new sampling protocol are : (a) measure to reduce cross - contamination ; (b) how and where to collect bulk samples ; (c) how to separate microplastics from bulk samples ;(d) a digestion protocol that is quick and little effect on polymer interiority, possibly enzymes; (e) criteria for visual identification , with the aid of staining dyes. Moreschiet al.2019 studied the microplastics in freshwater environments and recommended about assimilation and, eliminations of microplastics and materials and methodsinclude (I) sampling site and collected specimens ;(II) microplastics used in the experiment;(III) experiment design;(IV) filtration assessment, (V) assimilation analysis; (VI)elimination assessment ;(VII) statistical analyses. Table 4 summarises the concentrations and sizes of microplastics found in fresh water samples.

Table-4: Concentrations and sizes of microplastics found in samples from freshwater environments.

Location	Average concentrationfromthe studies	Estimated MP units· L^{-1}	Sample	Size	Methods	Reference
Poyang Lake (China)	0.2034 g/L	226	Sediment and Surface water	Size classes:< 0.5 mm	Raman	Yuan et al. (2019)
Pathian basin (Europe)	0.4716 g/L	524	Sediment and	Size classes:	FTIR	Bordós et al. (2019)

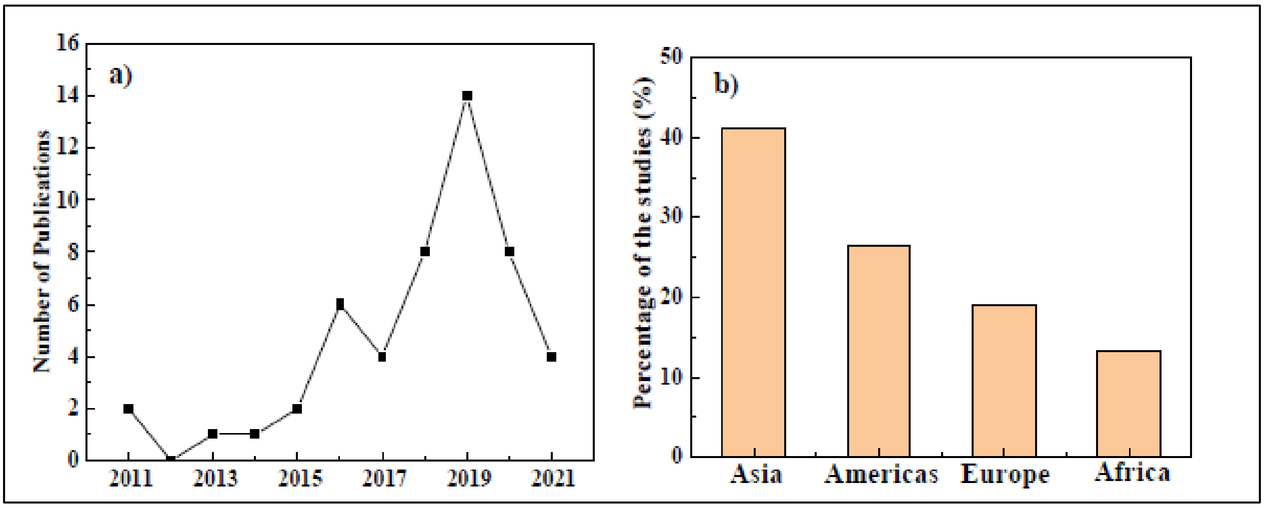
Location	**Average concentrationfromthe studies**	**Estimated MP units· L^{-1}**	**Sample**	**Size**	**Methods**	**Reference**
			surface water	<0.3m		
Carpathian Basin (Europe)	0.4716 g/L	524	Sediment and surface water	Size classes: <0.3mm	FTIR	Bordós et al. (2019)
Flemish rivers (Belgium)	0.0153 g/L	17	Water	Size classes: <5 mm	FTIR and Raman	Slootmaekers etal. (2019)
Maribyrnong (Malaysia)	0.108 g/L	120	Surface water	Size classes: 3 μm	Visual	Praveena et al., (2018)
Vembanad Lake (India)	0.27 g/L	300	Sediment	Size classes: 0.2 mm – 1 mm	Raman	Sruthy and Ramasamy (2017)
LakeWinnipeg (Canada)	1.7397 g/L	1933	Surface water	Size classes: <5 mm	SEM-EDS	P.J. Anderson et al. (2017)
Canadian lakes and rivers	0.495 g/L	550	Sediment and surface water	Size classes: 2 mm - 5 mm	Visual Inspection	J.C. Anderson et al, (2016)

Note: SEM: scanning electron Microscope; FTIR: Fourier Transform Infrared

2.7. Comparison of Microplastic Sources, Types, and Distributions in Lake Systems:

- **Status of Current Literature:**

(Yang et al, 2021), has summarized the studies related to microplastic pollution in the lake systemas shown in **Fig.13** in three scenarios from 2011 to 2020.**Fig. 13(a**) presents the increasing trend in research on lake microplasticpollution over the last ten years, indicating that more attention is beingpaid to research about microplastics in limnetic ecosystems. It isnotable that the drop in the upward trend in the literature from the peak in 2020 is likelydue to the impacts of COVID-19. Fig.**13 (b)** summarizes the proportions ofpublications from different continents.**Fig.13(**c)represents the number of different sampling matricesfor microplastics in limnic ecosystems, illustrating that studies in waterand sediment are much more common than in organisms, sand, snow, lakeshore, and ice.



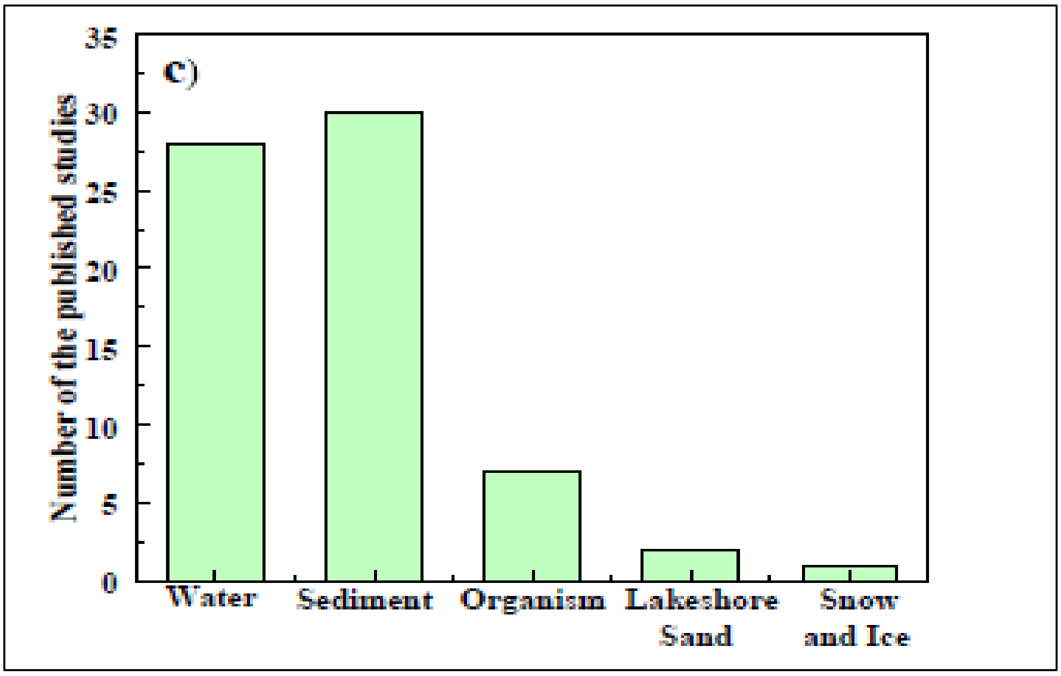


Fig.13. The number of micro plastic studies on lake systems as a function of (a) time; (b) location; and (c) sampling type.

2.8. Analysis Methodology for Microplastics Comparison:

(Cable et al., 2018) stated that it is necessary to note the uncertainty in the microplastics analysis. Sampling variability can be very high within a lake (often two orders of magnitude) and even in a sample replicate.

- **Unification of microplastic abundance units:**

The microplastics in water and sediments samples are mainly measured separately to determine their abundance. Microplastic abundance in water is measured primarily counted by items/m^2,items/m^3,items/KM^2 but general unit in sediment in sediment is items/m or items/kg. The units of microplastic abundance in water can be chosen as items/$m^3$and microplastics in lake water are normallycollected from the surface layer; thus, the conversion between items/$m^3$and items/area can be achieved using equations. (1) and (2) as follows.

C_W (j)=C'_W (j)/H_1………………………... (1)

C_W (j)=1000000*C''_W (j)/H_1……………... (2)

Where, C_W (j), C'_W (j), C''_W are the average microplastics abundances in the water of late 'j' in the measuring units of items/m^3, items/m^2, items/KM^2 , respectively. (Wang et al., 2017; Jiang et al., 2018) or plankton nets (Su et al., 2016; Li et al., 2019), stated that the microplastics in surface water are normally sampled using the manta trawls. Most of the researchers reportedthe height of the trawl/net opening at ~0.2 m (Wang et al., 2017; Jianget al., 2018; Binelli et al., 2020), and half of the opening height issampled (Binelli et al., 2020); therefore, H_1 is set as 0.1 m.

2.9. Microplastic Abundance in the Water and Sediment ofLakes:

(Sruthi and Ramasamy, 2017; Vaughan et al.,2017) has stated that urbanization and population are closely associated with the level of microplastic pollution. For comparison of the abundance of microplastics in lakes from different countries and regions, a worldwide distribution map of microplasticswas produced based on the collected data **(Fig. 14**).

(Lenaker et al, 2019) stated that the sampling and analysis methods for measuring of microplastic abundance significantly affected the final conclusions. They found that in Lake Michigan, the total concentrationsof microplastics from water surface samples (collected 0–20 cmbelow the water) were greater than those for water subsurface samples(Collected between 0.40 and 13.7 m below the water)ranged from0 to 5 cm (e.g., Vaughan et al., 2017; Jiang et al., 2018; Scopetani et al.,2019).(Qin et al.,2019) stated in addition, the different mesh sizes used for water sampling canalso affect the measured microplastic abundance, which determines thesize and number of particles trapped in the trawl.(Song et al., 2014) stated different types of trawls, mesh sizes, poresizes present in filter membranes and characterization units can result indifferent estimates of microplastic abundance and affecting the comparisonof microplastic concentrations.(Freeet al., 2014; Su et al., 2016; Wang et al., 2017, 2018; Xiong et al., 2018;Yin et al., 2019; Gopinath et al., 2020; Mao et al., 2020; Pico et al.,2020; Bharath et al., 2021)been stated Microplastic pollution in lake water from different countries presentsexplicit regional differences in abundance. In Asia, microplastic abundancesin lake water in China range from 1.81 to 34,000 items/m^3.In India, (Sruthy and Ramasamy, 2017;) reported that microplasticconcentration reaches 252.80 items//m^2.In Europe, studies found in Italy and Finland revealrelatively low microplastic concentrations in lake water with ranges of0.057–8.82 and 0.0037–0.66 items/m3, respectively.

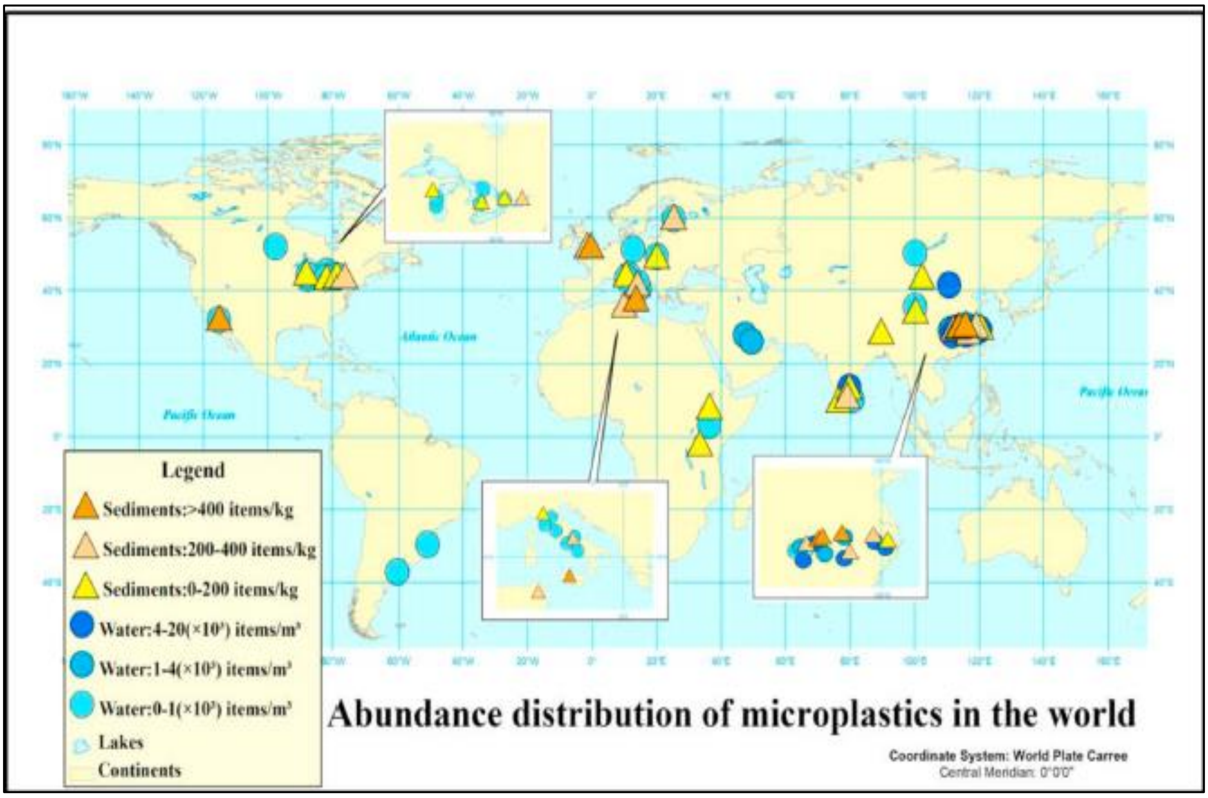


Fig. 14. Microplastic distribution in the water and sediment of different lake systems worldwide (Chemosphere 286 (2022) 131806:S. Yang et al.)

Lake Tollense in Germany (Tamminga et al., 2019) and Lake Tisza-t´o in Hu ngary (Bordos et al., 2019) contained microplastic with concentrations of 0.14items/m^3 and 23.12 items/m^3 respectively.

2.10. Microplastic Morphologies in the Water and Sediment of Lake Systems:

By morphology and polymer type, micro plastics discovered in the lakes are separated into two groups. While the second group consists of polyethylene terephthalate (PET), polystyrene (PS), polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), and polyamides, the first group consists of fibers, films, fragments, pellets, and foams (PA, nylon). The general morphology of micro plastics is depicted in **Fig. 15**. According to (Sighicelli et al., 2018), the sources of micro plastics are closely related to their morphological characteristics. For instance, while films typically come from packaging materials, fibers typically come from fishing line or textiles.

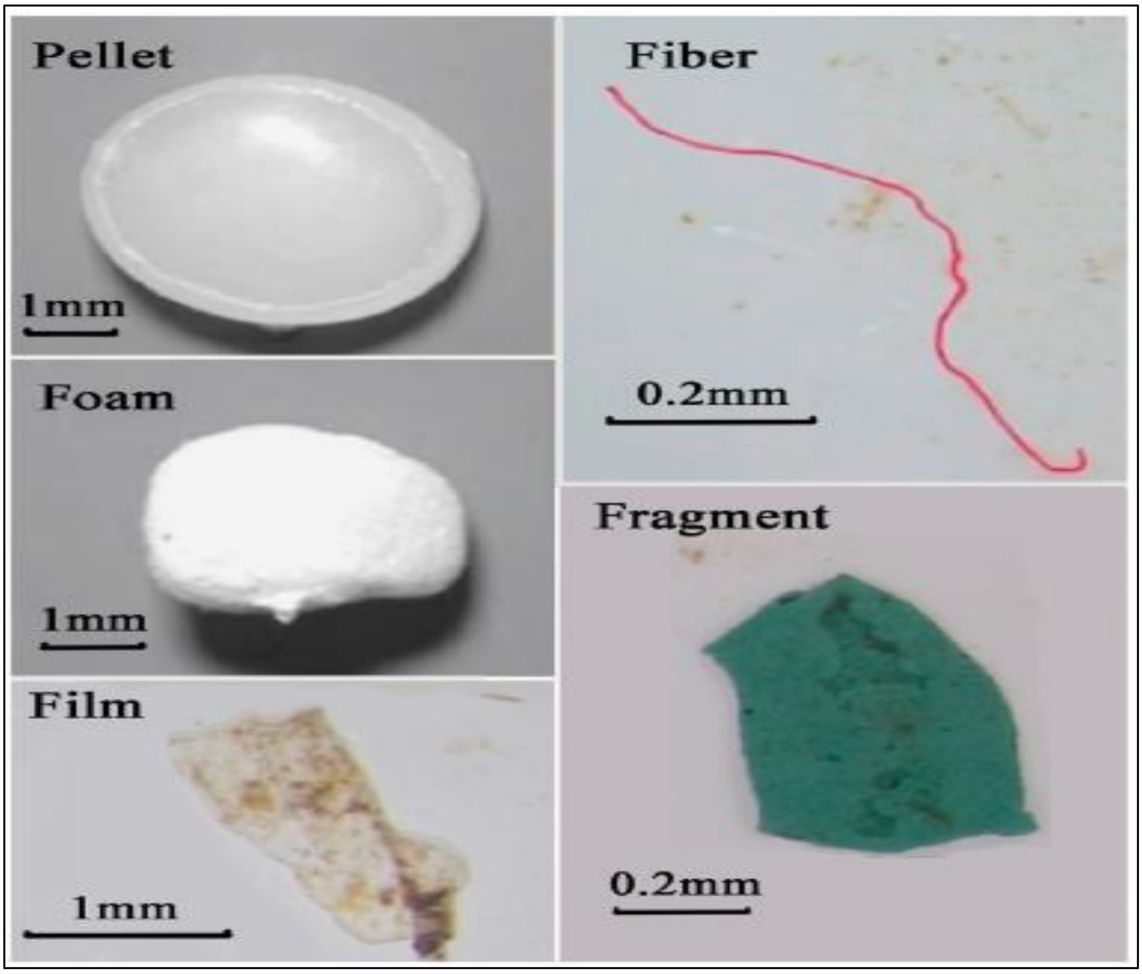


Fig. 15. The morphologies of different microplastics (Jiang et al., 2018; Wu et al., 2018; Yin et al., 2019).

(Sighicelli et al., 2018) summarized the five common microplastic morphologies in water andsediment from lake systems among various continents, namely, fibers, fragments, films, pellets, and foams (Fig 15). **Figs. 16** represent the proportions of different microplastic morphologies in water and sediment in W-continent and theS-continent.

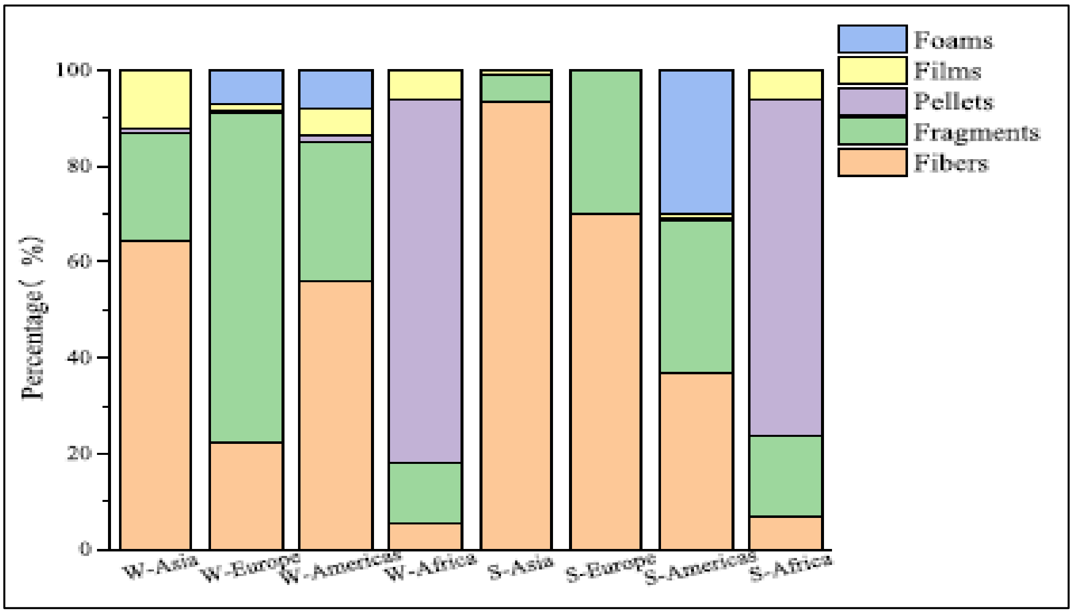


Fig. 16. Distribution of microplastic morphologies in water and sediments from lake systems among different continents.

The microplastics extracted from the lake water worldwide showing the diversity in terms ofmicroplastic morphology. The microplastics in the limnic waters of Asia aremostly fibers (64.5 %), followed by 22.6 % fragments, 12.1 % films, and0.8 % pellets.In the United states of America, fibers (56.2 %) arethe primary morphology of microplastics in lake water, while fragmentsaccount for the second-largest proportion (28.8 %), followed by 8.1 %foams, 5.6 % films, and 1.3 % pellets. Microplastics in the water of lakes in Europe contain amore fragments (68.8 %) than fibers (22.1 %), with only 7.2 %foams, 1.1 % films and 0.8 % pellets.

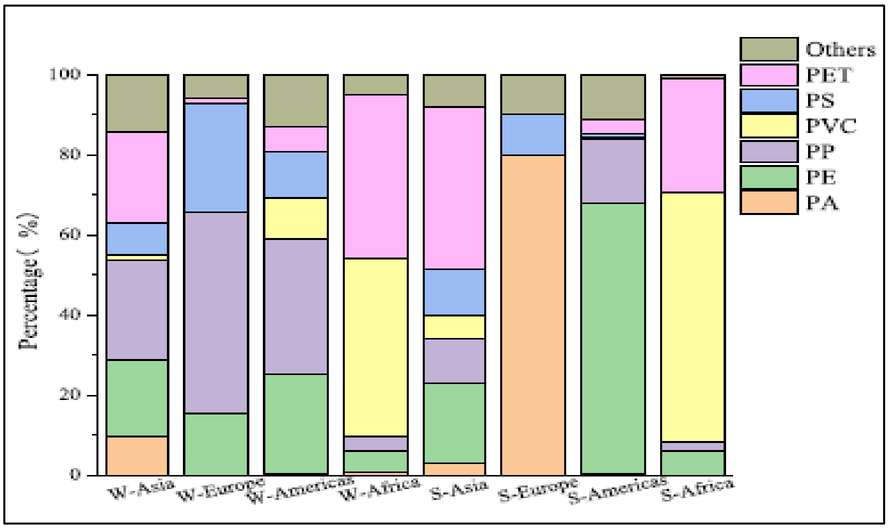


Fig. 17. The distribution of microplastics in water and sediment from lake systems across different continents as a function of composition

In Africa, pellets accounted for the highest proportion of microplastics in lake water (75.7 percent), followed by fragments (14.0 percent), films (6.0 percent), and fibers (5.3 percent). Microplastics in Asian lake sediments are mostly fibers (93.5%), with 5.6 percent fragments, 0.7 percent films, 0.1 percent foams, and 0.05 percent pellets. Fibers and fragments are the two primary morphologies of microplastics found in European lakes, accounting for 70.1 percent and 29.9 percent, respectively. Microplastics in lake sediments in the United States of America were found to be slightly more fibres (37.0 percent) than fragments (31.8 percent) and foams (29.9 percent), with 0.7 percent films and 0.5 percent pellets. In Africa, the largest proportion of microplastics found in the lake systems are pellets (70.3 %), while the second most common morphology is fragments (16.8 %), as fibers, films and foams present 6.9%, 6.0 % and 0.01 % of the total.(Browne et al, 2015) stated that the Fibers are the primary microplastic morphologies detected in lakes, possibly owing to the large quantities of domestic sewage discharged from washing by clothing, which releases fibers that cannot be easily removed by the current wastewater treatment process. (Browne, 2015; Wu et al.,2018) also stated that fragments are also a significant proportion of the total number of microplastics because the primary source of microplastics is the fragmentation of larger plastic items. (Corcoran et al., 2019) has recently studied and has seen that a significant proportion offibers are actually cellulose rather than plastic, which can affect the accuracy of fiber numbers.

2.11. Microplastic Compositions in the Water and Sediments of Lake Systems:

(Yang et al,2021) has summarized microplastic compositions in water and sediment. Six typical polymer compositions were selected for this comparativestudy, namely, PP, PE, PS, PA, PVC, and PET. Other polymer compositions, such as PU (polyurethane) and PMMA (polymethyl methacrylate), accounted for a small proportion and were included in the category of “others”.

According to Hendrickson et al. (2018), the most common types of microplastics found in lake systems worldwide are PET, PVC, PP, and PE. PE (36%) and PP (21%) account for the majority of global non-fiber plastic production, followed by PVC, PET, and PS. As a result, the microplastic polymer compositions presented in this study are consistent with global plastic production. In the United States of America, PP (33.8 percent), PE (25.1 percent), PS

(11.9 percent), and PVC (10 percent) make up the majority of microplastics in lake waters, while PET (6.3 percent) has the lowest proportion, with 12.8 percent others. However, in Africa, PVC (44.5%) accounts for the greatest proportion of microplastics in lake water, followed by 40.9 percent PET, 5.4 percent PE, 3.4 percent PP, 0.7 percent PA, and 5.1 percent others. (Matsugumaet al., 2017) investigated all continents and discovered that the proportion of PP in water is greater than that in sediment, owing to the fact that PP polymers with a density of 0.90-0.91 g/cm3 can float on surface water.

2.12. Correlations among microplastic distributions, development level and economic structure:

It has been found the difference in development levels and economic structures primarily causes regional differences in microplasticdistributions. Toreveal the reason for this difference, a correlation analysis was conducted which are shown in **Fig. 18 and 19**. The microplastic data which are showing in **Fig. 18 and 19** are derived from supplementary materials. The Y-axis index selects the relevant data from the country from which the lake was chosen in this study and there is a data query corresponding to the provided sampling year. The macroeconomic and population data that reflect national industry and population activities are selected as variables, including the agricultural GDP, industry GDP, service GDP, GDP per capita, total GDP, population, and population density. The GDP and population data were obtained from the World Bank (Group, 2021) and United Nations (2021), respectively. Due to the limited data availability, it can be concluded that the data for the correlation analysis may not be complete.

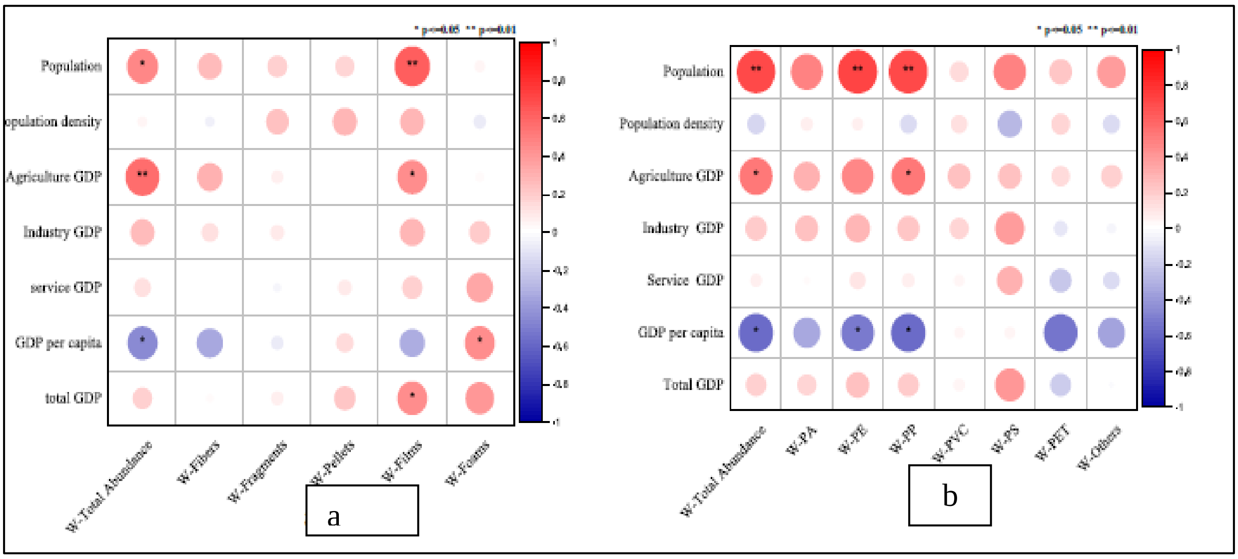


Fig. 18. a) Thecorrelation between microplastic morphologies in water and economic factor and demographic factors and **b)** correlation between microplastic morphologies in sediment andeconomic factor and demographic factors.

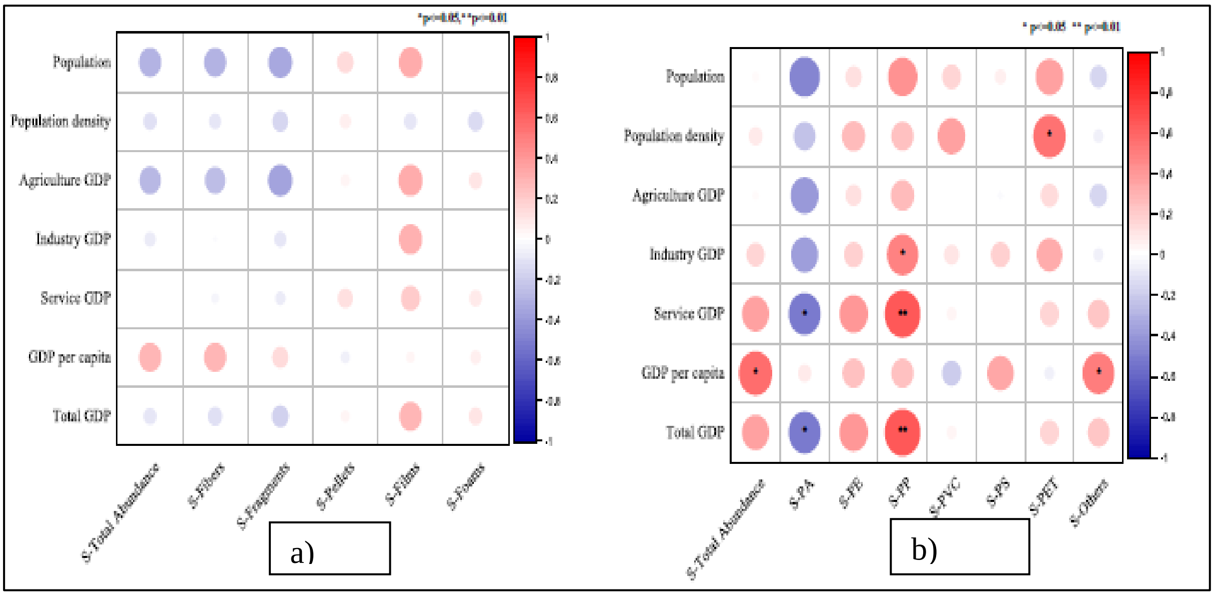


Fig. 19. a) The correlation between microplastic compositions in water and economic factor and demographic factors and**b)** correlation between microplastic compositions in sediment and economic factor and demographic factors

Fig. 18. shows that the total microplastic morphologies in lake water and sediments are strongly correlated with the local economy and population andas shown in **Fig. 18a**, the total abundance of microplastics in water is positively correlated with the population and agricultural GDP which indicate that the microplastic abundance in the lake system is higher in areas with more people and agricultural activities.(Alimi et al., 2020; Meng et al., 2020) shows that Fig. **18.b)** reveals that the abundance of microplastics in lake sediment is weakly correlated with the local economy and population; hence, it is not enough to make a reliable analysis. **Fig. 19.a)** reveals that the abundance of microplastics in water is strongly correlated with the population, agricultural GDP and GDP percapita of the countries. PP in water presents the same trend as total and shown in Fig. 18. b, the abundance of PP is strongly correlated with the service GDP, industry GDP and the total GDP, which is consistent with the fact that PP has multiple uses in many industries, including flexible and rigid packaging, fashion and sporting goods, medical applications, consumer products and the automotive industry. Fig.19. b also reveals that the abundance of PA in the sediments was negatively correlated with the service industry and the total GDP.

2.13. Correlations between microplastic and environment indicators in the water system:

(Xionget et al.,2022) stated that the microplastic abundance in summer Session exhibited positive correlations with DO and pH and negative correlations with nitrate and nitrite. On other hand in December, microplastic abundance can be remained in the principal component with similar water parameters, but the contribution should be lower than in summer season. (Herath et al, and Satoh et al, 2015) stated that due to the heavy inputs during the aquaculture process, nitrogen and phosphorus nutrients have been considered as critical aquaculture pollutants that affect the water environment of surrounding natural water.

According to (Feldman et al, 2002), the chemical transformation of microplastics and microbial activities on their surfaces will directly shape water quality. This has been observed in the relationship between microplastics, nutrients, and dissolved oxygen. The oxygen usually could be participated in the oxidative reaction of polymer as it consisted of C- O bonds, which could be the new functional groups in the microplastic's chemical structures. Irradiation resulted in the dissolved organic carbon from plastics, according to (Zhu et al., 2020). Furthermore, the bioassay demonstrates that the released carbon was readily bioavailable. A microcosm experiment (Chen et al., 2020) confirmed the nutrient release and oxygen consumption of microbes on the surface of microplastics. As a result of the activated bacterial metabolism, DO was reduced, and this study proposed that the relationship between microplastics and DO indirectly represents the microbial activity and oxidation process occurring on microplastics.

2.14.Microplastic classification by machine learning technique:

Images of microplastic can be categorized using support vector machines (SVM) and convolutional neural networks (CNN) models. The SVM-Linear, SVM-RBF, and CNN models are used to automatically extract useful high-level features because they produce results that are comparable to each other, including hyperspectral image classification. SVM linear encountered a hardware processing capacity issue when classifying the data after training and accuracy testing. The best overall accuracy of the suggested methodology is provided by the SVM-RBF model, at about 90%.

Chapter – 3

CRITICAL LITERATURE REVIEW:

- Most of the studies related to microplastic plastic pollution in freshwaters werecarried out in Europe (Western-Central Europe) and North America (United State and Canada). However, it is necessary to enlarge the scientific efforts in Asia and South America, particularly in low-middle income countries. Increasing population levels, booming economy and rapid urbanization have greatly accelerated the plastic waste generation rate, while treatment, recycle alternatives, recovery routes and final disposal are still deficient in many developing countries within these continents like India.
- Asia is experiencing the highest levels of micro plastic pollution, followed by Europe, America, and Africa. Among the nations, micro plastic pollution in developing nations is more severe than in developed nations, and it is worse in nations where industry is the main source of income than in nations where agriculture is the main source of income.
- To date, there have been few reviews of the status of micro plastics in lake water systems, which differ hydrologically from other bodies of water like oceans or rivers.
- Numerous types of micro plastics have been found in lake water systems, but fibers (such as those from synthetic textiles), fragments, and films are the most frequent ones. PP, PE, and PET were the most prevalent materials, which is consistent with global plastic production, according to the classification of polymer compositions.
- In lentic systems, micro plastics might spread through the food chain. Additionally, the two main migration routes for micro plastics to lentic systems

are atmospheric transport and surface runoff. Regional differences in weather and hydrological conditions of the lentic environment were thought to be the cause of the different distribution of microplastics in water from the same lake.

- There are numerous indications that microplastic pollution is a problem, including the ubiquity of heavy metals and microplastics in freshwater.
- One of the most significant sources of microplastics in India are the tourist and pilgrimage destinations of Varanasi, Haridwar, Thiruchendur, Rameshwaram, and Kanpur. In addition to the dynamic population's single-use plastic packaging waste, pilgrims and visitors who prefer to bathe frequently wash and discard their clothing along the banks of rivers and lakes. For instance, the Netravathi River in Karnataka and the Ganga River in Varanasi, Uttar Pradesh, are the two main sources of microfibers.
- Since, the outbreak ofCOVID-19 (SARS-CoV-2) there has been a surge in thenumber of discarded single-use surgical and face masks and latex gloveswhich are seen littering the streets and roads, medical facilities, parking lots, dumpsites, beaches, gutters, and shopping carts. From the past fewmonths amid the pandemic, the world has been witnessed an unprecedented rise in demand for plastic products such as disposable gloves, masks,bottled water, disposable wipes, hand sanitizers, and cleaning agents. In view of existing policies and COVID-19 protocols by India, the mandatory use of single-use facemasks(face shields) will potentially boost microplastic pollution in fresh water.
- In India, very few studies on microplastic have been published. The majority of studies have focused on sediment samples and marine environments.
- The initial investigation into microplastics is in the sediment of Vembanad Lake, an Indian Ramsar site (Sruthy et al.2017). (Gopinath et al., 2020) studied microplastic concentration for Red Hills Lake in Chennai, Tamil Nadu, India. While research on this emerging pollutant is ongoing, there are currently no data on how much microplastic is present in limnetic water in India.
- The toxicological evaluation of microplastics is not accurately demonstrated and their presence in different life forms especially the lower aquatic biota is not well documented. The details studies on the vertical distribution of microplastics in the freshwater can provide a holistic understanding of microplastics pollutions in the aquatic ecosystem and their possible toxic effects on organisms living at different depths.

- A thorough assessment of the toxicity of microplastics and their associated contaminants in various life forms is required. It will aid in reducing the potential negative effects on both people and other animals and helps policy makers to develop policy to control the pollution.

Chapter – 4

OBJECTIVES AND SCOPE:

- **Objectiveof the Research:**

The objective of the present investigation is to estimate the microplastic concentration inLake/ pond water, to identify the morphological characteristics of the microplastics and study the correlation between microplastic concentrations withother water quality parameters.

- **Scope of the Research:**

1. Collection of pond water samples for post-monsoon and pre-monsoon seasons.
2. Characterization of the collected water samples:

a) pH

b) Turbidity

c) TDS

d) BOD_5

e) Concentration of pathogenic organism

3. Analyzation of microplastic concentration using National Oceanic and Atmospheric Administration (NOAA) protocol
4. Correlation of microplastic concentration with turbidity, TDS, pH, BOD_5 and pathogenicmicroorganism's microorganism concentration using Pearson correlation coefficient (SPSS-2025)
5. Identification of the type of microplastic by machine learning technique.

Chapter – 5

METHODOLOGY:

- **Collection of pond water sample for physico-chemical and biological analysis**: The grabwater samples have been collected from all the 25 selected pond's locations at 0.5 m below the water surfaceusing plankton net during November-December, 2021, March-April, 2022 and May-June, 2022. Samples were collected in plastic bottles and immediately preserved with 5%methyl aldehyde for further physico-chemical analysis. For the determination of dissolved oxygen (DO) and biochemical oxygen demand (BOD) the samples were collected in BOD bottles.

- **Characterization of the collected water samples**: After collecting the samples immediately they have been transferred to the Environmental Engineering laboratory of the Civil Engineering Department, Jadavpur University for anaysing differentwater quality parameters (like**: pH, Turbidity, TDS, DO, BOD_5, concentration of pathogenic organism etc**. as per standard methods of APHA (APHA,2012). All the experiments are performed triplicate for better accuracy.

- **Determination of pH of water sample**:

The term "pH" refers to the measurement of the hydrogen ion activity in the solution. As the direct measurement of the pH is very difficult so specific electrodes to be needed for quick and accurate pH determination. The pH of water sample is measured on a scale of 0 to 14, in which lower values indicate the high H^+ (more acidic) and the higher values indicate the low H^+ ion activity (less acidic). A pH of 7 is considered as neutral. Every whole unit in pH represents a ten-fold increase in or decrease in hydrogen ion concentration.

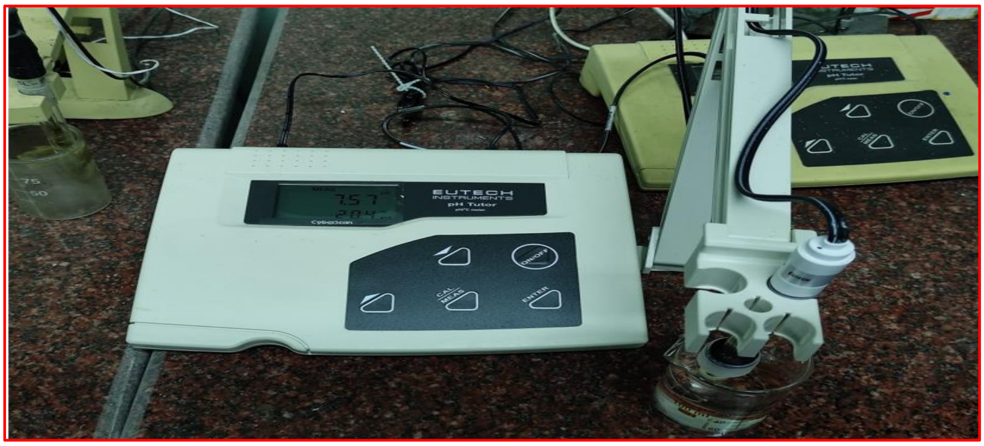


Figure-20: pH meter for determination of pH of water sample

The pH of a water sample was measured using a digital pH metre (manufactured by UTECH Instruments Tutor), which consists of a detecting unit consisting of a glass electrode, a reference electrode, typically a calomel electrode connected by KCl Bridge to the pH sensitive glass electrode, and an indicating unit that indicates the pH corresponding to the electromotive force. The pH meter was calibrated using buffers prior to measurement.

- **Determination of turbidity of water sample:**

Principle: The intensity of light scattered by the sample under characterised conditions is compared to the power of light scattered by a standard reference suspension under similar conditions to determine turbidity.

The turbidity of the water sample is thus estimated from the amount of light scattered by the sample, using a standard turbidity suspension as a reference. The turbidity increases as the power of scattered light increases. The unit of turbidity is the Nephelometric Turbidity Unit (NTU).

Reagents needed for determination of turbidity of water sample:

1. Turbidity free water: -

Generally, distilled water is considered turbidity-free water for any test.

2. Stock turbidity solutions: -

Solution 1: - For the making of solution the dissolve 1.0 grams hydrazine subplate $(NH_2)_2.H_2SO_4$has been mixed in distilled water and dilutes it to 100 ml in a makeup flask.

Solution 2: -For making the 2nd Solution the Dissolve 10.0 grams hexamethylenetetramine $(CH_2)_6N_4$ in distilled water and dilute it to 100ml.

Solution 3: -After that, the solutions 1 and 2 has been mixed in 100ml flask by taking each 5ml and left it stand for 24 hrs., then it has been diluted to 100ml and mix thoroughly. The turbidity of this solution is 400 NTU.

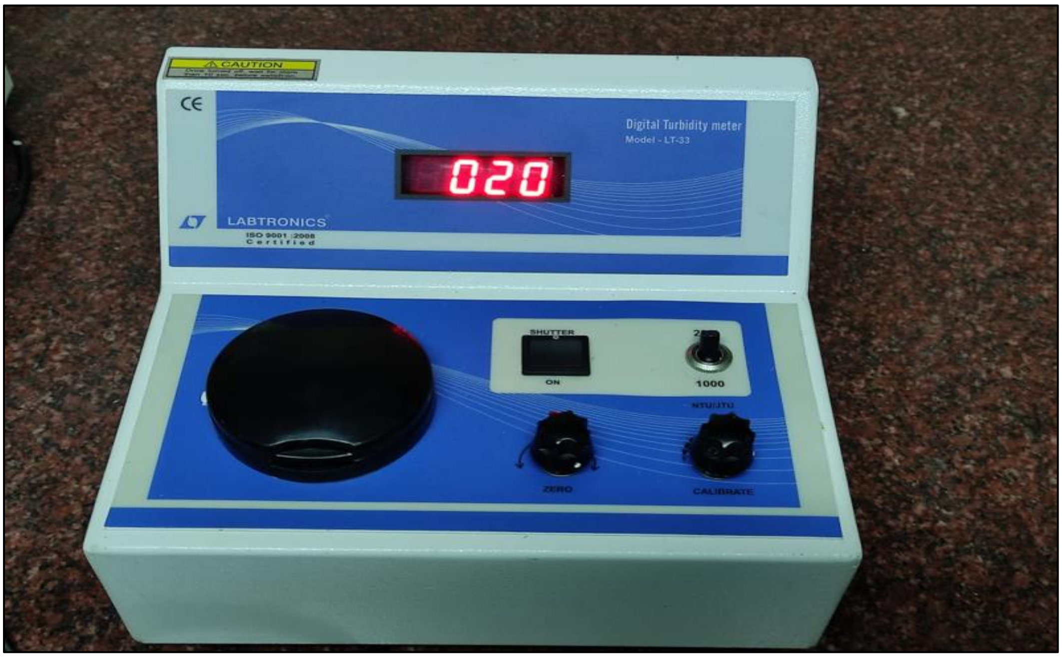


Figure 21: **Turbidity meter**

Standard Turbidity Solution: -To make a standard turbidity solution, dilute 10.0ml of solution 3 in 100ml of flask with turbid free water to 100ml. This suspension has a turbidity of 40 NTU.

❖ **Procedure of Turbidity of Water Test**

a) Calibration of Nephelometer: -

On the Nephelometer, the appropriate NTU range has been selected.

The distilled water sample was then placed in the test tube, and the Nephelometer reading was reset to zero using the knobs provided for this purpose.

Fill the test tube with the 40 NTU standard solution and adjust the Nephelometer reading to 40 NTU using the calibration knobs.

b) Determination of turbidity of sample water:

1. Turbidity less than 40 units:

It is essential to allow the samples to come to room temperature before analysis. Mix the sample to thoroughly disperse the solids. Wait until air bubbles disappear then pour the sample into the turbidity meter tube. Now, read turbidity value in NTU directly from the instrument display or from the appropriate calibration curve.

Digital Turbidity meter (manufactured by: Labtronics India, model-LT-33)was used to determine the turbidity of the water sample.

- **Determination of dissolve oxygen by Winkler Method of sample water:**

Reagents used:

- 2ml Manganese sulfate
- 2ml alkali-iodide-azide
- 2ml concentrated sulfuric acid
- 2ml starch solution
- Sodium thiosulfate (($Na_2 S_2 O_3$) solution

Apparatus: Incubated BOD bottle (300 ml volume)

Steps:

1) For making dilution water 2mL/L of following regents has been added in distilled water.

   a) Phosphate buffer solution

   b) Magnesium sulphate solution

   c) Calcium chloride solution

   d) Ferric chloride solution

   e) Sodium sulphate solution

2) 300 mL sample has been taken in a BOD bottle. Two sets of this sample have been prepared and kept one sample for sample day. Another sample has been in incubator for 5 days at 20°C. After that prepare duplicate sample has been analyzed at sample day.

3) Next, for a given sample bottle 1mL of alkali azide and 1mL magnesium sulfate solution has been added. Then bottle has been shaken well and kept for 5 minutes for settle the precipitate and 2mL of concentrated $H_2 SO_4$ has been added and placed the cap on the bottle. Then bottle has been shaken for a time until the precipitates are dissolved.

4) 203 mL of sample was placed in a conical flask and titrated with standard sodium thiosulphate solution (0.025N) until the colour of the sample changed from dark yellow to light yellow. Then a few drops of starch indicator were added and the titration was continued

until the colour of the sample solution became colourless or changed back to its original sample solution colour. Then volume of 0.025N sodium thiosulfate consumed has been noted.

5) And finally, D.O value has been calculated and it has been kept in mind that in 200mL sample 1ml of sodium thiosulfate of 0.025N equals to 1 mg/L dissolve oxygen.

Dissolve oxygen (mg/L) = mL of sodium thiosulfate (0.025N) consumed.

- **Determination of total dissolve solids (TDS) of water sample by using TDS meter:**

The total dissolve solids present in water sample has been measured by using **TDS** meter (manufactured by: 6a TESTER). For measurement of TDS of water sample, TDS meter has been submerged into the sample for 10 seconds.

(Figure-22): **TDSmeter.**

•**Determination of Biochemical oxygendemand of sample water:**

Object: To find the biochemical oxygen demand exerted by the given sample of pond water.

Materials required for BOD test:

- **Reagents used:**

a) Alkaline-iodide-azide solution**,**

b) Manganese sulphate**,**

c) ConcentrateSulphuric acid,

d) Starch solution**,**

e) 0.025N sodium thiosulphate

- **apparatus used:**

a) BOD bottle, b) Pipettes,**c**) Measuring cylinders**,** d) BOD Incubator**, e)** Burette and burette stand,**f)** Standard flask, **g)** Magnetic stirrer,**h)** Stir bar,**i)** Glass funnel,**j)** Gloves,**k)** Tissue paper,**l**) Water bottle, etc.

Procedure:

Step-1: The water sample has been collected from a pond.

Step-2: 200 mL of water sample has been taken in 2 BOD bottle and diluted it with distilled water by filling the water up to bottle neck.

Step-3:1ml of MnSO4 has been added solution to Sample a bottle.

Step-4: 1ml of Alkali-iodide-azide has been added solution to Sample abottle**.**Carefully so that there is no bubble formation.

Step-5: In this stage the solution has been mixed by shaking BOD bottle upside-down for 25-30 times and allowed the precipitate to settle down at bottom.

Step-6:1-2 mL of concentrated H_2SO_4 has been added carefully without forming air bubbles, to the solution.

Step-7: The solution has been mixed by inverting the BOD bottle till all the precipitate dissolve.

Step-8:203 ml of sample has been taken in a conical flask using pipette.

Step-9: 0.025 sodium thiosulfate ($Na_2S_2O_3$) has been taken in the burette

Step-10: titration has been done against sodium thiosulfate ($Na_2S_2O_3$) and Added 1ml Starch once the colour of the solution changes to pale yellow, now the colour changes to blue then continue the titration till blue colour becomes colourless.The initial and final burette reading has been noted.

Step-11: Sample B has been kept and put it into the BOD incubator for 5 days. Calibrate the temperature of BOD incubator for approximately 20°C.

Step-12: Repeat**step -3** to 11 for Sample B. Note down the Initial and final Burette reading. Determine the BOD of the sample using formula.

Step-13: BOD= ($DO_{Initial}$– DO_{Final}) X volume of bottle / Volume of Sample

Figure-23 BOD sample preparation

❖ Methods for the Analysis of Micro-plastic in Lentic Environment (Water Samples):

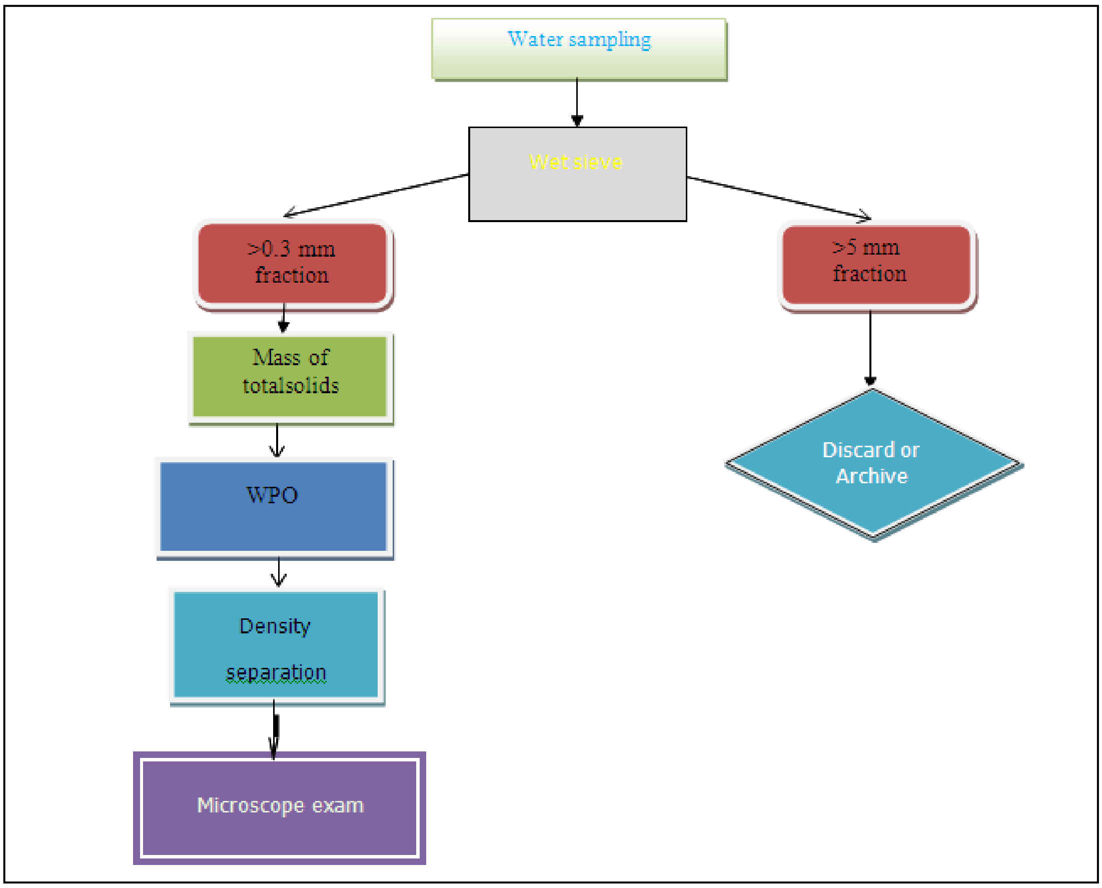
National oceanic & Atmospheric Administration: US (NOAA) method has been used for the analysis of plastic debris as suspended solids in water samples collected by a plankton net. The Plastics include hard plastics, soft plastics, films, line, fibers, and sheets etc. The NOAA method entails filtering solids obtained in a 0.335 mm surface sampling net through 5.6 mm or 0.3mm sieves to isolate solid material of the appropriate size, as shown in fig.24. The sieved material can be dried in these methods to determine the solids mass in the sample. To digest labile organic matter, the solids are subjected to wet peroxide oxidation (WPO) in the presence of a Fe (II) catalyst. The plastic debris has not been altered. The wet peroxide oxidation (WPO) mixture is floated after density separation in NaCl to isolate the plastic debris. A density separator can be used to separate the floating solids from the denser undigested mineral components. Floating plastic debris are collected in the density separator by using a custom 0.3 mm filter, air-dried, and plastic material is removed and weighed to determine the micro-plastics concentration.

Collection of pond water Sample: The water has been collected by a surface net from different ponds in two seasons' viz. post monsoon(November-December, 2021and March, 2022) and pre-monsoon (May-June, 2022) at 0.5m depth. The sample site was selected to be representative of the dense urban and rural lentic environments. Floating microplastics werebe collected by keeping the net submerged.

Figure 24. Note: the variety in these field samples, all collected from pond waters.

- At 0.5 m deep. Approximately 1L of samples have been collected and immediately be preserved with 5%methyl aldehyde in an l-L plastic bottles for further analyses.

Figure 25. Flow diagram for the analysis of micro-plastics in water samples.



❖ **Wet Sieving:**

Pour the sample through a stacked arrangement of stainless-steel mesh sieves measuring 5.6 mm (No. 3.5) and 0.3 mm (No. 50). (Figure- 26).

To transfer all residual solids to the sieves, rinse the sample with a squirt bottle filled with distilled water. This also cleans the field sample of salts. Repeat as needed.

Using distilled water, thoroughly rinse the sieves. Ensure that all materials have been thoroughly washed, drained, and sorted.

Depending on the individual study objectives, discard or archive material retained on a 5-mm sieve.

Figure 26. Sieving and rinsing field samples.

❖ **Transfer Sieved Solids:**

Weigh a 500-mL clean and dry beaker to the nearest 0.1 mg.

Transfer the solids collected in the 0.3-mm sieve into the tared beaker with a spatula and a squirt bottle of distilled water.

Ensure that all solids have been transferred to the beaker.

To test the dryness, place the beaker in a 90°C drying oven for 24 hours or longer (Fig-27).

- **Wet Peroxide Oxidation (WPO):**

20 mL of 0.05 M Fe (II) aqueous solution is added to the beaker containing the 0.3 mm size fraction of collected solids.

Figure 28. Natural organic material is oxidized by adding 20 mL of aqueous 0.05 M Fe (II) solution and 20 mL of hydrogen peroxide.

- Allow the mixture to stand at room temperature on the lab bench for ten minutes before proceeding to the next steps.
- Cover the beaker with a watch glass and add a stir bar. Then, on a hotplate, heat to 75°C.When gas bubbles appear on the surface, the beaker is removed from the hotplate and

placed in the fume hood until the boiling stops. If the reaction appears to be about to overflow the beaker, add distilled water to slow it down.

Figure-29: Heating to 75°C on a hotplate.

- Heat for another 30 minutes at 75°C. If natural organic material is visible, add an additional 20 mL of 30% hydrogen peroxide (figure-29). Repeat until no natural organic material is visible.
- Add 6 g of salt (NaCl) per 20 mL of sample to increase the density of the aqueous solution (5 M NaCl).
- Heat the mixture to 75°C, stirring constantly, until the salt dissolves.

❖ **Density Separation:**

Step 1.5: Transfer the WPO solution to the density separator (Figure 30).

•Rinse the WPO beaker with distilled water to ensure that all remaining solids are transferred to the density separator.

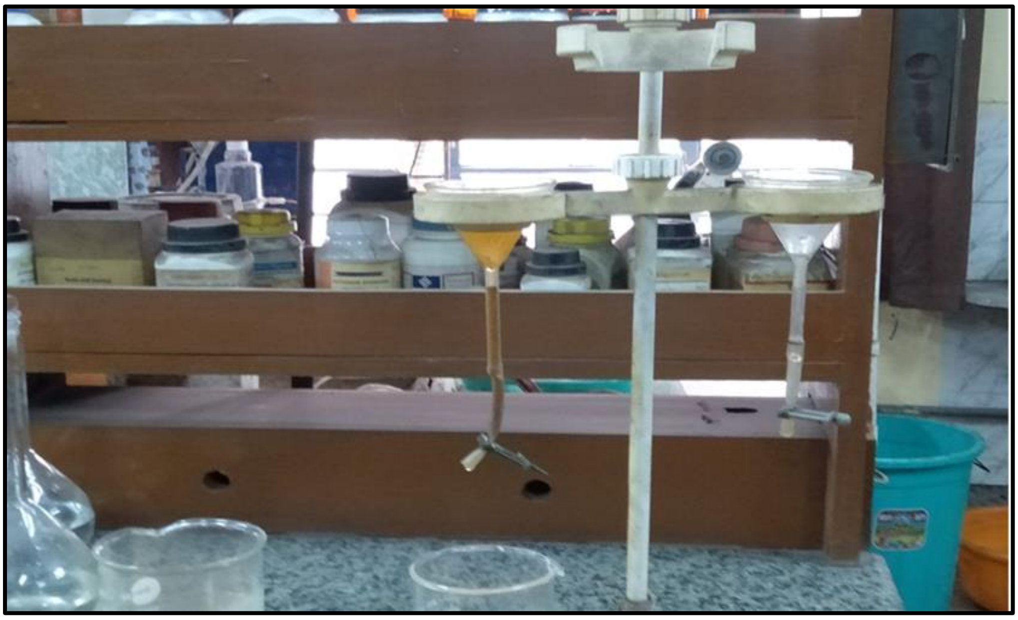


Fig.30: Collecting floating solids in a clean 0.3-mm custom sieve

Wrap loosely in aluminums foil. Allow the solids to settle for the night. Examine settled solids visually for microplastics. If any microplastics are present, drain the settled solids from the separator and remove them with forceps. Archive or throw away.

Drain and discard settled solids from the separator. Using a clean 0.3-mm custom sieve, collect floating solids (Figure 30). Rinse the density separator several times with distilled water to ensure that all solids are transferred to the 0.3-mm sieve. Allow the sieve to air dry for 24 hours while loosely wrapped in aluminums foil (Figure 31).

Collect floating solids in a clean 0.3-mm custom sieve (Figure 31).

Rinse the density separator several times with distilled water to ensure that all solids are transferred to the 0.3-mm sieve.

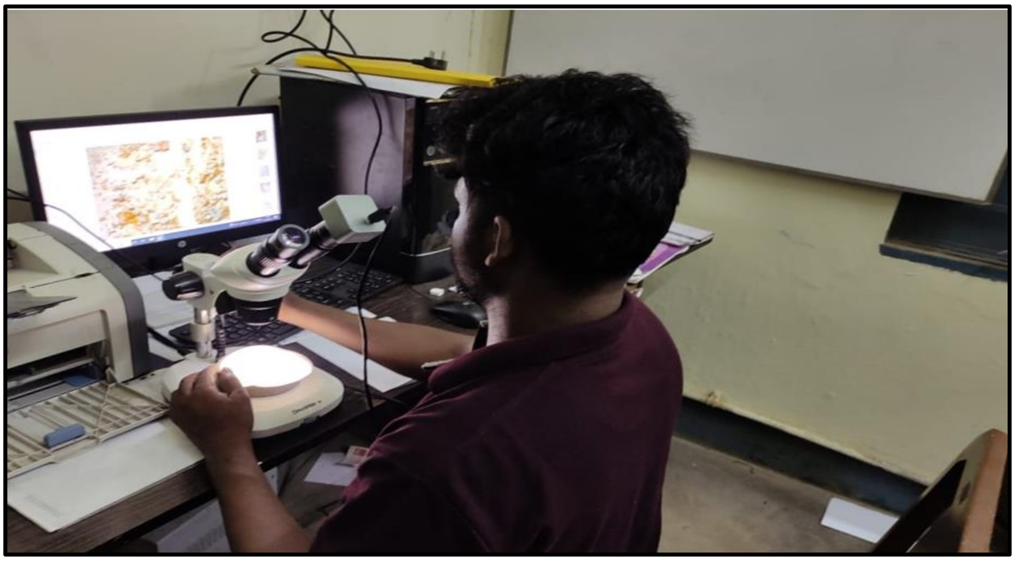
Allow the sieve to air dry for 24 hours while loosely wrapped in aluminium foil (Figure 31).

Figure 32. A prepared sample is ready for microscope examination.

❖ **Microscope Exam:**

- Weigh a clean and dry 4-mL vial. Include the label and cap.

- Under a dissecting microscope at2X 4X magnification (manufactured by:Labomed, model: AB-38-2 CSM2, (**Figure 31**), has been use forceps to collect identifiable microplastics from the 0.3-mm sieve and transfer them to the tared vial **(Figure 32).**



❖ **Machine learning technique for microplastic classification:**

Image Classification Using the Support Vector Machine (SVM): SVM is a well-known method for machine learning and microplastic image classification. The main goal of the microplastic image classification is to use its features to predict the categories of the inputmicroplastic image. The following are the main steps in the microplastic image classification proce

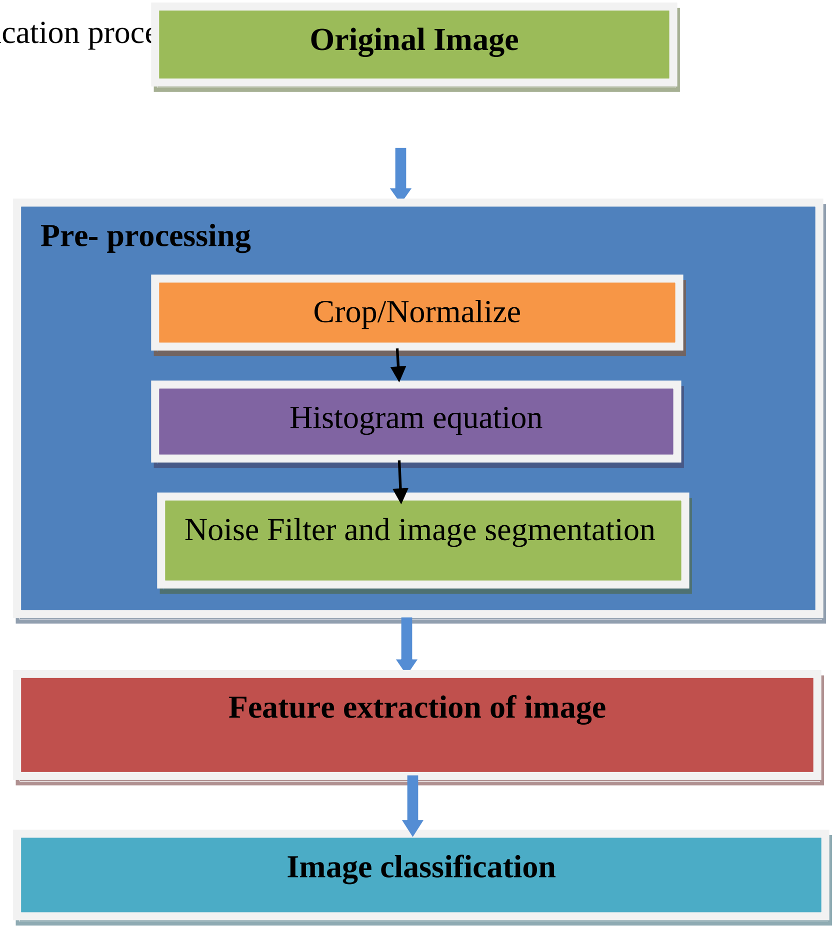


Figure -33: Flow diagram for image classification of microplastic

For morphological classification of microplastic MATLAB R-2020 a has been used and following steps has involved in the classification of morphologies.

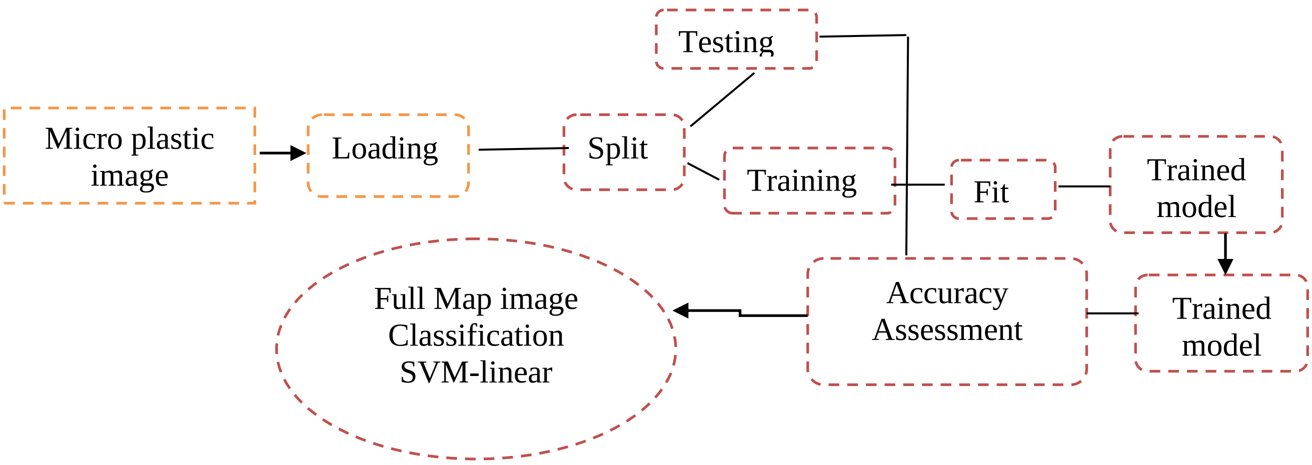


Figure-34:Flowchart for image classification

Chapter – 6

STUDY AREA

The present study has been carried out for two seasons (i.e., **post-monsoon** and **pre-monsoon**) from 2021-2022. The ponds water bodies identified for the present study are situated within the municipal boundary of Kolkata, West Bengal. The water sampleswere collected from different pondswhich are situated near JadavpurUniversity, Baghajatin railway station roads,Bansdroni bazar, BehalaEast, Maidan, Taratala, andSalt Lake sector-3 area and the ponds are following - Bengal Lamp Pond, BaghajatinJheel, KajirPukur ,Vidyasagar Pally Pond, Baghajatin E-Block, Park Circus -1, Park Circus -2, Park Circus -3, Adiganga Pond Bansdroni, Panchnan Pally Pond, Sciencity Lake, Mirania lake, Bansdroni Bazar Pond, Maidan, Kasturi Das Multispeciality Hospital Pond, SantoshpurPukur, Mahehtala Pukur, Keshtopur, Minto park,Bhirab pukur etc. as presented in Figure 35.

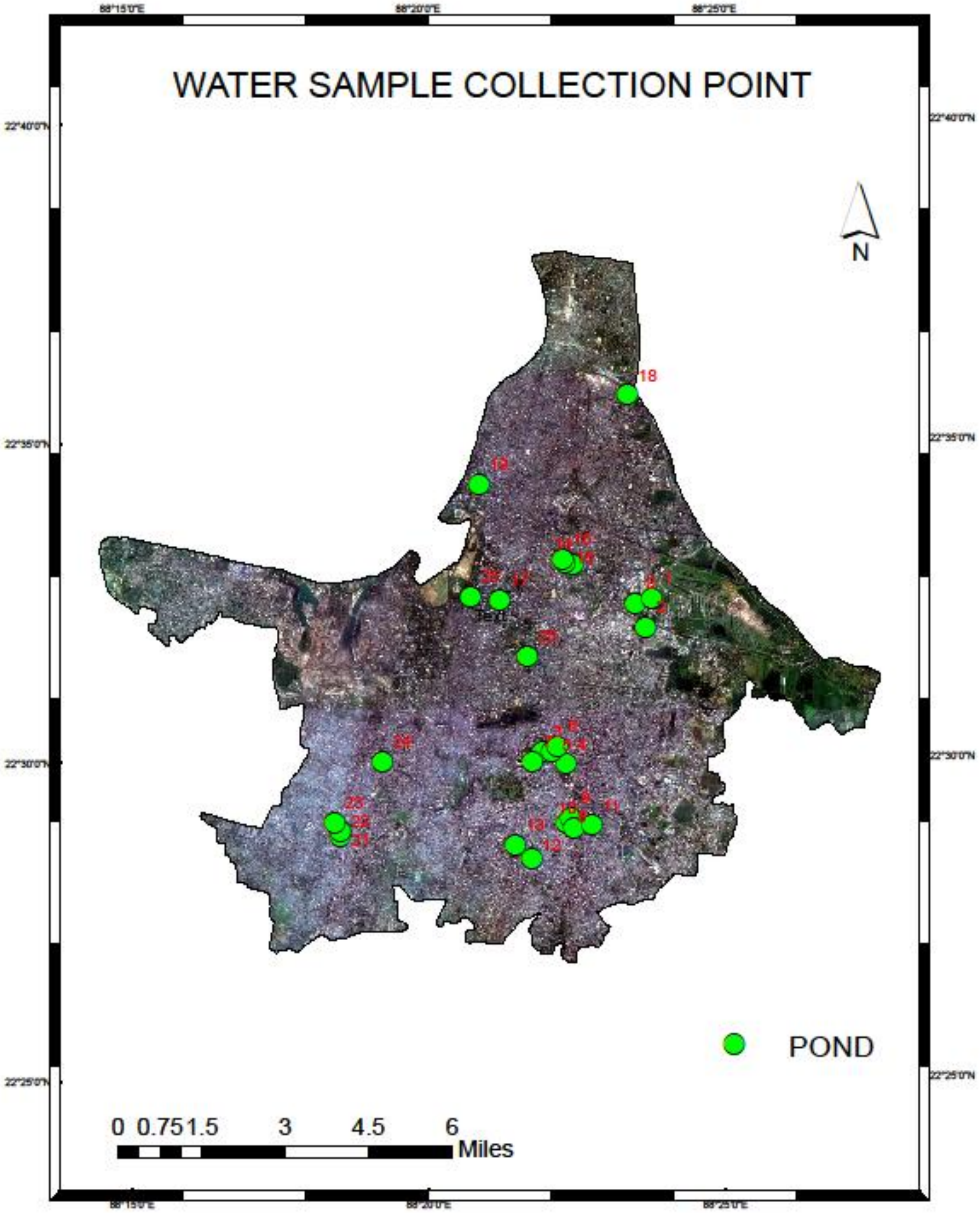


Figure 35: Sampling points for investigation of microplastics within KMC area

Table 5 presents the general features of the studied ponds under Kolkata municipal corporation (KMC) area

Sample Location	Source of Water	Purpose of Use
Jadavpur University Pond -1	Rain fed, water seepage and surface runoff	Fish culture, washing etc.
Jadavpur University Pond -2	Rain fed, water seepage and surface runoff	Fish culture, washing etc.
Jadavpur University Pond -3	Rain fed, water seepage and surface runoff	Fish culture
Jadavpur University Main Hostel Pond	Rain fed, water seepage and surface runoff	Domestic purposes, washing, bathing etc.
Bengal Lamp Pond	Rain fed, water seepage and surface runoff	Linked with land and domestic waste water, domestic purposes, washing car, idol immersion, bathing etc.
BaghajatinJheel	Rain fed, water seepage and surface runoff	Bathing, washing, fish culture etc.
KajirPukur	Rain fed, water seepage and surface runoff	Domestic purposes, washing car, bathing etc.
Vidyasagar Pally Pond	Rain fed, water seepage and surface runoff	Domestic purposes, washing, fish culture etc.
Baghajatin E-Block	Rain fed, water seepage and surface runoff	Domestic purposes, washing, fish culture etc.
Park Circus -1	Rain fed, water seepage and surface runoff	Bathing, washing, vehicle washing, and idol immersion etc.
Park Circus -2	Rain fed, water seepage and surface runoff	Bathing, washing, vehicle washing, and idol immersion etc.

Sample Location	Source of Water	Purpose of Use
Park Circus -1	Rain fed, water seepage and surface runoff	Bathing, washing, vehicle washing, and idol immersion etc.
AdigangaPond Bansdroni	Rain fed, water seepage and surface runoff	Linked with land and domestic waste water, domestic purposes, washing car, idol immersion, bathing etc.
PanchnanPally Pond	Rain fed, water seepage and surface runoff	Bathing, washing, vehicle washing, and idol immersion etc.
Sciencity Lake	Rain fed, water seepage and surface runoff	Fish culture
Mirania lake	Rain fed, water seepage and surface runoff	Bathing, washing, vehicle washing, and idol immersion etc.
BansdroniBazar Pond	Rain fed, water seepage and surface runoff	Linked with land and domestic waste water, domestic purposes, washing car, idol immersion, bathing etc.
Maidan Pond	Rain fed, water seepage and surface runoff	Domestic waste water, domestic purposes, washing etc.
Kasturi Das Multispeciality Hospital Pond	Rain fed, water seepage and surface runoff	Fish culture, linked with land and domestic waste dumping, domestic purposes, washing car, idol immersion, bathing etc.
SantoshpurPukur	Rain fed, water seepage and surface runoff	Fish culture, Bathing, vehicle washing, domestic use etc.
Mahehtala Pukur	Rain fed, water seepage and surface runoff	Linked with land and domestic waste dumping, domestic purposes, washing car, idol immersion, bathing etc.
Minto Park pond	Rain fed, water seepage and surface runoff	Fish culture
Bhirab pukur	Rain fed, water seepage and surface runoff	Fish culture, Bathing, vehicle washing, domestic use etc.
Keshto pukur	Rain fed, water seepage and surface runoff	Fish culture, Bathing, vehicle washing, domestic use etc.

Chapter-7

Results and Discussion

Table 6 presents the pH values of the collected samples using pH meter.

Table-6 pH values of the collected samples in Post-monsoon and Pre-monsoon seasons

Sample location	Post-monsoon		Pre-monsoon	
	Date	pH value	Date	pH value
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	**7.63**	27/05/2022	**7.94**
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	**7.84**	01/06/2022	**7.45**
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	**7.65**	01/06/2022	**7.02**
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	**8.75**	13/05/2022	**7.4**
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	**7.89**	01/05/2022	**7.16**
baghajatin E-BLOCK	17/11/2021	**7.18**	10/05/2022	**7.33**
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	**7.32**	20/05/2022	**6.91**
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	**7.32**	10/05/2022	**7.55**
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	**8.25**	02/06/2022	**8.2**
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	**7.86**	02/06/2022	**8.4**
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	**7.12**	02/06/2022	**7.9**

Sample location	Post-monsoon		Pre-monsoon	
	Date	pH value	Date	pH value
Adiganga pond Bansdroni	04/12/2021	**7.14**	11/05/2022	**6.55**
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	**7.15**	11/05/2022	**7.33**
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	**7.55**	14/05/2022	**7.4**
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	**7.6**	14/05/2022	**7.37**
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	**7.4**	14/05/2022	**7.4**
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	**7.15**	23/05/2022	**6.67**
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	**6.79**	3/06/2022	**8.2**
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	**7.3**	13/05/2022	**7.8**
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	**7.62**	13/05/2022	**7.8**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	**7.2**	13/05/2022	**7.35**

Water pH: The average pH of allstudied pond water has been found **7.40** during the post-monsoon season and during the pre-monsoon season it has been found **8.80.** The magnitude of the fluctuation of pH depends on the buffering capacity and rates of photosynthesis, respiration etc. (Saha et al, 2017 studiedthe physico-chemical parameters in different urban pond water of West Bengal and an average pH of **7.23**was observed during the premonsoon and **7.32** during to the monsoon season. (Dey et al, Botta et al, Kallam et al, Angadala et al, 2021) also reported average pH of pond water during the premonsoon was **8.27.** The results found during present study are somewhat similar to the above findings. On all the seasons the pH value has been found above 7.0 except during the pre-monsoon seasons in Maidan Pond (pH=6.79) and BaghajatinJheel (pH-6.91), Adiganga pond water (pH= 6.55), Bansdroni Bazar pond water (pH= 6.67) during the post monsoon seasons. pH value of collected water samples are sitable for aquatic life.

Table 7 presents the turbidity values in NTU of the collected samples using turbidity meter.

Table-7Turbidity (NTU) values of collected water samples in Post-monsoon and Pre-monsoon seasons

Sample location	**Post-monsoon**		**Pre-monsoon**	
	Date	**Turbidity (NTU)**	**Date**	**Turbidity (NTU)**
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	**1**	27/05/2022	**5**
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	**2**	01/06/2022	**6**
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	**1**	01/06/2022	**6**
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	**5**	13/05/2022	**3**
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	**1**	01/05/2022	**2**
Baghajatin E-BLOCK	17/11/2021	**7**	10/05/2022	**37**
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	**3**	20/05/2022	**4**
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	**5**	10/05/2022	**4**
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	**26**	02/06/2022	**8**

Sample location	Post-monsoon		Pre-monsoon	
	Date	Turbidity (NTU)	Date	Turbidity (NTU)
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	**5**	02/06/2022	**5**
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	**1**	02/06/2022	**6**
Adiganga pond Bansdroni	04/12/2021	**7**	11/05/2022	**6**
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	**3**	11/05/2022	**3**
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	**5**	14/05/2022	**2**
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	**26**	14/05/2022	**37**
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	**16**	14/05/2022	**13**
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	**7**	23/05/2022	**23**
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	**16**	30/06/2022	**16**
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	**6**	13/05/2022	**12**
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	**5**	13/05/2022	**7**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	**6**	13/05/2022	**7**

Water turbidity: The average turbidity of all studied pond water has been found **7.33** NTU, during the post-monsoon seasonand during the pre-monsoon season it has been found **10.09**NTU. (Dey et al,2021) studied the physico-chemical parameters of urban pond water and reported that the average turbidity of pond water was **38.11** NTU. The results obtained of turbidity at present study are less than the above findings may be attributed to the reason that water samples are collected in pre and post monsoon seasons where the suspended solid concentrations are less than monsoon seasons.

Table 8 presents the TDS values in ppm of the collected samples using TDS meter.

Table-8: TDS (ppm) values of collected water samples in Post-monsoon and Pre-monsoon seasons

Sample location	**Post-monsoon**		**Pre-monsoon**	
	Date	**TDS (ppm)**	**Date**	**TDS (ppm)**
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	496	27/05/2022	616
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	552	01/06/2022	739
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	328	01/06/2022	548
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	368	13/05/2022	633
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	511	01/05/2022	674
baghajatin E-BLOCK	17/11/2021	234	10/05/2022	822
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	190	20/05/2022	263
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	200	10/05/2022	262

Sample location	Post-monsoon		Pre-monsoon	
	Date	TDS (ppm)	Date	TDS (ppm)
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	458	02/06/2022	860
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	556	02/06/2022	740
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	355	02/06/2022	208
Adiganga pond Bansdroni	04/12/2021	569	11/05/2022	852
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	215	11/05/2022	430
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	566	14/05/2022	863
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	446	14/05/2022	740
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	382	14/05/2022	382
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	331	23/05/2022	224
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	227	3/06/2022	426
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	324	13/05/2022	321
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	174	13/05/2022	320
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	213	13/05/2022	282

TDS OF WATER SAMPLE: The average TDS of all studied pond water has been found **362.14** ppm, during the post-monsoon session and during the pre-monsoon season it has been found **531.8** ppm,which has exceeded the BIS standard (300 mg/l).While (Ghosh et al, 2021) studied Water quality assessment of the urban ponds in Chandannagar city.its lowest TDS value was found to be 311.39 mg/l and the highest to be 652.44 mg/l.

Table 9 presents the DO values in ppm of the collected samples.

Table-9: D.O values (ppm) values of collected water samples in Post-monsoon and Pre-monsoon seasons

Sample location	**Post-monsoon**		**Pre-Monsoon**	
	Date	**D. O. (mg/L)**	**Date**	**D. O. (mg/L)**
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	**5.75**	27/05/2022	**8.6**
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	**6.44**	01/06/2022	**5.7**
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	**5.7**	01/06/2022	**5.9**
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	**7.4**	13/05/2022	6.7
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	**6.67**	01/05/2022	**7.2**
baghajatin E-BLOCK	17/11/2021	**6.2**	10/05/2022	**6.8**
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	**10.4**	20/05/2022	**7.6**
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	**9.25**	10/05/2022	**8.3**
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	**6.38**	02/06/2022	**6.6**
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	**10.4**	02/06/2022	**6.7**

Sample location	Post-monsoon		Pre-Monsoon	
	Date	D. O. (mg/L)	Date	D. O. (mg/L)
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	**11.3**	02/06/2022	**7.78**
Adiganga pond Bansdroni	04/12/2021	**9.2**	11/05/2022	**7.37**
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	**6.58**	11/05/2022	**8.21**
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	**5.6**	14/05/2022	**6.57**
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	**10**	14/05/2022	**7.5**
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	**5.92**	14/05/2022	**7.68**
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	**8.23**	23/05/2022	**5.70**
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	**8**	3/06/2022	**7.2**
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	**10.4**	13/05/2022	**7.46**
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	**7.25**	13/05/2022	**6.5**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	**10.58**	13/05/2022	**7.89**

Dissolve oxygen: The average DO concentration of all 21 studied pond water has been found**8.08 mg/L**during the post-monsoon session and during the Pre-monsoon season it has been found **7.08 mg/**L. The DO level isvarying from minimum 5.70 mg/L to 11.3 mg/L for the entire seasons. (Saha et al, 2017), studied the physico-chemical parameters in different urban pond water of West Bengal and found average DO concentration wasminimum **3.55**

mg/L and maximum **5.67** mg/L during the monsoon season. (Dey et al, 2021) also reported average DO Level of pond water during the pre-monsoon was minimum**2.6 ppm** and **maximum 14.6 ppm.** The DO concentrations obtained from the present study are more than DO values reported by the other researchers. Considering the limits of DO concentrations for different designated best use (DBU) by CPCBit can be told that following water bodies are safe for organized bathing for all the seasons.

Table 10 presents the BOD_5 values in ppm of the collected samples.

Table-10: B.O.D_5 values (ppm) of collected water samples in Post-monsoon and Pre-monsoon

Sample location	Post-monsoon		Pre-Monsoon	
	Date	B.O.D(mg/L)	Date	B.O.D (mg/L)
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	**4.05**	27/05/2022	**4.11**
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	**7**	01/06/2022	**3.16**
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	**3.38**	01/06/2022	**2.83**
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	**7.3**	13/05/2022	**4.8**
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	**4.77**	01/05/2022	**6.9**
baghajatin E-BLOCK	17/11/2021	**5.96**	10/05/2022	**4.52**
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	**15.96**	20/05/2022	**5.95**
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	**4.46**	10/05/2022	**3.05**
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	**14.23**	02/06/2022	**6.21**

Sample location	Post-monsoon		Pre-Monsoon	
	Date	B.O.D(mg/L)	Date	B.O.D (mg/L)
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	**16.25**	02/06/2022	**5.21**
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	**8.65**	02/06/2022	**5.02**
Adiganga pond Bansdroni	04/12/2021	**7.3**	11/05/2022	**8.37**
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	**2.34**	11/05/2022	**5.49**
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	**2.35**	14/05/2022	**4.25**
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	**0.86**	14/05/2022	**5.43**
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	**1.86**	14/05/2022	**2.73**
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	**4**	23/05/2022	**6.85**
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	**1.85**	3/06/2022	**4.92**
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	**6.2**	13/05/2022	**5.58**
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	**4.12**	13/05/2022	**4.95**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	**2.15**	13/05/2022	**6.86**

Biochemical oxygen demand (BOD): The **average** value of BOD_5 of all studied pond water has been found**6.25 mg/L** during the post-monsoon seasonand during the pre-monsoon season it has been found**5.08 mg/L.** The BOD5 level is varying from minimum **5.70 mg/L to 11.3 mg/L** for the entire seasons. (Saha et al, 2017), while studying the physico-chemical parameters in different urban pond water of west Bengal found an average **BOD value 3.08 mg/L and3.8 mg/L** during the monsoon and ----season respectively. (Dey et al, et al, 2021) also reported average BOD_5 Level of pond water during the pre-monsoon seasons. DO concentration was **minimum 9.2 mg/L and maximum 12.9 mg/L in premonsoon season.** The results found during present study are greater than Sahoo et al., 2017 study but less than Angadala et al., 2021 study. The BOD_5 of unpolluted water is usually **less** than 1.00 mg/L, moderately polluted water 2.00 to 9.00 mg/L and heavily polluted water has the BOD more than 10.00 mg/L.The BOD5 values in different urban ponds are indicating that the ponds are moderately polluted and in terms of DBU as mentioned CPCB the ponds are not fit for organized bathing.

Table 11 presents the Coliform count (MPN/100 mL) of the collected samples.

Table-11Coliform count (MPN/100 mL) of collected water samples in Post-monsoon and Pre-monsoon seasons

Sample location	Post-monsoon		Pre-monsoon	
	Date	MPN/100 mL	Date	MPN/100 mL
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	13	27/05/2022	230
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	140	01/06/2022	170
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	38	01/06/2022	130
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	220	13/05/2022	920
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	26	01/05/2022	120
baghajatin E-BLOCK	17/11/2021	220	10/05/2022	350
(22°28´59´´N88°22´23´´E)	17/11/2021	79	20/05/2022	1600

Sample location	Post-monsoon		Pre-monsoon	
	Date	MPN/100 mL	Date	MPN/100 mL
BaghajatinJheel				
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	23	10/05/2022	150
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	210	02/06/2022	240
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	210	02/06/2022	350
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	210	02/06/2022	430
Adiganga pond Bansdroni	04/12/2021	1600	11/05/2022	1600
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	47	11/05/2022	210
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	430	14/05/2022	350
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	330	14/05/2022	340
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	920	14/05/2022	110
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	430	23/05/2022	430
(22°33´18´´N88°20´54´´E) Maidan Pond	02-01-2022	210	3/06/2022	540
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	470	13/05/2022	130
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	920	13/05/2022	540

Sample location	**Post-monsoon**		**Pre-monsoon**	
	Date	**MPN/100 mL**	**Date**	**MPN/100 mL**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	350	13/05/2022	280

Coliform (MPN/100mL): The average value of coliform (MPN/100mL) of all studied pond water has been found **344.3**during the post-monsoon seasonand during the Pre-monsoon season it has been found **461**. The coliform (MPN/100mL) level is varying **from minimum 13 to maximum of1600** for the entire seasons. (Dinda et al, 2014) while studying the physico-chemical parameters in different urban pond water of West Bengal, found average coliform (MPN/100mL) values**2400, 170, 350, 120, 60** etc. during the different seasons. The results found during present study are somewhat similar to the above findings related to the coliform level range. Since the coliform count is less than 500/100ml then the ponds can be used for organized bathing as per CPCB standard for surface water.

Table 12 presents the Micro plastic (items/ litre) concentration of the collected samples.

Table-12Micro plastic (items/ litre) concentration of collected water samples in Post-monsoon and Pre-monsoon seasons

Sample location	**Post-monsoon**		**Pre-Monsoon**	
	Date	**MPs (items/ litre)**	**Date**	**MPs (items/ litre)**
(22°30´55´´N88°22´21´´E) JU POND-1	17/11/2021	**15**	27/05/2022	**5**
(22°30´00´´N88°22´12´´E) JU POND -2	17/11/2021	**14**	01/06/2022	**7**
(22°30´02´´N88°17´22´´E) JU POND -3	17/11/2021	**15**	01/06/2022	**10**
(22°29´59´´N88°22´06´´E) Bengal lamp pond	18/11/2021	**20**	13/05/2022	**9**

Sample location	**Post-monsoon**		**Pre-Monsoon**	
	Date	**MPs (items/ litre)**	**Date**	**MPs (items/ litre)**
(22°30´08´´N88°21´59´´E) Ju main hostel pond	18/11/2021	**14**	01/05/2022	**11**
baghajatin E-BLOCK	17/11/2021	**16**	10/05/2022	**7**
(22°28´59´´N88°22´23´´E) BaghajatinJheel	17/11/2021	**13**	20/05/2022	**14**
22°29´06´´N88°22´26´´E) Kajirpukur pond	24/11/2021	**15**	10/05/2022	**10**
(22°32´31´´N88°22´54´´E) PARK CIRCUS -1	26/11/2021	**10**	02/06/2022	**12**
(22°32´29´´N88°22´49´´E) PARK CIRCUS -2	26/11/2021	**10**	02/06/2022	**14**
(22°32´31´´N88°22´45´´E) PARK CIRCUS-3	26/11/2021	13	02/06/2022	13
Adiganga pond Bansdroni	04/12/2021	**17**	11/05/2022	**17**
(22°28´52´´N88°22´30´´E) Vidyasagar pally pond	28/01/0222	**14**	11/05/2022	**12**
(22°32´06´´N88°23´23´´E) Mirania lake	28/01/0222	**14**	14/05/2022	**16**
(22°32´31´´N88°22´54´´E) Panchnan pally pond	28/01/0222	**9**	14/05/2022	**10**
(22°32´04´´N88°23´37´´E) sciencity lake	28/01/0222	**10**	14/05/2022	**10**
(22°28´36´´N88°21´33´´E) Bansdroni bazar pond	29-01-2022	**6**	23/05/2022	**10**
(22°33´18´´N88°20´54´´E) Maidan	02-01-2022	**6**	3/06/2022	**12**

Sample location	Post-monsoon		Pre-Monsoon	
	Date	MPs (items/ litre)	Date	MPs (items/ litre)
Pond				
(22°30´52´´N88°16´16´´E) Kasturi Das multispeciality hospital pond	23-03-2022	**12**	13/05/2022	**16**
(22°30´52´´N88°16´16´´E) Meheshtalapukur	23-03-2022	**14**	13/05/2022	**13**
(22°30´52´´N88°16´22´´E) Santoshpurpukur	23-03-2022	**10**	13/05/2022	**14**

Micro plastic (items/litre): The minimummicroplastic(items/litre) concentration of all studied pond waters was **5 items/litre** during the pre-monsoon session and during the postmonsoon season it has been found **6items/litre**. The microplastic level is varying from minimum 6items/litre to maximum of 17 items/litre for the entire seasons. The microplastic concentration in the pond at Bengal lamp **(22°29´59´´N88°22´06´´E) is maximum at post monsoon season may be attributed to the solid waste dumping bin adjacent to the pond.** Bharath K et al. (2021) detected microplastic concentration for Veeranam Lake, Tamil Nadu, 2014 as**28 items/km^{2}**. While (Gopinath et al.2020) reported microplastic concentration in the Red Hills Lake, Tamil Naduas **5.9 particles/**L. (Ganesan et al. 2019) studiedmicroplastic concentration in front of Kerala, southwest coast ofIndia, Chennaimarina and reported the concentration as **11 items/L** for different seasons. The results found during present study are somewhat similar to the reported values of microplastic concentrations of different lakes of India.

- **Morphological characteristics of microplastics in lentic environment:**

Table 13 presents the ***Morphological characteristic*** of Micro plastic (items/ litre) of the collected samples.

Table -13 Morphological characteristic of microplastic of collected ponds

SLNO	NAME OF PONDS	POST-MONSOON						PRE-MONSOON					
		Fiber	**Film**	**Fragments**	**Pellets**	**Foam**	**Others**	**Fiber**	**Film**	**Fragments**	**Pellets**	**Foam**	**Others**
1	Jadavpur University pond -1	8	0	1	0	0	3	10	2	3	0	0	3
2	Jadavpur University Pond - 2	18	2	2	1	0	2	12	3	1	0	0	4
3	Jadavpur University Pond -	17	5	2	1	0	3	13	2	1	0	0	0

SLNO	NAME OF PONDS	POST-MONSOON						PRE-MONSOON					
		Fiber	**Film**	**Fragments**	**Pellets**	**Foam**	**Others**	**Fiber**	**Film**	**Fragments**	**Pellets**	**Foam**	**Others**
	3												
4	Jadavpur University Main Hostel Pond	15	3	0	1	0	5	15	2	0	0	0	6
5	Bengal Lamp Pond	17	3	3	2	0	4	17	4	1	0	0	2
6	BaghajatinJheel	14	3	0	0	0	5	14	3	1	0	0	2
7	KajirPukur	15	4	0	1	0	3	12	4	1	0	0	3
8	Vidyasagar Pally Pond	14	3	0	0	0	5	10	4	2	1	0	0
9	Baghajatin E-Block	14	2	3	0	0	3	12	5	3	1	1	2
10	Park Circus -1	15	2	2	1	1	3	16	4	5	2	1	5
11	Park Circus -2	10	3	0	1	0	5	8	3	2	1	1	
12	Park Circus -1	15	3	2	0	0	2	12	4	3	2	0	2
13	AdigangaPond Bansdroni	12	5	1	0	0	3	12	3	2	1	0	5
14	PanchnanPally Pond	10	3	2	0	0	1	8	3	1	0	0	2
15	Sciencity Lake	9	1	1	0	0	3	8	2	0	0	0	2
16	Mirania lake	19	3	0	2	1	3	10	2	1	0	0	1
17	Bansdroni Bazar Pond	15	4	2	2	0	0	14	2	1	0	1	5
18	Maidan Pond	13	3	2	0	1		12	4	2	0	0	3
19	K. Das Multispecialty Hospital Pond	16	2	1	1	0	2	9	3	2	0	0	3
20	SantoshpurPukur	15	3	1	1	0	1	12	4	2	1	0	4
21	Maheshtala pond	12	4	1	1	1	3	10	3	2	3	2	6
	Total no.	**278**	**53**	**26**	**15**	**4**	**105**	**246**	**59**	**38**	**12**	**6**	**58**

During the observation of microplastic in thepost-monsoon seasons, the major portion were fibers (58 %), followed by films (11%), fragments (5.0%), others (i.e., glass, leathers) (22%) and pellets (3.0 %) as presented in Figure 37.

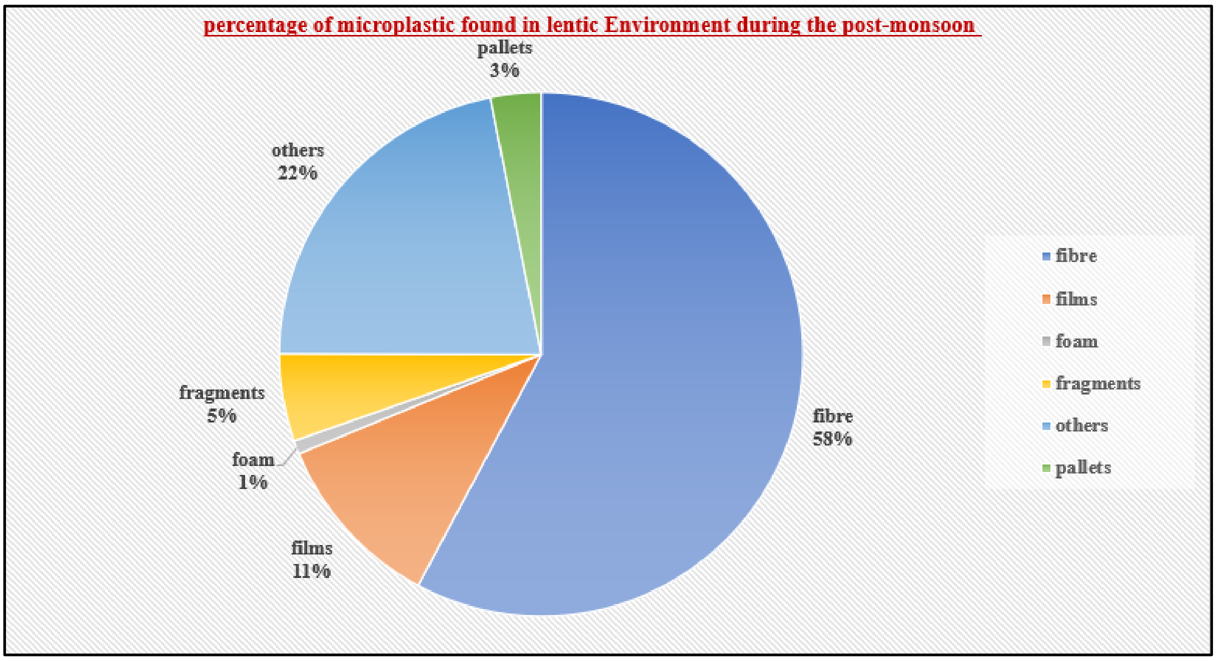


Figure-36:Microplastic particles found during the post-monsoon in lentic environment

For pre-monsoon seasons out of total 419 microplastic particles collected the main type of plastics observed were fibres (59 %), followed by films (14 %), fragments (9.0%), others (i.e., glass, leather) (14%), foam (2%) and pellets (2.0 %) as shown in Figure 38. Gopinath et al., 2020 also observed that for Red Hill Lake, Chennai city, Tamil Nadu fibers (37.9%) is the dominant microplastic followed by fragments (27%), films (24%), and pellets (11.1%). The abundance and distribution of microplastics in bodies of water can be established by examining the environmental and anthropogenic variables that surround them. The main sources of these microplasticsmay be mainly due to the breakdown of plastic products due to weathering process and also from fishing nets, cosmetic products, washing of clothes during bathing, disposal of flowers in plastic bag which are the major contributors of microplastics in water.

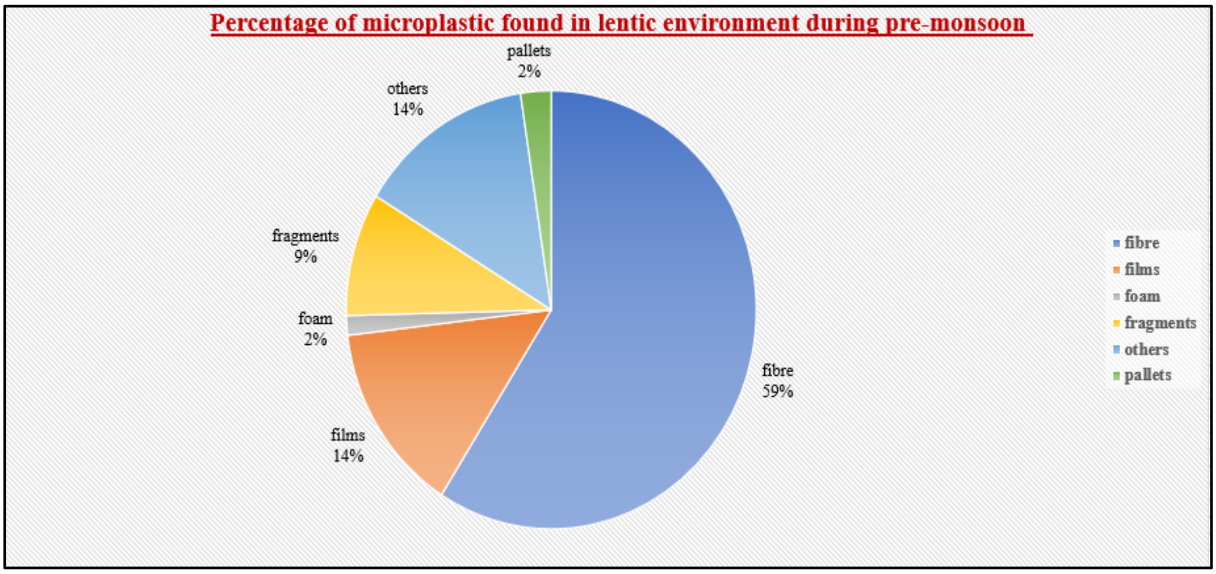


Figure-37:Microplastic particles found during the Pre-monsoon in lentic environment

- **Spatial and temporal changing trends between estimated water quality parameter and microplastic concentrations:**

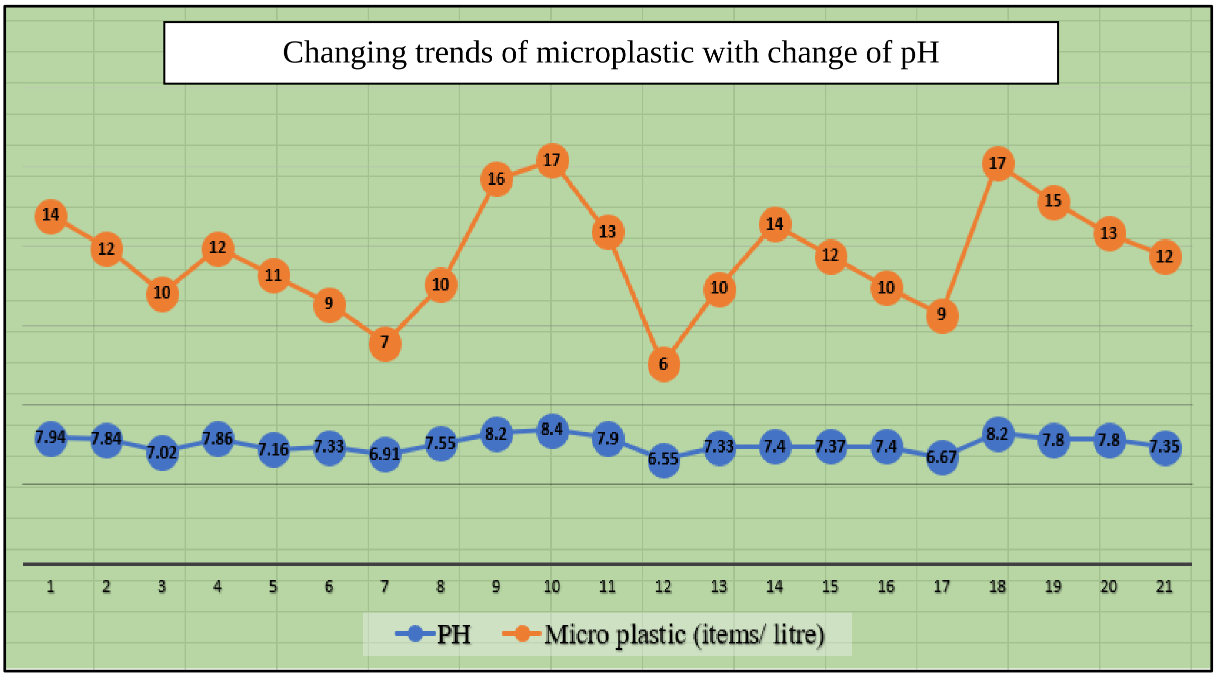


Figure 38: Changing trends of Microplastic concentration(item/litre) with change of pH during pre-monsoon season

The correlations between pH and microplastic concentration during both post-monsoon and pre-monsoon are presented in Figure 38. Form Figure 38 it is clear when pH increases microplastic concentration also increases like in point 4, 10 and 18. (Xiong et al., 2022) also stated that the microplastic abundance in summer season was a significant contributor to the principal component with pH, which exhibited positive correlations with pH.

❖ **Changing trends of microplastic concentration with D.O:**

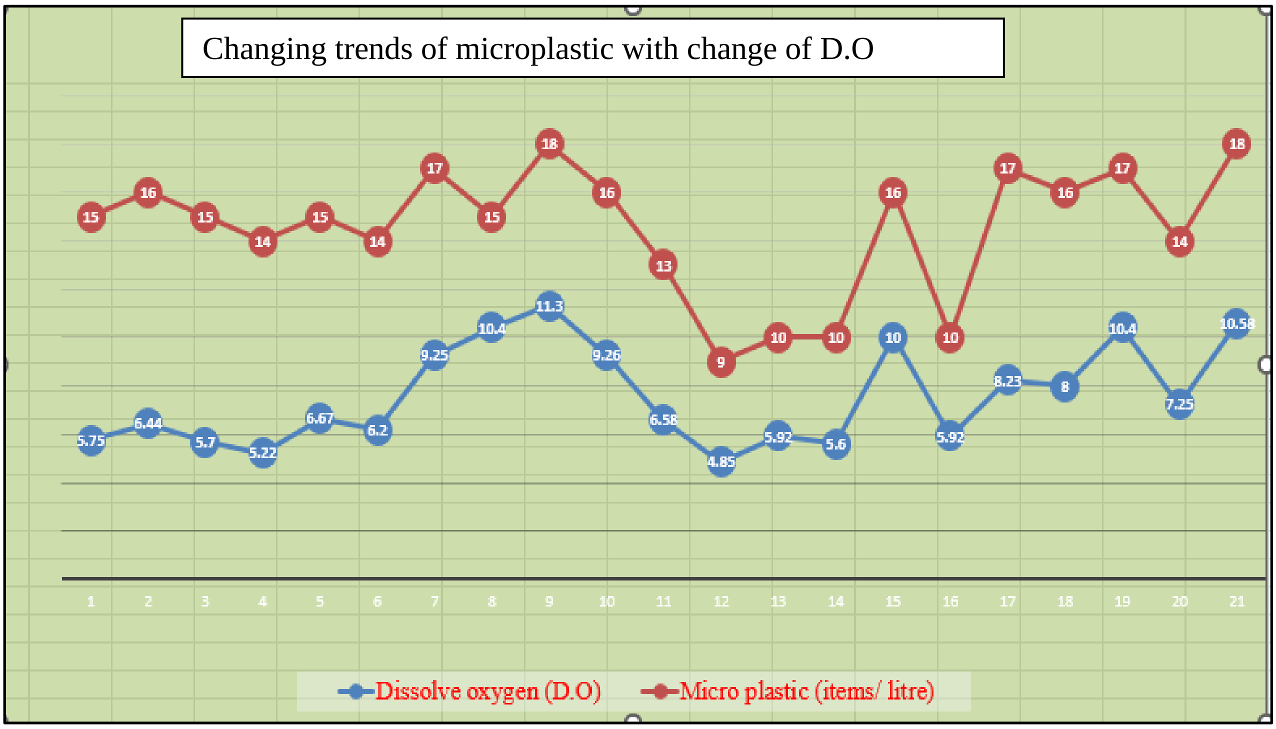


Figure 39: Changingtrends ofMicroplastic(items/litre) concentration with D.O

The changes of DO and microplastic concentrations during post-monsoon are presented in Figure 39. Form Figure 39 it is clear when microplastic concentration increases, DO concentration also increases like in point 2, 9 and 19.2X 4X magnification (manufactured by: Labomed, model: AB-38-2 CSM2 (Xiong et al., 2022) also stated that the microplastic abundance in summer season was a significant contributor to the principal component with D.O, which exhibited positive correlations with D.O.

❖ **Changing trends of BOD_5 and microplastic:**

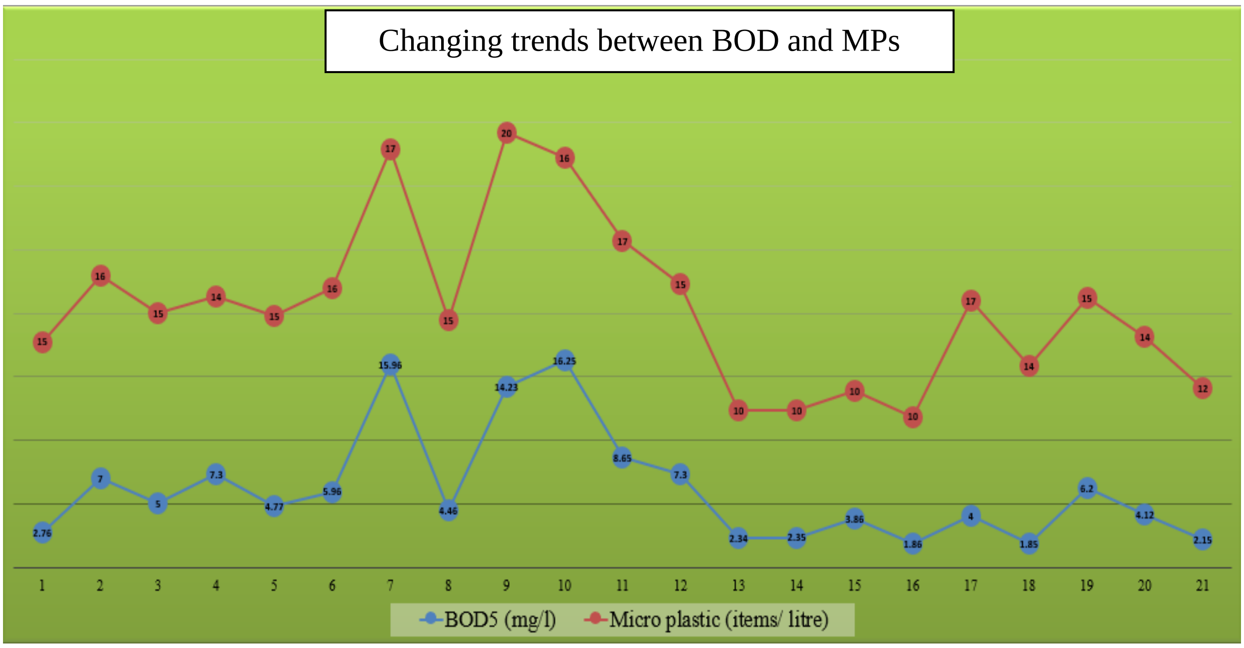


Figure 40– Changing trends ofMicroplastics (mg/l) and BOD_5 (mg/L) during the post-monsoon season

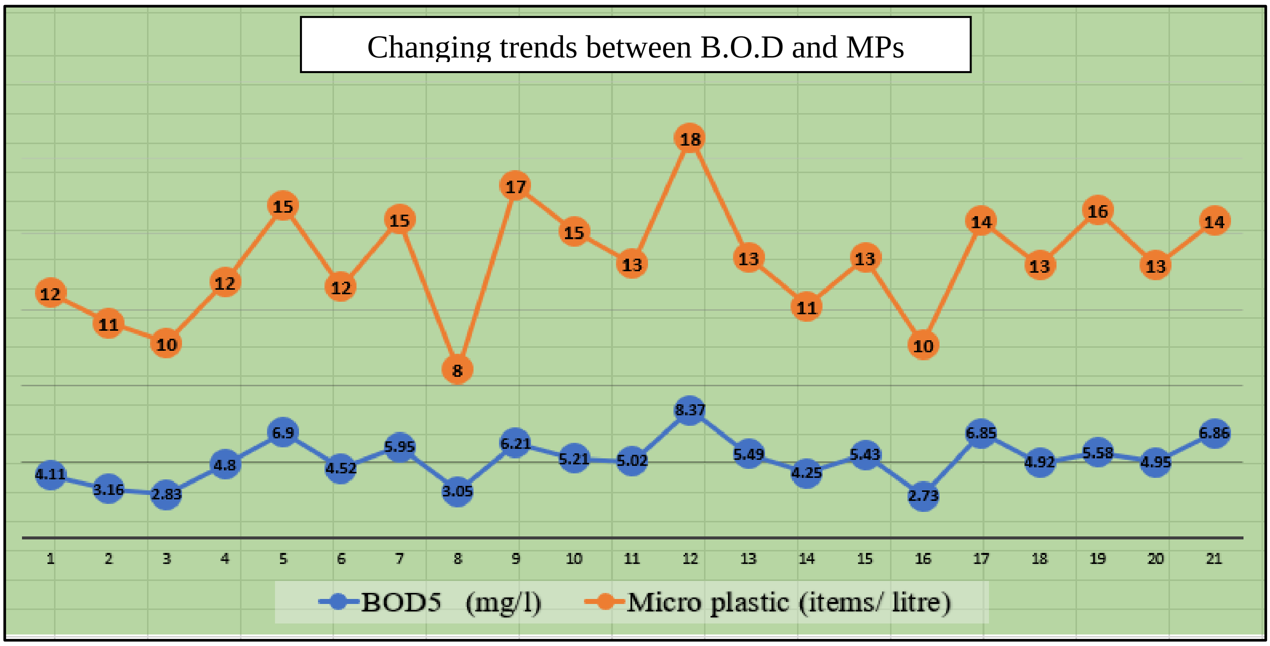


Figure 41- Changing trends ofMicroplastics (mg/l) and BOD_5 (mg/L) during the pre-monsoon season

The BOD reflects the quantity of dissolved oxygen required for microorganisms to decompose organic materials under aerobic circumstances. The high BOD level detected in waterbodies suggests that organic matter has contaminated the water body.The changing trends of B.O.D and microplastic during both post-monsoon and premonsoon as shown in Figure 40 and 41 reveal that there is positive correlation between B.O.D and microplastic. The BOD variable also denotes the presence of plastic-degrading bacteria, often known as binding aerobic bacteria. These bacteria, like all living things, require oxygen to survive (Galgani et al., 2018). That is why may be more microplastic concentration attributed to more BOD value.

❖ **Identification of Micro plastic fragments:**

The microscope captures the following types of microplastic images while examining a prepared sample at 4X magnification using(2X 4X magnification (manufactured by: Labomed, model: AB-38-2 CSM2) -----**.**

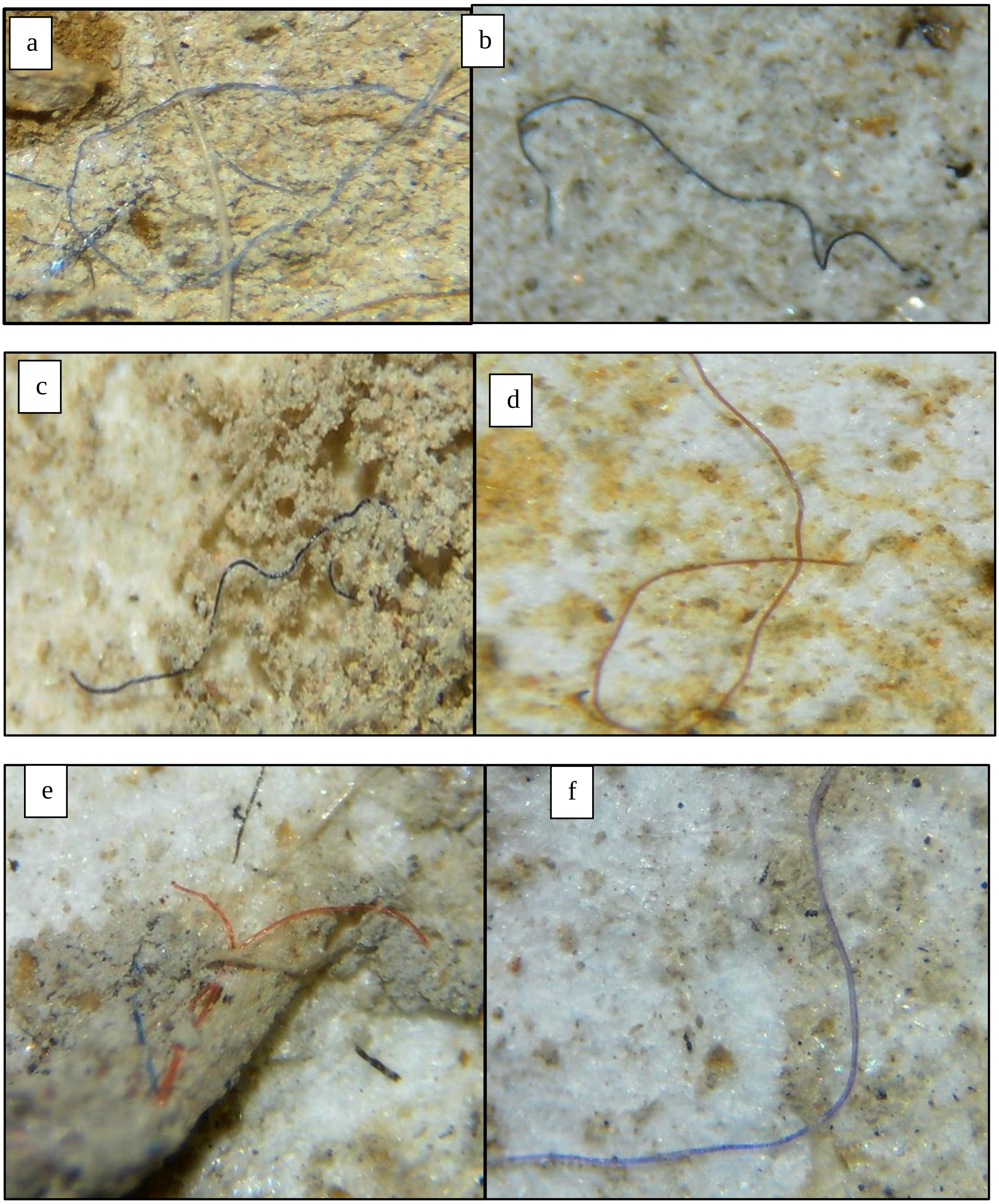


Figure -42 (a, b,c,d, e, f) Images of micro plastics in 4X magnification

Table 14 presents the Pearson correlation between water quality parameters and microplastic concentration. All the water quality parameters are significantly correlated with microplastic concentration at 90% or 95% significance level. DO concentration is negatively correlated with microplastic where BOD_5 and total coliform count are positively correlated with microplastic. Microorganisms are attached with microplastics and consume more DO therefore BOD_5 increases while DO decreases with microplastic concentration.

Table 14Pearson correlation between water quality parameters and micro plastic concentration

Correlations

		microplastic	Temp	PH	Turbidity	DO	BOD5	TDS	MPN
microplastic	Pearson Correlation	1	.265	.055	-.021	-.274	.129	-.078	.097
	Sig. (2-tailed)		.063	.705	.884	.054	.371	.592	.505
	N	50	50	50	50	50	50	50	50
Temp	Pearson Correlation	.265	1	.139	.046	-.148	.109	-.016	.079
	Sig. (2-tailed)	.063		.334	.751	.305	.452	.910	.586
	N	50	50	50	50	50	50	50	50
PH	Pearson Correlation	.055	.139	1	.094	.043	.245	-.016	-.224
	Sig. (2-tailed)	.705	.334		.517	.766	.086	.910	.117
	N	50	50	50	50	50	50	50	50
Turbidity	Pearson Correlation	-.021	.046	.094	1	-.032	.131	.254	.525**
	Sig. (2-tailed)	.884	.751	.517		.825	.363	.075	.000
	N	50	50	50	50	50	50	50	50
DO	Pearson Correlation	-.274	-.148	.043	-.032	1	.344*	-.234	-.086
	Sig. (2-tailed)	.054	.305	.766	.825		.015	.102	.555
	N	50	50	50	50	50	50	50	50
BOD5	Pearson Correlation	.129	.109	.245	.131	.344*	1	-.028	-.073
	Sig. (2-tailed)	.371	.452	.086	.363	.015		.844	.614
	N	50	50	50	50	50	50	50	50
TDS	Pearson Correlation	-.078	-.016	-.016	.254	-.234	-.028	1	.094
	Sig. (2-tailed)	.592	.910	.910	.075	.102	.844		.515
	N	50	50	50	50	50	50	50	50
MPN	Pearson Correlation	.097	.079	-.224	.525**	-.086	-.073	.094	1
	Sig. (2-tailed)	.505	.586	.117	.000	.555	.614	.515	
	N	50	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Similar correlation was obtained by (Jiang et al., 2020), whilestudied that the contamination of microplastics was related to the physical and chemical parameters of the water quality.

- ❖ Morphological classification by machine learning:

For morphological classification support vector machine (SVM) learning technique was used. The whole analysis has been done in MATLAB (R2020a) by coding. The coding was depicted below.

```
cd D:\data
df=[];
```

```
for i = 1:70
    x=imread(strcat(int2str(i),'.jpg'));

    y=rgb2gray(x);
    lbpB1=extractLBPFeatures(y,'Upright',false);
    lb1=sum(lbpB1);
    glcm=graycomatrix(y,'offset',[2,0;0,2]);
    st1=graycoprops(glcm,{'contrast','homogeneity'});
     st2=graycoprops(glcm,{'correlation','energy'});

     f1=st1.Contrast;
     f2=st1.Homogeneity;
     f3=st2.Correlation;
     f4=st2.Energy;

     Fr=horzcat([lb1,f1,f2,f3,f4]);
     df = [df;Fr];

end

cd ..

[f,p]=uigetfile('*.*');
test=imread(strcat(p,f));

y=rgb2gray(test);
    lbpB1 = extractLBPFeatures(y,'Upright',false);
    lb1=sum(lbpB1);
    glcm=graycomatrix(y,'offset',[2,0;0,2]);
    st1=graycoprops(glcm,{'contrast','homogeneity'});
     st2=graycoprops(glcm,{'correlation','energy'});

     f1=st1.Contrast;
     f2=st1.Homogeneity;
     f3=st2.Correlation;
     f4=st2.Energy;

     Testftr=horzcat([lb1,f1,f2,f3,f4]);

     TrainingSet=df;

GroupTrain={'1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','1','2','2','2','2','2','2','2','2
','2','2','2','2','2','2','2','2','2','2','3','3','3','3','3','3,','3','3','3','3','3','4','4','4','4','4','4','4','4','4','4','4','
4','5','5','5','5','5','5','5'};
     TestSet=Testftr;

     Y=GroupTrain;
     classes=unique(Y);
     SVMModels=cell(length(classes),1);
     rng(1);
```

```
for j=1:numel(classes)
        idx=strcmp(Y',classes(j));
        SVMModels{j}=fitcsvm(df,idx,'ClassNames',[false
true],'Standardize',true,'KernelFunction','rbf','BoxConstraint',1);
end
    xGrid=Testftr;
for j=1:numel(classes)
       [~,score]=predict(SVMModels{j},xGrid);
       score(:,j)=score(:,2);
end

    [~,maxscore] = max(score,[],2);
    result=maxscore;

if result == 1
        msgbox('Flim')
elseif result == 2
        msgbox('Fibre')
elseif result == 3
        msgbox('Fragment')
elseif result == 4
        msgbox('Pellet')
    elseif result == 5
        msgbox('Foam')
else
        msgbox('None')
end
```

For this morphological analysis total 100 images were used (70 % training and 30 % testing). The training procedure has been done successfully and in case of testing procedure most of the images were easily classified morphologically still very less of images can’t be recognized.The overall accuracy is 89 % of morphological analysation .

Chapter – 7

SIGNIFICANCE OF THE PROJECT:

Determination of microplastic in freshwater environment is very significant for monitoring and controlling the water quality. Micro plastic determination helps us to evaluate the microplastic pollutant strength and toxicity nature of microplastic. The adsorption capacity of heavy metals by Microplastic under multiple environmental factors can evaluate the influence of environmental factors on the interactions. Micro plastic determination helps us to evaluate the ecological and toxic effects of microplastic at environmentally realistic concentrations. Shape and types of microplastic can help in determining their source and, their size and colour might influence their ingestion in aquatic biota and also indicate the amount of degradation. Micro plastic determination of lentic water bodies helps to understand the aquatic ecosystems which contain a great diversity of microorganisms and play as a critical role in many biogeochemical processes. This project helps us to assess the risk of MPs and heavy metals on human health which is the combined pollution of microplastics and heavy metals that is harmful to human health. Microplastic determination can evaluate the presence of pathogenic bacteria that can travel the waters on MPs. It is very significant to know the water quality criteria for microplastics-related pollutants for the control of microplastic emissions, protection of human health, and ecosystem safety.

Chapter – 8

Conclusions:

In this study the spatial and temporal variation of microplastic concentration in different urban fresh water bodies were reported. Every week from November 2021 to mid-June 2022, water samples are collected from the chosen ponds to determine its water quality by measuring its physicochemical properties. A total of 21 pond water samples were collected from ponds present in Kolkata Municipal Corporation area, for the evaluation of pond water quality and the analysis of micro plastic present in pond water. The microplastic level is varying from minimum 6 items/litre to maximum of 17 items/litre for the entire seasons. For the correlation analysis between water quality parameters and the micro plastic present in pond water, a total of six parameters are used viz. pH, turbidity, total dissolve solids, DO, BOD_5, and coliform (MPN/100ml). The average pH of all studied pond water has been found 7.40, during the post-monsoon season and during the pre-monsoon season it has been found 8.80. The average turbidity of pond water has been found 7.33 NTU during the post monsoon and 10.09 NTU during pre-monsoon, the average DO content during post monsoon has been found 8.08mg/lit and during the pre-monsoon 7.08 mg/l, the average BOD_5 content has been found 6.25 mg/L during post-monsoon and 5.08 mg/L during pre-monsoon. The average concentrationof coliform (MPN/100 mL) present in pond water is 344.3 during post-monsoon and 461 during the observation of pre-monsoon and coliform (MPN/100 mL) level is varying from minimum 13 to maximum 1600 forthe entire season. All the water quality parameters are correlated significantly with microplastic concentration in 90-95% level. While BOD_5 has positive correlation, DO has negative correlation with microplastic concentration. Fibre was observed most dominant shape for all the seasons followed by films, fragments, others, foam (2%) and pellets. Support vector machine was successfully adopted for morphological classification of microplastics in this study.

The findings and analysis of all the data showed that pond utilisation activities could have a sizable impact on the quantity and characteristics of micro plastics found in pond water bodies. The majority of inland plastic wastes could be disposed of in the ponds because of lack of proper plastic waste management system. During the drainage period, man-made or natural drainage and canals connected to ponds may be served as conduits for the transportation of micro plastics, and after drainage, the water system of the ponds served as the sink for micro plastic.The study would help to get insight about microplastic pollution in urban lentic environment and help policy makers to prepare policy to minimize the pollution.

Chapter – 9

❖ *Future Scope of the Study*

The findings of this study on the detection of micro plastic in freshwater (lentic environment) suggested that additional research on the origins, environmental behaviour, and preventative measures of micro plastics in aquaculture ponds, particularly on the buildup of micro plastics in aquatic organisms in urban and semi-urban areas ponds aquaculture water systems, would be crucial for preventing micro plastic in artificial and natural water bodies throughout the entire seasons. It is evident from observing the analyzed data and results that further investigation and gap analysis are crucial for determining priorities in putting solutions into practice and creating new ones. The future scope of the study therefore may be:

- Determination of spatial and temporal variation of microplastics in lentic water bodies not only for urban and semi urban areas and also for rural areas
- Identification of the influencing parameters of microplastic concentrations.
- Measurement of the Microplastic concentration of the sediment of water bodies.
- Analysation of compositional characteristics of microplastics by EDAX and FTIR.
- Analysation of correlation between heavy metal concentrations and Microplastic concentration
- Risk assessment of microplastic on ecology and human health

❖ **Recommendation**

Based on the observation and analysis of micro plastics in pond water samples, it is essential to create smarter, more recyclable plastics and improve recycling processes through the investigation and isolation of microorganisms that break down micro plastics as well as the tracking and removal of micro plastics through sophisticated water treatments. Combinations of these processes could control and lessen the pollution caused by micro plastics in pond water. Future origins of micro plastic should be less susceptible to environmental influences in terms of distribution, shape categories, and relationships. Measures including sourcecontrol, remediation, and cleanup should be taken. Countries should be encouraged not to use microbeads impersonal care products and biodegradable plastics such as polylactide and polyhydroxyalkanoates should be used instead. Utilization efficiency and circularity of plastics should be improved. Existing wastewater treatment plant should be upgraded to improve the removal efficiency of microplastics and to prevent microplastics from entering aquatic system. Moreover, strategies of cleanup and bioremediation technologies should be developed.

Furthermore, future research should concentrate on developing highly effective analytical techniques (e.g., fully or semi-automated analytical technologies) to facilitate quick and accurate identification and quantification of micro plastic particles present in lentic environment. These techniques should be standardized for sampling and extracting micro plastics from lentic environmental matrices. Additionally, there is a growing need to develop dependable and effective tools and analytical methods capable of effectively detecting and quantifying plastic particles at micron- or even nano-scales in ponds in order to estimate the ecological risks of these microscopic plastic particles. In order to establish standardized methodologies to gauge the severity of this problem on a global scale, a thorough understanding of the sampling and analytical techniques currently employed in the micro plastics monitoring programmers conducted in aquatic environments should be studied.

Using a single analytical technique, it is challenging to quantify and categories micro plastics in pond water samples. As a result, it is preferred to combine several different techniques, which heavily depends on the sizes of the micro plastics.

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