College of Natural and Computational Sciences

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Occurrence and distribution of plastic debris along shores sediment of Lake Hawassa, Ethiopia

MSC Thesis

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ACRONYMS AND ABBREVATIONS

MPS	Micro-plastics
°C	Degree Celsius
H_2O_2	Hydrogen peroxide
$ZnCl_2$	Zinc Chloride
NaCl	Sodium Chloride
kg	Kilogram
g	Gram
mm	millimeter
cm	Centimeter
ml	Milliliter
hrs	Hours
Pvc	Poly Vinyl Chloride
PE	Poly Ethylene
UV	Ultra violate radiation

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ABSTRACT

Micro-plastic particles are carriers of harmful substances including pathogenic bacteria and potentially invasive species. Their small size enables them to spread from one aquatic environment to another. Plastic pollution has been reported in sediment, surface water, and biota of freshwater systems especially in Europe, North and South America, and Asia with limited studies focusing on Ethiopia lakes. This study therefore investigated the occurrence and distribution of plastic debris along the shore sediment of Lake Hawassa. The occurrence and distribution of plastic debris along the shore sediment of Lake Hawassa was investigated at five sampling site(Tikur Wuha, Fiker haike, Amora gedel, Referral, and Loke) 1 kg of sediment was randomly collected with a stainless steel shovel from a random 1×1m at every sampling sites. Collected samples were immediately transferred to the laboratory and stored at 60°C by sealing in a perfect in Aluminum foil sack. Homogenized 50 g of each dried sediment sample was placed in a 1000 ml glass beaker, and 1.6g/ml zinc chloride in a750 ml was added. The mixture was manually stirred for 5 min, and after settlement the suspension was decanted in a beaker. The result shows that the average micro-plastics abundance in sediment samples ranged from 160 ± 2.55 to 326.67± 0.57 Items/kg. The highest abundance was found in the sediment of the Tikur wuha site about 326.67items/kg, and the lowest was at the Fiker hayik site about 160.00items/kg. MP size classes quantified between 0.25-0.5mm were the most abundant in sediment of all study sites. The most common MP particle types were fragment (41.1%), fibers (30.5%), spherical (12.2%), film (9.1%), and foam (7.1%) and also the large size shape of plastics was listed from the most dominant to smaller fragment, fibers , spherical, foam, and film . The common colors of MP identified were 49.2% white, 29.4% black, 7.6% yellow, 6.6 green, 4.6% red and 2.5 % blue. The plastic spatial distribution revealed major Plastic pollution in areas where recreational and tourism activities have been developed except Fikir Hayik site where low plastic distribution was recorded. These results demonstrated that the Tikur Wuha sites along Lake Hawassa are hotspot area for plastic pollution of the lake and should therefore be targeted for the management of plastic pollution of Lake Hawassa.

Keywords: Lake Hawassa, micro-plastics, meso-plastics, ma-plastics, sediment, shores.

1 INTRODUCTIO

1.1 Background

Plastics have been produced on a large scale and used widely since the early 1950s. Due to their malleability, low cost, and resistance to water and light, plastics can be molded to create a wide range of products of different sizes and shapes (Zhang *et al.*, 2017). After World War II, the production of plastics surpassed that of all the other synthetic materials (Jambeck *et al.*, 2015), and plastic products became necessities for daily life. As the majority of plastic products are designed for single-use, global solid waste production also increased rapidly (>10-fold from 1960 to 2005) in both developing and developed countries (Savrık *et al.*, 2010).

In particular, it is known that macro-plastics > 5mm, sensu Gallitelli and Scalici (Gallitelli *et al.*, 2022) have a negative impact on aquatic wildlife, for instance, organisms can be entangled or suffocated, their ingestion can cause the occlusion of the gastrointestinal tract, and plastic fishing nets can cause the phenomenon of ghost fishing (Blettler *et al.*, 2021). Macro-plastics are estimated to be one of the main sources of marine plastic pollution and secondary micro-plastics, and have direct negative effects on ecosystem health and human livelihood (Gallitelli *et al.*, 2022). On the environment, macro plastic trapped and deposited in sediments will incidentally eaten by sea animals and also cover the root system of mangrove and seagrass (Purba *et al.*, 2018). Those conditions can cause ecological instability, decrease the water quality and coastal ecosystem. The accumulation of macro plastic in waters and sediment can affect the health of people who lived in the nearby environment and all people who consumed fish, shell or crustacean in that ecosystem (Barboza *et al.*, 2018).

Micro-plastic (MP) is defined as an organic synthetic polymer with a particle size of less than 5 mm (Van *et al.*, 2014) and MP pollution has been considered an important emerging environmental problem in recent years due to its pervasiveness and persistence (Gall, 2015; Thompson, 2015). Such particles are already highly prevalent in freshwater (Eerkes *et al.*, 2015), terrestrial (Fok *et al.*, 2015), marine environments (Van *et al.*, 2013), and atmospheric fall out (Dris *et al.*, 2016). In addition, a large number of studies have investigated micro-plastics in bottled water(Schymanski *et al.*, 2018), and found that it tends to contain higher levels of micro-plastics than tap water (Kosuth *et al.*, 2017) although the latter has been the subject of a limited number of studies. Global plastic production in 2016 exceeded 330 million tons (Zhang, 2017).

Micro-plastic particles are carriers of harmful substances including pathogenic bacteria and potentially invasive species (Karthik *et al.*, 2018), their small size enables them to spread from one aquatic environment to another (Isobe *et al.*, 2014) they can also be ingested by a wide range of organisms(Lusher, 2015) and release toxic chemicals used as additives during the production process(Brå *et al.*, 2018), which may cause oxidative stress, endocrine disorders, impaired reproductive function (Rochman *et al.*, 2013), neurotoxic effects (Ding *et al.*, 2018) and other harmful physiological effects. MPs arise from two main sources. Primary micro-plastics which are manufactured at the MP scale are typically found in personal care products and enter water bodies in the course of human use (Fendall *et al.*, 2009).

Secondary MPs are MP fragments originating from the degradation of larger plastic fragments, both in the aquatic and on land (Wang *et al.*, 2016) fragmentation occurs when physical, chemical, and biological processes damage the structural integrity of plastic fragments (Andrady *et al.*, 2015).

The main sources of micro-plastics in fresh water are domestic and industrial sewage, sea littering, and running off water (Boyle *et al.*, 2020). Household sewage contains many micro-plastic particles in cosmetics and detergents used in everyday life, which are mainly introduced into sewage when washing faces or showers (Sun *et al.*, 2020). Industrial sewage mainly comes from the plastics industry, such as plastic pellets and abrasives used in the manufacture of plastic products (Carr *et al.*, 2016). Micro-plastics enter freshwater environments through various routes including discharge of domestic wastewater (Murphy *et al.*, 2016), application of sludge from wastewater treatment plants in agriculture (Futter *et al.*, 2016), landfill leachate (He *et al.*, 2019), surface run-off (little is known about transport by run-off), and atmospheric deposition (Dris *et al.*, 2016).

The occurrence, abundance, and quality of MPs have been investigated in different aquatic environments, including sediments and wastewater worldwide in urban and remote areas. Dominantly, studies investigating MPs have mostly failed to assess the pollution in the terrestrial and soil environments. However, recent reports also considered the assessments of MP pollution in the terrestrial and soil environments in such a way that the agrochemicals could be a potential source for the pollution of MPs (Dioses *et al.*, 2020). The presence of micro-plastics has been reported in air samples, food, and drinking water (Gasperi *et al.*, 2018)

Global Sampling of Sediment from Shores for MPs accumulation study in South Africa was included as one of the shores, recorded as the first report in the African waster system (Browne *et al.*, 2011). Even in some countries, like our country Ethiopia which has the longest river (Blue Nile, lakes, Lake Tana, and several small lakes and/or rivers in the Rift Valley, almost none of the research have been conducted on MPs till now. In 2020, the first study on micro-plastic pollution assessments in Lake Ziway, Ethiopia, was reported by (Merga *et al.*, 2020).

Different studies have shown that once in the aquatic environment, micro-plastics are ingested by a range of organisms, with further impact due to the leaching of toxic plastic additives including bisphenols and phthalates (Wei *et al.*, 2019). As for processes, there is an insufficient understanding of appropriate sampling and analysis techniques for micro-plastics in fresh water (Li *et al.*, 2018), with variations in methodology hindering comparisons of study results. Sampling methods may involve either small-volume while analysis methods mainly include the use of spectroscopic instruments and identification by a microscope or the naked eye (Hidalg *et al.*, 2012).This study were investigated the occurrence, abundance, and distribution of micro-, meso-and macro-plastic debris along shores and sediment of Lake Hawassa Surface sediment samples were collected from selected study sites. Micro-plastics were characterized by quantity, shape, color, and size using our naked Eye and microscope.

1.2 Statement of the problem

Plastic pollution has been reported in sediment, surface water, and biota of freshwater systems, especially in Europe, North and South America, and Asia with limited studies focusing on African lakes in general and specifically Ethiopian lakes (Browne *et al.*, 2011). According to EUROMAP (European Plastics and Rubber Machinery), Ethiopia was recognized as the second largest importer of plastic raw material in Central and Eastern Africa with fastest growing plastic industry in the continent. The per capita plastic consumption of the nation had shown a tremendous improvement from 0.7 kg in 2009 to 1.9 kg in 2015 (EUROMAP, 2016). Having asymmetrical plastic waste generation and management rate, Ethiopia is currently facing plastic pollution and its consequences (Teshome, 2021). Besides, the waste water management systems of Ethiopia were not well developed in most parts of the country; sewages ending in water bodies barely untreated. Numerous reports across the globe have highlighted the contamination of water bodies with micro-plastic particles arising from mismanaged plastics and waste waters (Cox *et al.*, 2021; Egessa *et al.*, 2020; Wang *et al.*, 2016). Once MPs enter in to aquatic systems, they can decrease the water quality and get incorporated with the biota. Fishes ingest MPs in aquatic environment by mistaking it for food, unintentionally through water intake, or while consuming a prey that has already been contaminated with MPs (Peters and Bratton, 2016; Cole *et al.*, 2011; Lonnstedt and Eklov, 2016). These MPs have different shape, density, size, chemical nature and ingredients that enable them accumulate organic and inorganic toxicants as well as pathogenic micro-organisms on their surfaces from their surrounding environment. Organisms ingesting MPs lacking the proper mechanism for clearance of these synthetic materials, are therefore exposed to physical, chemical and biological impacts (Horton *et al.*, 2017; Turner and Holmes, 2015; Virsek *et al.*, 2017). Moreover, MPs can get incorporated to the food chain and pose a threat to public health. Ethiopia as a land locked nation depends on fresh waters for its livelihood activities. Fish has been considered as an income source for the fisherman and a staple meat source for Ethiopian population both during fasting as well as non-fasting times. MP pollution of the fresh waters therefore can impact the ecosystems and the people of Ethiopia both economically and health wise.

The Ethiopian rift valley lakes are struggling with multiple threats arising from industrialization urbanization and population growth (Gebretsadik and Mereke, 2017). Demographic pressure and intensive anthropogenic activities are the chief sources of micro-plastics entry into lakes (Oni *et al.*, 2020). Lake Hawassa, an Ethiopian rift valley lake, being located near to the highly populated city of Hawassa in the Sidama region is no longer an exception to plastic pollution. Textile and apparel sector is a known the source of synthetic microfibers in to water bodies (Deng *et al.*, 2020). Therefore, the empirical data obtained from this study, will help in providing awareness for the environmental protection stake holders and researchers in the country to stimulate further studies, to develop new plastic waste management policies and design preventive measures to protect the limited fresh water resources of Ethiopia.

This study aims to fill this knowledge gap by investigating plastic abundance in sediments, and thus elucidate the pollution status of plastics the lake. Regarding the occurrences and distribution of plastics in Lake Hawassa few studies investigated in surface water little is known about micro-plastics in and around Lake Hawassa
None of the research has been conducted on plastics Sediment from Shores for plastics accumulation study, and South Africa was included as one of the shores, recorded as the first report in African water system (Browne et al., 2011). Even in some countries, like Ethiopia having the longest river (Blue Nile), Lakes, lake Tana, and several small lakes and/or rivers in the rift valley, almost none of the research been conducted on micro plastics till now. In 2020, the first study on micro-plastic pollution assessments in Lake Ziway, Ethiopia, was reported by Merga *et al.*, 2020. And also the occurrence and distribution of plastics debris in the shore sediment of Hawassa lake from a different sites are difficult because plastics were entered to the lake from different sources for example by Human activities, by tourist (visitors), from the wastes of Hawassa industrial parks, by runoffs, by fishing activities, from farming lands of fertilizers, from the cosmetics, from household solid waste plastic, and other materials and also from the site of Tikur wuha and it carries different micro-plastics around the lake environment and This study, therefore, investigated the occurrence and distribution of plastic debris along the shores sediment of Lake Hawassa.

1.3 Objective of the Study

1.3.1 General Objective

The General objective of this study was to investigate the occurrence, abundance, and distribution of micro-, meso- and macro-plastic debris along the shores sediment of Lake Hawassa.

1.3.2 *Specific Objectives*

1 To characterize the occurrences of micro-, meso- and macro-plastic debris in sediment

2 To assess the distribution of micro-, meso- and macro-plastic debris at different sites of the lake shore sediment

3 To differentiate the types of micro-plastics in the sediments of the lake

4 To evaluate the size of micro-plastics in the sediments of the lake

4 To assess the type of plastic color in the sediment of the Lake

1.3.3 Research questions

1. How is the occurrence of Macro, Meso, and Micro-plastics in the sediment of the study area?

2. What is the distribution of plastics in the study area?

3. What are the types (shapes) of micro-plastics in the sediment sample of the study area?

4 What type of color of micro-plastic the dominant in the sediment sample of Lake Hawassa?

1.4 Significance of the Study

As of Jan 2022, one report has been published on the level of micro-plastic pollution in sediment and Fishes of Lake Ziway in Ethiopia and the abundance, composition and spatial distribution of micro-plastics in surface waters of Lake Hawassa (Semere Gebrearegawi, 2022). This study is first of its kind to monitor the level of plastic pollution in shore sediments of Lake Hawassa. Many people depend on Lake Hawassa for a variety of vital functions. Therefore, it is very important to determine the level of plastic pollution on water compartments. To the best of our knowledge no studies have reported the occurrence and distribution of potential sources for plastic pollution in Lake Hawassa.

1.5 Scope of the Study

It may be useful to study further industries related to the proposed organization however, a large-scale study requires large financial resources, time, and human power. Therefore, this study is delimited only to the occurrences and distribution of plastics n the sediment of Lake Hawassa, Ethiopia.

1.6 Limitations of the study

Sediment samples in the lake are may contain complex matrices constituents, the studied sampling sites may not be absolutely representative of the total area of Lake Hawasa. Scaling the quantified amount of MP from the lab-scale sample size to weights in large-scale may produce sizable errors. Thus, it may require larger sample sizes (Haave *et al.*, 2019). Even though control measures were employed for every laboratory procedure at every step in the procedure, the chance of contamination and/or losses of MPs in the sample could occur. Furthermore, undermined or overseas reading errors may arise from the visual counting and qualification of the physicochemical properties of MPs in the samples that may result from the extraction and separation chemical effects.

2 LITERATURE REVIEW

2.1 Definition of the Terms

Micro: - is anything extremely small.

Micro-plastics: - Micro-plastics are fragments of any type of plastics less than 5mm in length. Meso-plastics: - are plastics less than 2.5 cm.

Macro plastics: - are different from both micro and meso plastics which are large plastics

Plastic: - a synthetic material made from a wide range of organic polymers such as polyethylene, PVC, nylon, etc., that can be molded into shape while soft, and then set into the rigid or slightly elastic form

2.2 Types of Micro-plastics

2.2.1 Primary Micro-plastics

Plastics that are manufactured to be of a microscopic are defined as primary micro-plastics. These plastics are typically used in facial-cleansers and cosmetics (Zitko and Hanlon, 1991), or as air-blasting media (Gregory, 1996), whilst their use in medicine as vectors for drugs is increasingly reported (Patel *et al.*, 2009). Under the broader size definitions of a micro-plastic, virgin plastic production pellets typically 2–5 mm in diameter can also be considered primary micro-plastics, although their inclusion within this category has been criticized (Andrady, 2011; Costa *et al.*, 2010).

Micro-plastic ‘‘scrubbers’’, used in exfoliating hand cleansers and facial scrubs, have replaced traditionally used natural ingredients, including ground almonds, oatmeal, and pumice (Derraik, 2002; Fendall and Sewell, 2009). Since the patenting of micro-plastic scrubbers within cosmetics in the 1980s, the use of exfoliating cleansers containing plastics has risen dramatically (Fendall and Sewell, 2009; Zitko and Hanlon, 1991).

Typically marketed as ‘‘micro-beads’’ or ‘‘micro-exfoliates’’, these plastics can vary in shape, size, and composition depending on the product (Fendall and Sewell, 2009). For example, Gregory (1996) reported the presence of polyethylene and polypropylene granules (<5 mm) and polystyrene spheres (<2 mm) in one cosmetic product. More recently, Fendall and Sewell (2009) reported an abundance of irregularly shaped micro-plastics, typically <0.5 mm in diameter with a mode size <0.1 mm, in another cosmetic product. Primary micro-plastics have also been produced for use in air blasting technology (Derraik, 2002; Gregory, 1996). This process involves blasting acrylic, melamine, or polyester micro-plastic scrubbers at machinery, engines and boat hulls to remove rust and paint (Browne *et al.*, 2007; Derraik, 2002; Gregory, 1996.)

2.2.2 Secondary Micro-plastics

Secondary micro-plastics describe tiny plastic fragments derived from the breakdown of larger plastic debris, both at sea and on land (Ryan *et al.*, 2009; Thompson *et al.*, 2004). Over time a culmination of physical, biological, and chemical processes can reduce the structural integrity of plastic debris, resulting in fragmentation (Browne *et al.*, 2007). Over prolonged periods, exposure to sunlight can result in the photo-degradation of plastics; ultraviolet (UV) radiation in sunlight causes oxidation of the polymer matrix, leading to bond cleavage (Andrady, 2011; Barnes *et al.*, 2009; Browne *et al.*, 2007; Moore, 2008; Rios *et al.*, 2007). Such degradation may result in additives, designed to enhance durability and corrosion resistance, leaching out of the plastics (Talsness *et al.*, 2009).

The cold haline conditions of the aquatic environment are likely to prohibit this photo-oxidation; plastic debris on beaches, however, has high oxygen availability and direct exposure to sunlight so will degrade rapidly, in time turning brittle, forming cracks and ‘‘yellowing’’ (Andrady, 2011; Barnes *et al.*, 2009; Moore, 2008). With a loss of structural integrity, these plastics are increasingly susceptible to fragmentation resulting from abrasion, wave-action, and turbulence (Barnes *et al.*, 2009; Browne *et al.*, 2007). This process is ongoing, with fragments becoming smaller over time until they become micro-plastic in size (Fendall and Sewell, 2009; Rios *et al.*, 2007; Ryan *et al.*, 2009). It is considered that micro-plastics might further degrade to be nano-plastic in size, although the smallest micro-particle reportedly detected in the oceans at present is 1.6 lm in diameter (Galgani *et al.*, 2010).

The presence of nano-plastics in the aquatic environment is likely to be of increasing significance in the years to come, and researchers, including (Andrady, 2011) have already begun to speculate on the impact that such a pollutant might have on the base of the aquatic environment food web. The development of biodegradable plastics is often seen as an available replacement for traditional plastics. However, they too may be a source of micro-plastics (Thompson *et al.*, 2004). Biodegradable plastics are typically composites of synthetic polymers and starch, vegetable oils or specialist chemicals (e.g. TDPA™) designed to accelerate degradation times (Derraik, 2002; O'Brine and Thompson, 2010; Ryan *et al.*, 2009; Thompson *et al.*, 2004) that, if disposed of appropriately, will decompose in industrial composting plants under hot, humid and well-aerated conditions (Moore, 2008; Thompson, 2006).

However, this decomposition is only partial: whilst the starch components of the bio-plastic will decompose, an abundance of synthetic polymers will be left behind (Andrady, 2011; Roy *et al.*, 2011; Thompson *et al.*, 2004). In the relatively cold aquatic environment, in the absence of terrestrial microbes, decomposition times of even the degradable components of bio-plastics will be prolonged, increasing the probability of the plastic being fouled and subsequently reducing UV permeation on which the degradation process relies (Andrady, 2011; Moore, 2008; O'Brine and Thompson, 2010). Once decomposition does finally occur, micro-plastics will be released into the aquatic environment (Roy *et al.*, 2011).

2.3 Source and Transfer of Micro-plastics

Marine litter results from the indiscriminate disposal of waste items that are either directly or indirectly transferred to our seas and oceans (Lozano and Mouat, 2009;Ryan *et al.*, 2009). In this section, we look at several sources of plastic litter and discuss both direct and indirect routes by which plastic can enter the aquatic environment. Whilst the emphasis of this review is on micro-plastics, in this section we also consider the indiscriminate disposal of micro-plastics, as, with time, they have the potential to degrade into secondary micro-plastics. A plastic litter with a terrestrial source contributes 80% of the plastics found in marine litter (Andrady, 2011). Such plastics include primary micro-plastics used in cosmetics and air-blasting, improperly disposed of ''user'' plastics, and plastic leachates from refuse sites. With approximately half the world's population re siding within fifty miles of the coast, these kinds of plastic have a high potential to enter the marine environment via rivers and wastewater systems, or by being blown off-shore (Moore, 2008; Thompson, 2006).

Micro-plastics used both in cosmetics and as air-blasting media can enter waterways via domestic or industrial drainage systems (Derraik, 2002); whilst waste-water treatment plants will trap macro-plastics and some small plastic debris within oxidation ponds or sewage sludge, a large proportion of micro-plastics will pass through such filtration systems (Browne *et al.*, 2007; Fendall and Sewell, 2009; Gregory, 1996). Plastics that enter river systems – either directly or within waste-water effluent or in refuse site leachates – will then be transported out to sea. A number of studies have shown how the high unidirectional flow of freshwater systems drives the movement of plastic debris into the oceans (Browne *et al.*, 2010; Moore *et al.*, 2002). Using water samples from two Los Angeles (California, USA) rivers collected in 2004–2005, Moore (2008) quantified the number of plastic fragments present that were <5 mm in diameter. Extrapolating the resultant data revealed that these two rivers alone would release over 2 billion plastic particles into the marine environment over 3 days. Extreme weather, such as flash flooding or hurricanes, can exacerbate this transfer of terrestrial debris from land to sea (Barnes *et al.*, 2009; Thompson *et al.*, 2005).

2.3.1 Source and Transfer of Micro-plastics in Terrestrial Environment

Although micro-plastics obviously enter the terrestrial environment (e.g. due to littering and application of sew-age sludge to land) and soils have been assumed to be a sink for micro-plastics, there are only extremely few data on micro-plastic concentrations in the terrestrial environment (Barnes *et al.*, 2009). It was suggested to use synthetic fibers as indicators of previous sludge application to land (Zubris, & Richards, 2005). Using polarized light microscopy, Zubris and Richards (Zubris, & Richards, 2005). Showed that up to 15 years after sludge application, levels of plastic fibers in soil of a long-term experimental field site clearly exceeded levels at control sites.

2.3.2 Source and Transfer of Micro-plastics in Freshwater Environment

So far, there are only relatively few studies on micro-plastics in the freshwater environment. These studies have focused on larger rivers and lakes, while there are no data on the occurrence of micro-plastics in smaller streams or lakes (Lambert *et al.*, 2014).

During a 2-year survey, Lechner *et al.*, 2014 evaluated the abundance of small plastic items (0.5–20 mm) in the surface layer of River Danube between Vienna (Austria) and Bratislava (Czech Republic). In 2010, mean concentration of small plastic items was 0.938 items/m3; 86 % of these items were pre-production plastics. In 2012, plastic abundance was much lower (0.055 items/m3); pre-production plastics accounted for 31 % of these items. The high levels of pre-production plastics in 2010 were apparently caused by leakages in the pipe system of a plastic producer and by a strong rain event, during which pellets were washed into the Danube (Carson *et al.*, 2011) Recently, a similar mean micro-plastic concentration (0.29 items/m3) was derived for the surface layer of the River Rhône (Muraru. G, 2017).The micro-plastics mainly consisted of fragments (40 %), foams (37 %) and fibers (14 %). A clear effect of a municipal WWTP on micro-plastic levels was demonstrated in North Shore Channel (Chicago, USA).

Mean micro-plastic concentration in the surface layer increased from 1.94items/m3 up stream of the WWTP to 17.93items/m3 downstream of the WWTP (McCormick *et al.*, 2014). In sediments from St. Lawrence River (Canada), plastic granules with diameters of 0.4–2.2 mm and mainly grey or black color were detected. Based on their melting point, it was assumed that the granules consist of PE. Personal care products were mentioned as possible source. How-ever, highest concentrations (136,926 items/m2) were found in the effluent canal of a nuclear power plant, while concentrations at the other nine sampling sites ranged from 0 to 243 items/m2 (Castañeda *et al.*, 2014) This suggests that the granules may originate from a source other than personal care products that remains to be identified.

2.4 The Occurrence of Micro-plastics in the Lake

The great lakes have been formed at the end of the glacial period 14, 000 years ago in such a way that the ice sheet is treated and exposed to the basins which had been carved into the land, eventually filled out with melted. Mostly, there are shallow areas that could be up-flow filled and drained by groundwater based on groundwater balance. Also, rainfall and the nearby rivers are sources for lake waters. Thus, the source of plastic waste in the lake is come from runoffs, rivers, and municipal and industrial effluents, and accumulated from the surface water as well as the sediments depending on the plastic densities.

In African Countries' lakes, MPs pollution has been reported in Lake Eleyele from Nigeria, Lake Victoria from the coast of Tanzania, Oxbow Lake from Nigeria urban lakes, and Lake Ziway from Ethiopia. In Oxbow Lake, the abundance is significantly varied from 1004 to 8329 items m− 3 and 201 to 8369 items m− 3 for the dry and rainy seasons, respectively, in surface water with different sampling sites. From the surface sediment, 347 to 4031 items kg−1 and 507 to 7593 items kg−1 were recorded in the dry and rainy season, respectively (Oni *et al.*, 2020).

In Lake Ziway, the abundance was found with varied ranges across different sampling zones (0.0002–385.2 mg/k WW in fish), and (400–124,000 particles/m3) in sediment samples (Merga *et al.*, 2020). These varied ranges are attributed to the varied feed sources of the plastics to the lake. The seasonal variations in the MP's abundance arise due to the lack of proper sewage management and unselective dumping around the site, and also, the farming and fishing activities which contribute a significant variation. Based on the sample site perspective, the sites where the boat station near the coast have observed higher MP abundance as compared with other sites. Also, the MPs distribution where the site near the lakeshore was detected in high abundance is due to recreational tourism-related plastic goods that could contribute a huge abundance (Zhang *et al.*, 2018).

2.5 Abundance of Macro Plastic

Waste worldwide is dominated by plastic waste which found on coastlines, sea surfaces and oceans, reaching up to 90% of the total waste like on the coastlines around 32-90%, sea surface amount of 86% and seabed around 47-85%. The plastic waste floating in the water column and settles on the ocean floor. The rate of increase in the amount of plastic waste in the world's ocean is around 100.000 particles per m2 while in coastal environments around 350.000 particles per km2 (Suryono,2019). Macro plastic accumulation in waters is strongly influenced by human activities (land-based and sea-based). Meanwhile, environmental factors play an important role in their abundance and distribution when compare to anthropogenic factors (Herrera *et al.*, 2018). The abundance of macro plastic waste will be high if environmental factors are intense (Brach *et al.*, 2018).

2.6 Distribution of Macro Plastic

The non-degradable macro plastic waste dominates in two research locations, such as plastic, styro foam, sandals or rubber. This condition can cause tidal currents to be disturbed due to piles of garbage which can have an impact on reducing the balance of nutrients carried by currents or coastal ecosystems such as mangrove. The distribution of macro plastics depends on environmental factors such as ocean currents and waves and surface winds (Van *et al.*, 2020). Besides that conditions, the distribution of macro debris in sea water also influenced by human activities(Purba *et al.*, 2018). Other studies indicated that main total marine debris in Jakarta Bay is macro plastic around 77.7% followed by styro foam (18.1%) (Hastuti,2014). According to (Suryon *et al.*,2021). Muaragembong waters are influenced by the oceanographic conditions of Jakarta Bay which are driven by monsoon, i.e. the west monsoon in December to February and the east monsoon in June to August. Jakarta Bay water consisted of shallow water ranging from 5 to 32 meters (Rositasari *et al.*, 2015). This observation is reinforced by the statement from (Handyman *et al.*, 2019) that the distribution of debris was influenced by the water hydrodynamics. One of the west monsoon characteristics is rainfall and strong wind while the east monsoon is small and dry wind (Lubis *et al.*, 2012), the wind and current condition in Jakarta Bay is strongly influenced by the monsoons(Ihsan,2020). According to (Van *et al.*, 2020), In general at Muaragembong waters that the movement of current influenced by tides, moves to northeast and southeast following topographical pattern. The velocity of current to the southeast is low tide. This condition is assumed can transport marine debris along the coast of Muaragembong. Java Sea current also affect the distribution of waste in Muaragembong (Suryon *et al.*, 2021), because its assumed that Java Sea current enters the Muaragembong waters with a speed of 0.1 m/dt at high tide to low tide in April to October. The high tide current speed is greater than low tide [39]. The simulation of micro-plastic waste transportation by (Ihsan, 2020) shows that macro plastic waste transported from rivers which leads to Jakarta Bay will be trapped on the north coast of Jakarta. The distribution of macro plastic in other major rivers in

Indonesia, such as Musi River, South Sumatra, shows an abundance of macro plastic originating come from upstream as much as 5-32 types/m2 with an average of 27.82-126.89 gr/m (Almiza *et al.*, 2021).

2.7. Characterization of Plastic Wastes in the Fresh Water Ecosystems

Unlike traditional environmental pollutants, micro-plastics exist in the environment in different shapes, sizes, densities, colors, and polymer types, as well as other inherent and attached pollutants (Li *et al.*, 2020; Zhang *et al.*, 2018; Zhang *et al.*, 2020). The impact of micro-plastics on the environment and its fate are closely related to these characteristics (Machado *et al.*, 2018). The deposition of micro-plastics in sediments is related to their size, density, and shape (Besseling *et al.*, 2017). Hence, in addition to its abundance, characteristics of micro-plastics have also been recorded.

2.7.1. Shapes

Micro-plastics in the environment occur in a variety of shapes and sizes. Common shapes of micro-plastic include pellet/spherule, fragment/sheet, foam, fiber/line, and film (Akhbarizadeh *et al.*, 2018; Hidalgo *et al.*, 2012). These shapes depend on the original form of primary micro-plastics, the erosion and degradation processes of the plastic particle surface, and residence time in the environment (Machado *et al.*, 2018; Zhang *et al.*, 2020). Various shapes of micro-plastics including fragment, foam, fiber, and film have been detected in the freshwater sediments. The fiber is the most common shape of micro-plastic in freshwater sediments. In sediment collected from Ciwalengke River, fibrous micro-plastics were more dominant 91%, compared to fragment 9%(Alam *et al.*, 2019). In the sediments of Changjiang Estuary, fiber was the most prevalent shape (93%) among all micro-plastic particles (Peng *et al.*, 2017). However, in Shanghai (urban centers) and St. Lawrence River, the dominant shape of micro-plastics detected in sediment was pellet, contributed to approximately 90% of the total particle numbers and only 5–8% comprised fibers (Castañeda *et al.*, 2014; Peng *et al.*, 2018). Sediment studies in Nakdong River, Wen-Rui Tang Rive, Lakes in Tibet plateau, and other two studies also suggested that the main form of micro-plastics was fragment (Eo *et al.*, 2019; Wang *et al.*, 2018; Zhang *et al.*, 2016). However, the most common shape of micro-plastics in Brisbane River was film, followed by fragment and fiber (He *et al.*, 2020). Shape, to a large extent, can infer the initial material of micro-plastics, as certain shapes may be derived from specific products (Andrady, 2017; Zhang *et al.*, 2020). Fiber, for example, is the predominant shape detected in the sediment of the Changjiang Estuary, which is likely closely connected to textiles. Washing is an important pathway that releases them into the environment (Peng *et al.*, 2017). While fragmented micro-plastics could possibly originate from the exposure of larger plastic items to strain, fatigue, or UV light (Wen *et al.*, 2018; Xiong *et al.*, 2018; Zhang *et al.*, 2016). The surface texture of fragments and pellets (for example, grooves, cracks, adhered particles, and flakes) provides good evidence of mechanical wear and chemical weathering to produce micro-plastics (Su *et al.*, 2016; Zhang *et al.*, 2016). The film mainly comes from plastic bags and packaging materials. Foam- shaped micro-plastics come from the damage of styro foam (Xu *et al.*, 2020; Zhang *et al.*, 2018). Pellet is likely to virgin pellets spilled during transportation and processing (Corcoran *et al.*, 2015), or as spherule and micro-beads used in cosmetic products and sandblasting media, and in air-blasting agents or in industrial cleaner (Fahrenfeld *et al.*, 2019; Hartmann *et al.*, 2019; Mani *et al.*, 2015).

2.7.2. Size

The particle size of micro-plastics directly affects their migration in the water environment and whether they can be ingested by organisms, which is closely related to biosafety (Akhbarizadeh *et al.*, 2018; Li *et al.*, 2020; Zhang *et al.*, 2020). At this stage, the size range of micro-plastics varied greatly and the smallest size of detected micro-plastics becomes smaller with technological innovation (Besseling *et al.*, 2017; Hartmann *et al.*, 2019). Generally, micro-plastics with a particle size of less than 1 mm are more abundant in freshwater sediments and as particle size increased the micro-plastic abundances show a trend of decrease (Corcoran *et al.*, 2015; Ding *et al.*, 2017). For example, in Ciwalengke River, the majority of size of micro-plastics was 50–100 μm (34%), followed by 300–500 μm (18%) and 500–1000 μm (18%); while larger particles (1000–2000 μm) accounted for a smaller proportion (Alam *et al.*, 2019). In Nakdong River, the particle size range of 100–150 μm was the largest proportion in sediment with the average and median values of 248 μm and 155 μm, respectively (Eo *et al.*, 2019). However, in sediment samples of the in Xiangxi Bay of Three Gorges Reservoir, Thames River, and Qinghai Lake, the size of the micro-plastics was larger (1-5 mm), which may be related to its source (Xiong *et al.*, 2018; Zhang *et al.*, 2016; Zhang *et al.*, 2017).

2.7.3. Color

As colored micro-plastics particles are easily mistaken for food by aquatic organisms (He *et al.*, 2020; Rodrigues *et al.*, 2018), color is one of the focus of micro-plastics research. Various colors of micro-plastics have been recorded including white, transparent, red, yellow, green, brown, gray, etc. (Cheung and Fok, 2017; Cole *et al.*, 2015). Furthermore, colors are expected to identify potential sources of micro-plastics and potential contamination during sample preparation (Fahrenfeld *et al.*, 2019; Zhang *et al.*, 2020). Transparent micro-plastics are usually derived from disposable plastics, such as plastic bags, disposable plastic cups, and bottles, which are disposable and have short lifetimes (Li *et al.*, 2020; Prata *et al.*, 2019; Xiong *et al.*, 2018). Colored micro-plastics are likely to originate from a variety of plastic consumer products with along service life. (Andrady, 2017;Eo *et al.*, 2019). As color is not permanent and bleaching processes can occur in the sample preparation process(Li *et al.*, 2020; Yuan *et al.*, 2019).

Discussion of color to deduce the type or origin of micro-plastics must be cautious. The discussion on color is not very unanimous at present. Half of the studies on freshwater sediment have no description of the color of micro-plastics. While divergence still exists in the rest of the studies discussed the color of micro-plastics. Some research communities discuss the color of micro-plastics directly based on the results recognized by the naked eye. However, it has been suggested to group micro-plastics into four obvious colors (transparent, black, white, and colored); instead of evaluating other more controversial colors (e.g., yellow, green, blue, etc.) (Jiang *et al.*,2019; Zhang *et al.*, 2016).

The most common colors observed in micro-plastics of freshwater sediments were white and transparent. White micro-plastics made up the majority of micro-plastics in the sediments of Brisbane River (Heet *et al.*, 2020). 90% of the micro-plastics detected in urban rivers sediment of Shanghai were white (Peng *et al.*, 2017). Transparent was the dominant color in surface sediments of urban water in Changsha (Wen *et al.*, 2018). Colored micro-plastics were also very common. For example, in Antuã River, the majority of the color group in sediment samples was colored one, followed by black, white and transparent (Rodrigueset *et al.*, 2018). In addition, multiple colors of micro-plastics were observed in Pearl River and particles were yellow (36.2%), white (26.8%), and black (11.7%) (Lin *et al.*, 2018).

2.8 Spatial and Temporal Trends of Micro-plastics

Plastic litter has permeated in aquatic ecosystems across the globe (Derraik, 2002; Lozano and Mouat, 2009; Ryan *et al.*, 2009). Driven by ocean currents, winds, river outflow and drift (Barnes *et al.*, 2009; Martinez *et al.*, 2009; Ng and Obbard, 2006) plastic debris can be transported vast distances to remote, otherwise pristine, locations, including mid-ocean islands (Ivar *et al.*, 2009), the poles (Barnes *et al.*, 2010) and the ocean depths (Lozano and Mouat, 2009). However, whilst plastic litter may be found throughout the marine environment, the distribution of this debris is heterogeneous (Martinez *et al.*, 2009; Moore, 2008). In this section we discuss how micro-plastics accumulate along coastlines and within mid-ocean gyres, examine the variable position of micro-plastics within the water column and consider micro-plastic abundance over time.

2.8.1 Accumulation of Micro-plastics

Micro-plastics are of special concern since their bioaccumulation potential increases with decreasing size. Micro-plastics may be ingested by various organisms ranging from plankton and fish to birds and even mammals, and accumulate throughout the aquatic food web (Wright *et al.*, 2013). In addition, plastics contain a multitude of chemical additives (Dekiff *et al.*, 2014), and adsorb organic contaminants from the surrounding media (Bakir *et al.*, 2012). Since these compounds can transfer to organisms up on ingestion, MP acts as vectors for other organic pollutants (Zarfl *et al.*, 2010). And are therefore, a source of wildlife exposure to these chemical (Oehlmann *et al.*, 2009).

Coastlines receive plastic litter from both terrestrial and aquatic sources; terrestrial sources of litter will typically dominate close to urban areas, sites of tourism, and near river outflows, whilst marine debris will be deposited along shorelines when caught in near-shore currents (Ryan *et al.*, 2009). Using sediment analysis, Thompson *et al.*, 2004 found micro-plastics, consisting of nine different polymers, in 23 of 30 estuarine, beach and sub-tidal sediment samples taken around Plymouth, UK, including microscopic fibers and fragments typically derived from clothing, packaging, and rope.

Further work showed that micro-plastics were present in beach sediments throughout the UK. Browne *et al.*, 2010) used the same methodology to quantify micro-plastics in sediment throughout the Tamar estuary (Plymouth, UK), identifying 952 items in 30 sediment samples. An abundance of micro-plastics has also been found in productive coastal ecosystems off Alaska and California, where nutrient upwelling results in high densities of planktonic organisms (Doyle *et al.*, 2011). Using 505 lm meshes during surface plankton trawls for the National Oceanic and Atmospheric Administration (NOAA), Doyl *et al.*, 2011) found an abundance of plastic fragments derived from the breakdown of larger plastic debris, in addition to plastic fibers and pellets, although concentrations were significantly lower than those found in the adjacent North Pacific gyre. The source of this plastic debris was unable to be verified, however, it was suggested that the high concentration of plastics in southern Californian waters during winter was linked to urban run-off from major conurbations, whilst a marine source was more likely during the summer months when currents altered. After conducting beach surveys throughout the remote mid-Atlantic archipelago of Fernando de Noronha, Ivar *et al.*, 2009 identified plastic pre-production resin pellets on the windward beaches of the archipelago – yet no plastic-production facilities exist in the region. Therefore, it was hypothesized that they were brought to the remote location via trans-oceanic currents before being trapped in in-shore currents and washed ashore. Similarly, a survey of beaches on the island of Malta, in the Mediterranean Sea, found an abundance of the disc- and cylindrical-shaped plastic resin pellets (1.9–5.6 mm in diameter) on all beaches surveyed (Turner and Holmes, 2011).

2.8.2. Micro-plastics in the Water Column

Plastics consist of many different polymers and, depending on their composition, density and shape, can be buoyant, neutrally buoyant or sink. As such, micro-plastics may be found throughout the water column. Low-density micro-plastics are predominantly found in the sea-surface micro layer, as documented by numerous studies presenting data from surface trawls (Derraik, 2002; Gregory, 1996).

However, there is evidence that their position in the water column can vary: in estuarine habitats, low-density plastics, such as polypropylene and polyethylene, will be submerged if they meet water fronts. Furthermore, there is growing evidence that the attachment of fouling organisms can cause buoyant micro-plastics to sink (Barnes *et al.*, 2009; Browne *et al.*, 2010; Derraik, 2002; Thompson *et al.*, 2004).

Plastic debris in the aquatic environment can rapidly accumulate microbial biofilms, which further permit the colonization of algae and invertebrates on the plastics' surface, thus increasing the density of the particle (Andrady, 2011). The speed at which bio fouling may occur was recently demonstrated using polyethylene plastic bags submerged in seawater (16.2 C) in Plymouth harbor (UK), a biofilm was visible after just one week, and analysis showed a significant increase in microbial density over the 3-week experiment (Lobelle and Cunliffe, 2011). Notably, the plastic became less buoyant over time, and by the end of the experiment the plastic moved away from the surface and appeared neutrally buoyant. When assessing plastic litter in the North Pacific gyre, Moore *et al.*, 2001 randomly sampled debris for signs of fouling organisms. Only a small proportion (8.5%) of surface debris was colonized, and fouling decreased with particle size. However, at a depth of 10 m, a higher proportion of plastic debris was fouled with algae and diatoms. More recently, an analysis of micro-plastics (<1 mm) collected in surface tows from the western North Atlantic Ocean between 1991 and 2007, has shown evidence of fouling (Morét *et al.*, 2010).

2.8.3. Temporal Changes in Micro-plastic Abundance within the Marine Environment

Since the 1940s, when the mass production of plastics began in earnest, the volume of plastic produced has risen rapidly. With legislation to curb the indiscriminate disposal of plastic waste emerging slowly, plastic debris entering the marine environment increased in parallel with rates of production during this time (Moore, 2008; Ryan *et al.*, 2009; Barnes *et al.*, 2009).

Continuous fragmentation of larger plastic debris and the rising popularity of ‘‘plastic scrubbers’’ appears to have increased the volume of micro-plastic debris in the oceans, resulting in a decrease in the average size of plastic litter over time (Barnes *et al.*, 2009). Furthermore, incidence of plastic ingestion by Fulmars (ocean-foraging seabirds), washed ashore in the Netherlands, increased from 91% to 98% between the 1980s and 2000, whilst the average consumption doubled from 15 to 30 plastic fragments per bird during this period (Van *et al.*, 2011).

Concentration trends within the past decade are not overtly apparent, and there is some debate as to whether levels of plastic debris are still increasing or have stabilized. The study by Thompson *et al.*, 2004 indicated the minimal change in micro-plastic contamination between the 1980s and 1990s. Similarly, an evaluation of >6, 100 surface trawls conducted throughout the Northwest Atlantic Ocean found no significant difference in micro-plastic abundance over 22 years (Law *et al.*, 2010).

The average number of plastics debris items consumed by fulmars, beached on the shores of the Netherlands, decreased slightly from the mid-1990s, but has remained relatively stable since the turn of the century, currently averaging 26 plastic fragments per bird (van *et al.*, 2011). In contrast, Claessens *et al.*, 2011 indicate that micro-plastic concentrations have steadily increased over the past two decades. Analysis of sediment cores taken along the Belgian coast indicates micro-plastic pollution tripled from 55 micro-plastics/kg of dry sediment (1993– 2000) to 156 micro-plastics/kg of dry sediment (2005–2008), in line with global production rates. However, use of sediment cores is a new technique, and bio-turbation from tourism or sediment dwelling biota might have affected this data. Any further conclusions are hampered by both a lack of studies that have specifically considered trends of micro-plastic abundance over time. Meta-studies are difficult to develop due to varieties of sampling methodologies, huge spatial variations in micro-plastic abundance, and lack of standardized size definitions of micro-plastics (Ryan *et al.*, 2009; Barnes *et al.*, 2009).

2.9 Environmental Impact of Plastics

Environmental impacts are wide ranging and can be both direct and indirect. Direct impacts occur when marine life is physically harmed by marine debris through ingestion or entanglement (e.g., a turtle mistakes a plastic bag for food) or marine debris physically alters a sensitive ecosystem (e.g., a fishing net is dragged along the ocean floor by strong ocean currents and breaks and smothers a coral reef). Environmental impacts can also be indirect, such as when a marine debris cleanup results in ecological changes.

2.9.1 Direct Environmental Impacts

2.9.1.1 Ingestion

Seabirds, sea turtles, fish, and marine mammals often ingest marine debris that they mistake for food. Ingesting marine debris can seriously harm marine life. For example, whales and sea turtles often mistake plastic bags for squid, and birds often mistake plastic pellets for fish eggs. Moreover, a study of 38 green turtles found that 61 percent had ingested some form of marine debris including plastic bags, cloth, and rope or string (Bugoni *et al.*, 2001).

At other times, animals accidentally eat the marine debris while feeding on natural food. Ingestion can lead to starvation or malnutrition when the marine debris collects in the animal's stomach causing the animal to feel full. Starvation also occurs when ingested marine debris in the animal's system prevents vital nutrients from being absorbed. Internal injuries and infections may also result from ingestion. Some marine debris, especially some plastics, contains toxic substances that can cause death or reproductive failure in fish, shellfish, or any marine life. In fact, some plastic particles have even been determined to contain certain chemicals up to one million times the amount found in the water alone (Mallal *et al.*, 2002)

2.9.1.2. Entanglement

Marine life can become entangled in marine debris causing serious injury or death. Entanglement can lead to suffocation, starvation, drowning, increased vulnerability to predators, or other injury. Marine debris can constrict an entangled animal's movement which results in exhaustion or development of an infection from deep wounds caused by tightening material. For example, volunteers participating in the 2008 International Coastal Cleanup event discovered 443 animals and birds entangled or trapped by marine debris (2008 ICC Report).

2.9.1.3 Ecosystem Alteration

The direct impacts of marine debris are not limited to mobile animals. Plants, other immobile living organisms, and sensitive ecosystems can all be harmed by marine debris. Coral reefs can be damaged by derelict fishing gear that breaks or suffocates coral. Plants can be smothered by plastic bags and fishing nets. The ocean floor ecosystems can be damaged and altered by the movement of an abandoned vessel or other marine debris.

2.9.2. Indirect Environmental Impacts

2.9.2.1 Ecosystem Alteration

Efforts to remove marine debris can harm ecosystems. Mechanical beach raking uses a tractor or other mechanical device to remove marine debris from beaches and marine shorelines and can adversely impact shoreline habitats. This removal technique can be harmful to aquatic vegetation, nesting birds, sea turtles, and other types of aquatic life. Beach raking also can contribute to beach erosion and disturbance of natural vegetation when the raking is conducted too close to a dune.

2.9.2.2 Invasive Species

Marine debris can contribute to the transfer and movement of invasive species. Floating marine debris can carry invasive species from one location to another. Invasive species use the marine debris as a type of "raft" to move from one body of water to another. In a study performed by the British Antarctic Survey in 2002, it was estimated that man-made debris found in the oceans has approximately doubled the number of different species found in the subtropics (Barnes, D.K., 2002).

2.9.3 Economic Impacts

Marine debris can harm three important components of our economy: tourism, fishing, and navigation. Economic impacts are felt through loss in tourism dollars and catch revenue, as well as costly vessel repairs.

2.9.3.1 Tourism

Marine debris is unsightly and unwelcoming to beachgoers, which can result in lost revenue from tourism. In severe cases, marine debris can even cause beach closures. The costs to remove and dispose of the marine debris can be high and the loss of tourism dollars can be even higher. In an attempt to stop the draining of trash to the ocean, the Los Angeles County's Department of Public Works and the Flood Control District spends $18 million each year on street sweeping, catch basin cleanouts, cleanup programs, and litter prevention and education efforts (L.A. County Boards of Supervisors Staff Report, 2007).

2.9.3.2 Fishing

Fisheries experience significant economic impacts from marine debris. Commercial fisheries are impacted when commercial fish and shellfish become by catch in lost fishing nets or other fishing gear. This type of by catch can result in both immediate losses in the standing stock of available seafood, and decreases in the long-term sustainability of the stock due to negative impacts on its reproductive ability. For example, the Gulf States Marine Fisheries Commission has predicted blue crab ghost fishery leads to a loss of up to 4 to 10 million crabs a year in Louisiana alone (Virginia Institute of Marine Science, 2006). Fisheries also can be financially affected when fishing gear and vessels are entangled or damaged by marine debris. The high cost of replacing fishing gear and vessels, as well as loss of days at sea for fishing, can cause small fisheries to go out of business.

3 MATERIALS and METHODS

3.1 Description of the Study Area

Lake Hawassa is found in the middle of a series of rift valley lakes and located at the 6°33’-7°33’N latitude and 38°22’-39°29’E longitude in the Sidama region Ethiopia at a distance of 275 km south of Addis Ababa. The lake has one known small tributary namely, Tikur Wuhan River which fed the lake from the northeast direction. There is no known outflow from the lake. Different vegetation types that extend to the lake off-shore cover the littoral area of the lake. The lake is also known for commercial fisheries, as it is inhabited by different fish species such as Tilapia, African catfish and Barbus spp. This study were focused on five (5) site Amora gedel site, Tikur Wuhan site, Fiker hayike, Referral site and Loke site were selected and the wastes and plastics specially micro-plastics enter into the Hawassa lake from the different sources Human activities by tourist (visitors), from the wastes of Hawassa industrial parks, by runoffs , by fishing activities, from farming lands of fertilizers, from the cosmetics, from house hold solid waste and other materials, and also from the site of Tikur Wuhan and it carries different micro-plastics from its surrounding and entered into the lake.

Title: Geographical map of Ethiopia and Sidama region showing the location of the study area, Lake Hawassa

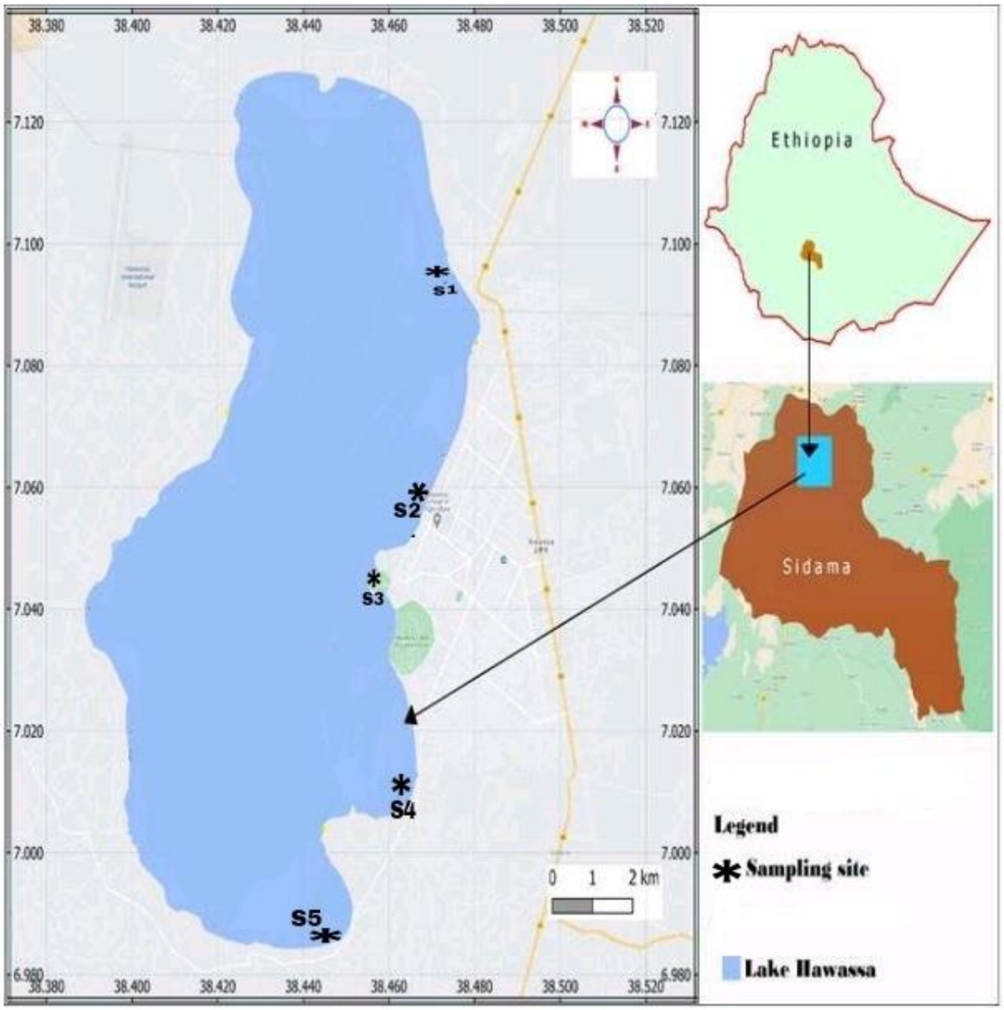

Figure 1 Geographical map of Ethiopia and Sidama region showing the location of the study area, Lake Hawassa

3.2 Study Design

Sediment samples were collected from the 5 sites (Tikur wuhan site S1, Fiker hayike site S2, Amora gedel site S3, Referral site S4, and Loke site S5) 15 kg sediment was randomly collected with a stainless steel shovel from a random 1×1m from the every sampling site and from the quadrants we take the sample randomly. Each site has three sub sites the sub sites are used to replication and we take 1kg from each sub sites. The sediment was then placed in an aluminum foil and stored at 60◦c for 72 hours (Leslie *et al.*, 2017).

3.3 Site Selection

In this research site selection was selected purposely based on high amount of plastic were entered or distributed in to the Lake Hawassa.

Tikur wuha site this site: study area, that fed the lake from the northeast direction and different micro plastics were entered into the lake. Fiker Hayik site: - this is also one of the study areas of our research. In this site micro-plastics distributed in to the lake by the different human activities for example shipping activities, visitors or tourist use different plastic and those plastics distributed into the lake. Amora gedel site: - this is also one of the study areas of our research. In this site micro-plastics distributed in to the lake by the different human activities for example shipping activities, visitors or tourist use different plastics, shopping activities and those plastics distributed into the lake. Referral Site:-this site is found back side of the Hawassa referral hospital. Plastic material which is used in hospital was distributed to the Lake Hawassa by the different Activities of human being. Loke Site:-in this site different plastics entered o distributed to the Lake Hawassa through farming activities farmers use fertilizers for their farming then micro-plastics were distributed to the Lake Hawassa.

3.4 Sampling Procedure

Sampling procedures were occurring in Lake Shore sediments. In each selected sites of our research sediment sample were taken using shovel from quadrant of 1m x 1m .Then the sample were foiled by aluminum foil and the samples were immediately taken to laboratory and stored into the incubator for 72 hours in 60°C (Leslie *et al.*, 2017).

3.5 Sample Analysis Methods (Laboratory Analysis)

After drying the sediment homogenize the sample and we used materials and chemicals such as 1000ml beaker, magnetic stirrer, hot plate, 0.25mm sieve, 0.5mm sieve 250ml bottle , orbital shaker, filter paper, distilled water, zinc chloride (1.6g/ml), 30% H_2O_2, milliQ water, and microscope. We use above mentioned materials and chemicals to analyses the micro-plastics.

3.5.1 Sample Processing

In the laboratory, a sediment sample was dried at 60 °C for 72 h to constant weight. Homogenized 50 g of each dried sediment sample was placed in a 1000 ml glass beaker, and 1.6g/ml zinc chloride in a750 ml was added. The mixture was manually stirred for 5 min, and after settlement the suspension was decanted in a beaker (Hurley *et al.*, 2018).

3.5.2 Sieving Plastic to Separate Plastic from Sediment

When sediment settles down we were filtered the supernatant through 0.25mm sieve and 0.5mm and rinsed it with distilled water and the settling for 15-30 minutes. Sieving procedure separates micro-plastics from sediment sample. The sieve physically traps the MPs, enabling water to get lost from the sample (Hidalgo *et al.*, 2012). The method which widely uses to sieve MPs in sediment samples is multi-step sieving, separating material of different sizes by passing the sample through a series of sieves with a mesh size reduction. Furthermore, to help in the separation of smaller MPs from smaller grains, several processes can be employed, such as density separation.

3.5.3 Organic Material Digestion

Organic matter in the suspension was degraded by treatment with 20 mL 30% H2O2 placed at 30 °C in an orbital shaker for 24 h, and the solution was filtered in 0.25 sieve and 0.5mm and rinse with MilliQ Water and transferred collected material to a clean glass with 20ml MilliQ water and close the jar and shake every 10minutes for 30-60 minutes. Keep in the dark 24 hours (Löder *et al.*, 2017).

3.5.4 Density Separation, Centrifuging, and Filtration

The sediment sample was dried at 60 °C for 72 h to constant weight. Homogenized 50 g of each dried sediment sample was placed in a 1000 ml glass beaker, and 1.6g/ml zinc chloride in a750 ml was added. The mixture was manually stirred for 5 minutes to suspend the particles to mix a magnetic stirrer when the sediments settle down we was filtered supernatant through 0.25mm and 0.5mm sieve it with filtered water (Hurley *et al.*, 2018).

3.5.5 Microscope Analysis

Identification includes direct observation of MPs by the naked eye (from 0.5 to 5mm particle size) and microscopic Examination (< 0.5mm particle size). A covered plate sample was subjected for examination and observed with ×10 magnifications. Then after MPs particles were identified and measured according to their physical characteristics. The MPs (>0.5mm) that was retained on the sieve were simply observed by the naked eye and sorted by their physicochemical characteristics.

Then after MPs particles were identified and measured according to their physical characteristics, following the method described by (Hazimah *et al.*, 2014). The number, shape, color, and size of the particles were recorded. plastic particles less than 0.25mm were not included in this study because of we used 0.25mm sieve and 0.5mm sieve. Microscopy techniques are used for studying morphological characteristics, also known as qualitative assessment of micro-plastics. Optical microscopes particularly have been utilized to classify micro-plastics based on their shapes such as fragments, fiber, sphere, and film (Ding *et al.*, 2020; Huang *et al.*, 2019).

3.5.6 Identification of Different Micro-plastics

After pretreatment of sediment sample containing micro-plastics, the sample is filtered using vacuum filtration on the selected filter/petri dish and stored for drying of the sample. The micro-plastics analysis comprises a four-dimensional challenge the least size of MPs particles, chemical composition of particle, shape of every particle within a sample, and abundance of any type of polymer particles in the sample (Hale 2017). The selection of filter material depends on the identification process were used for the sample

3.6 Statistical Analysis

A database was created using Excel 2010 software to perform the first analysis using descriptive statistics, as well as to explain the differences in the average numbers and characteristics of meso- and macroplastics between all samples collected from the five sites. The data were presented as mean ± SD. The results which are related to the occurrence of micro, meso- and macroplastics in all samples collected from the five sites were subjected to a one-way analysis of variance (ANOVA) to test for significant differences between them. Data were analyzed using the SPSS program, version 23. Differences between means were compared at a $p < 0.05$ level.

4 RESULTS and DISCUSSION

4.1 Occurrence and Distribution of Plastics

4.1.1 Occurrence and Distribution of Micro-plastics

Micro-plastics were observed in every sediment sample for each study sites. In this study a total of 197 micro-plastic items were collected from 15 sediment samples from the five sites. The item which we found from five study site was homogenized sediments 50gram per1kg. The mean concentration of micro-plastics in the sediments of the five sites ranged from 160.00± 2.55 to 326.67± 0.57items/kg. The overall mean concentration for the five sites was 262.67±1.82items/kg). The highest occurrence of MPs was observed in the Tikur wuha site sampling locations (326.67item/kg) flowed by Amora Gedel site (300 item/kg), Loke site (287 item/kg) Referral site (240 item/kg) and the lowest occurrence of micro-plastics was recorded in sediment sample of the Fiker Hayike study site160items/kg as shown in table1. A recent study conducted in Ethiopia, plastic particles were detected in all sediment samples taken at the shoreline sites of Lake Ziway (Merga et al, 2020). They reported the maximum concentration of 427particles/kg in the Lake Ziway sediment which is higher than the present study. Similarly in study conducted in Philippine River sediment, the abundance of MP particles were varied from 514–1, 357 particles/kg in dry sediments. The mean highest concentration of micro plastics in sediment of present study was in agreement with the study conducted in sediment of North China Estuaries by Zhou *et al., (*2017) which was 216.1 ± 92.1 items / kg. As evidenced by several previous studies (Castañeda *et al.*, 2014; Fischer *et al.*, 2016), the abundance of plastic particles in shoreline sediment of surface waters, was mainly explained by Urban activities. For Lake Hawassa, wastewater drainages (e.g. from Hawassa City), rivers which cross different villages (e.g. Tikur Wuha River), and surface runoffs upon heavy rain are likely the main routes through which plastic particles enter the lake. The high concentrations of plastic particles in sediment samples were recorded from Tikur Wuha site compared to the other study sites. This indicates that the location or site was high amount of micro-plastic entered to that selected area from the Hawassa city ditches and the feeding river called as Tikur wuha. According to Li *et al.*, 2018) water runoff may be the major micro-plastics pollution contributors, to water bodies. The second highest concentration MP at Amora Gedel site could be the highest in terms human interference and improper plastic disposal to the shoreline of the lake. In this study site the reason for the abundance of micro-plastics was exhibit high population densities; many peoples went to fishing activities, for visiting the lake environment and open to the public for recreational activities and for the other activities. Studies revealed that in high single-use plastic consumption and incorrect disposal, possibly serving as an important micro-plastics contributor (Schnurr *et al.*, 2018). In present study, the third highest micro-plastics occurrence was recorded from Loke site. In this study site the source of micro-plastic was distributed to the lake by human activities for example farmers use fertilizers and plastic generated by other actives in the study sites. The fourth highest micro-plastics occurrence was recorded in Referral site. The source of micro-plastics could be improper waste disposal from Hawassa referral Hospital and other Human activities around the Lake. The least number of micro-plastics was recorded in Fiker haike site. The reason for low concentration in the sediment of this site could be that in the shoreline of this site there were constructed briar structures located parallel to shorelines that are built to protect the lake behind it from storm and flood risk surges and wave action. Generally, the distribution patterns, abundance, contamination level, and pathway of MPs to the sediments of the lake highly influenced by anthropogenic activities, prior significant contributors to plastic pollution, topography, geography, and weathering conditions (Tibbetts *et al.*, 2018).

Table 1 Occurrence and distribution of micro-plastics

Site	Mean	SD	max	Min
1 Tikur wuha	326.67	0.57	420	260
2 Fiker haike	160.00	1.00	200	120
3 Amora gedel	300.00	3.05	380	240
4 Referral	240.00	3.50	320	180
5 Loke	286.67	1.00	360	250

4.1.2 Occurrence and Distribution of Meso-plastics and Macro-plastics

In our study, a total of 97 meso and macro plastics particles were recorded in all our study sites from the sediment samples. As shown in Table 2, in all our study sites for all particles of meso and macro plastics sizes classifications, the mean value range was recorded as from 3 ± 1 to 9.66 ± 3.51 Items/kg in the sediment sample.

The highest occurrence of meso-plastic and macro plastics was observed in the Referral site sampling locations of our study site. However, the lowest occurrence of meso and macro plastics, one third of that of the Referral site, was recorded in the fiker hayike sampling location of our study site. Type of macro- and meso-plastic debris(commercial products), quantity and abundance of macro plastic debris at each sampling site.

Table 2 Occurrence of meso and macro plastics in the sediment of Lake Hawassa

Site	Mean	SD	max	Min
1 Tikur wuha	4.33	0.57	5	4
2 Fiker haike	3.00	1.00	4	2
3 Amora gedel	7.33	3.05	10	4
4 Referral	9.67	3.5	13	6
5 Loke	8.00	1.00	9	7

4.2 Physical Characteristics of Plastics

4.2.1 Size of Micro-plastics

We compared the size proportioned abundance of MPs for both the large and small-sized classification in sediment samples for each sampling location. The proportion of MPs size, as shown in figure 2.In total, based on the size of the highest abundance of micro-plastic particles, particles in size 0.25-0.5mm was 57%, 58.33% 55.6% 61.1% and 41,87% at Tikurwuha , Fikir Hayik, Amora Gedel Referal and Loke Site respectively. In all study sites particle size 0.5-5mm the lower abundancey than particle size 0.25-0.5mm which were recorded 42.29%, 41.7% ,44.4%, 38.9%,and 58.1% at Tikur wuha , Fikir Hayik, Amora Gedel Referral and Loke Site respectively. At all study sites 0.25-0.5mm plastic particle sizes were most abundant particle size except Loke site. Generally in all sites, the frequency of micro-plastics increased with a decrease in size class. This study is agreed with Aragaw et al., (2022). They reported that the proportion of micro-plastics size of 0.00417–0.5mm was recorded as the most abundant particle size compared to the >0.5mm particle size of micro-plastics. Their study also revealed that micro-plastics with a size <0.5mm comprised 61.09% of the identified plastic particles, whereas the micro-plastics with a size >0.5mm were only 38.91%. Similarly the present study is an agreement with the study conducted by (Kathryn *et al.*, 2017). The high percentage of small-sized (0.25-0.5mm) micro-plastics was recorded at Referral site whereas the lowest percentage was recorded at Loke site. However the high percentage of large sized (0.5-5mm) was recorded Loke site and the lowest percentage was recorded at Referral site as shown in (Figure2). The high percentage of small-sized micro-plastics indicates that a higher probability of ingestion events for aquatic organisms, since their fine size is similar to zooplankton to suspend in waters (Cole et al., 2011; Botterell *et al.*, 2019). Small-sized MPs are mainly fragmented from larger plastic debris by various weather condition impacts such as mechanical forces, photo-degradation, and biodegradation processes (Zbyszewski *et al.*, 2014). They are considered to pose a more serious potential threat to aquatic organisms than large-sized MPs due to their greater surface area for possible adsorption of associated contaminants (Devriese *et al.*, 2017). The ingestion of micro-plastics by both low trophic and high trophic organisms, and both vertebrates and invertebrates, has caused adverse health effects (Ivar and Costa, 2014). As with the results of many published studies, the size of micro-plastics was inversely proportional to their quantity (Triebskorn *et al.*, 2019). This may be due to that large-sized micro plastics could be fragmented into several smaller particle sizes by the matrices effect from the municipality (Song *et al.*, 2017). Moreover, small sizes MPs have high specific surface areas resulting in easy to form biofilms by adsorbing different chemical substances (Selvam *et al.*, 2021). This results from the increased density and eases entry into the sediment matrix (Triebskorn *et al.*, 2019). Also, micro-plastics with relatively lower density and smaller size can increase travel further on the wind and waves.

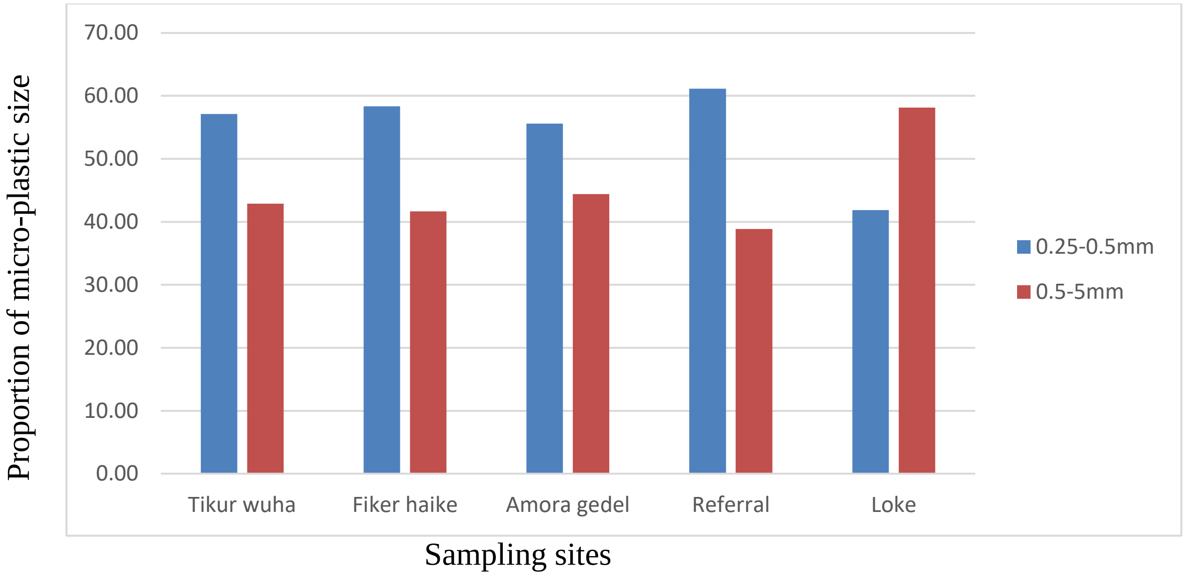

Figure2 Size distributions of micro-plastics in the study area

4.2.2 Shape of plastics

4.2.2.1 Shape of micro-plastics

Different shapes of MP particles (fragment, fiber, film, sphere, and foam) of various quantities across sampling locations were recorded as shown in Figure 3. Fragment micro-plastics were recorded as the dominant shape in sediment samples of all study sites except in Referral site in which the dominant shape was fiber type. Similar to some other studies (Cannon *et al.*, 2016; Possatto *et al.*, 2011; Romeo *et al.*, 2020; Rummelet *et al.*, 2016), fragments were the dominant (41.1%) shape of the plastic particles found in the sediment of Lake Hawassa (Figure 3), with 30.5% being fibers flowed by 12.18% spherical, as 7.10% foam and 9.13% film in sediment samples of all study sites. This indicates that fragmentation of larger plastic debris into smaller pieces (Rummel *et al.*, 2016) may be the key source of the particles in the lake, rather than other sources including effluents from wastewater treatment plants and laundry machines that mainly generate fiber plastic particles (Edo *et al.*, 2020; Falco *et al.*, 2018; Fischer *et al.*, 2016). However, our result differs to the result reported by Peters and Bratton (2016), who found to be dominant (96%) in the stomach of Lepomis macrochirus and Lepomis megalotis fishes. Peters and Bratton (2016) suggested that these fish species may reject fragments as the plastic particles do not easily adhere into organic food items while fibers plastic particles do.

In the this study, it can be suggested that the fragment particles abundance rate was high as compared with other shape of micro-plastics in the sediment samples. The proportion of fragment was recorded at 41.11% this study is in agreement with Aragaw *et al.*, 2022 a possible reason for the wide distribution of fragment micro-plastics is that they come from the widest range of plastic waste in the urban area that can be degraded and fragmented from plastic bags, plastic bottles, packaging materials, containers, and toys used in a daily manner. This study was the same agreement with Zhao *et al.*, 2015 and Peng *et al.*, 2018. This study is not agreed with Alam *et al.*, 2019, fibers had the highest micro-plastics concentration in sediment samples (56 %), followed by fragments (34 %), film (6 %), and pellets (3 %). High percentages of fibers were comparable to other studies, including the Ciwalengke River (Alam *et al.*, 2019).

The second most abundant type of micro-plastics was fiber in the sediment. The proportion of fiber was recorded at 30.45% this study is not agreed with Aragaw *et al.*, 2022 the fiber type of micro-plastics often exists in water from fish nets, laundry and daily cleaning microfiber-like products from cosmetics and disposable facial towels are major sources. The washing machines of fabrics release thousands of fiber type of micro-plastics into domestic wastewater through the urban ditches this study was the same agreement with (Hernandez *et al.*, 2017).

The third abundant type of micro-plastics particle was sphere and the proportion of the sphere was 12.18%. In sediment sample the sphere micro-plastic particles were recorded in small proportion as compared with the other shapes (fragment, and fiber), even though there was a record at most of the sampling locations. This is due to the source of the spheres shape usually being primary micro-plastics such as micro beads and plastic pellets. This finding is agreed with study conducted by Turner, (2018), and they are mainly originated from daily personal care products, such as cosmetics and cleaning media (Napper *et al.*, 2015). This indicates that spheres from personal daily care products such as tooth paste and shampoo usage and disposal in the city are minimal. Films are mainly generated by the fragmentation of plastic carrier bags (Hazimah *et al.*, 2014).

The fourth and least abundant type of micro-plastics was film and foam and the proportion of the foam and film were 9.13% and foam were least abundant type of micro-plastics the proportion of foam was 7.10 %. Film types of MP shapes are also can be formed from the degradation of daily used plastic that comes from agricultural films, an impermeable plastic film (Ding *et al.*, 2019). Mainly, the film particles sources are from thinner and softer plastic debris (Teuten *et al.*, 2007).

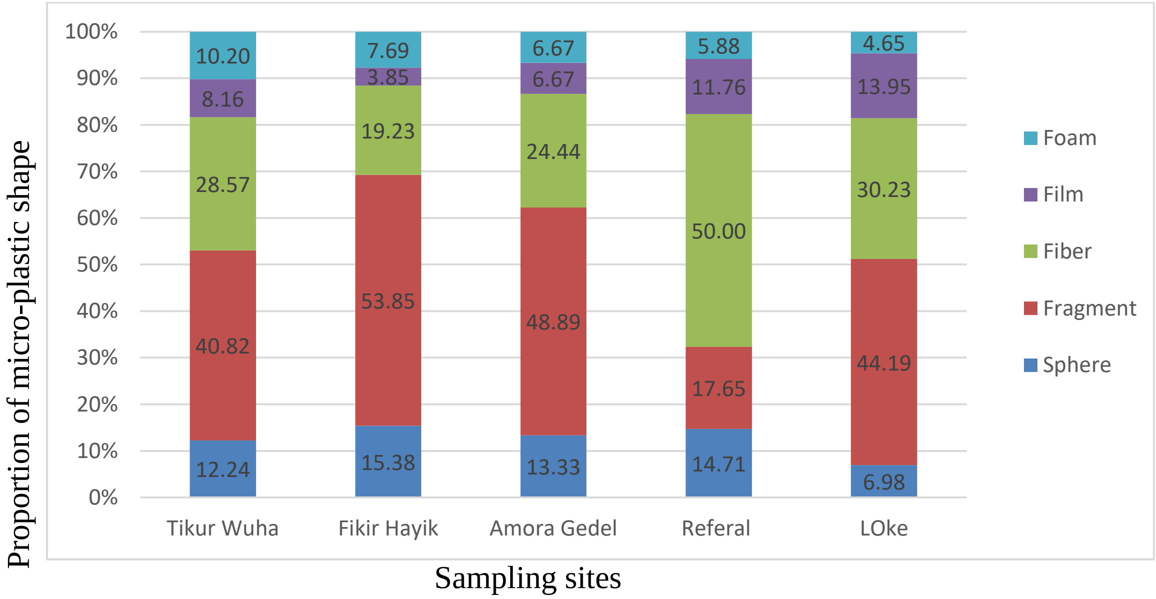

Figure 3 Shape Type of micro-plastics identified in the study area (Lake Hawassa Sediment)

4.2.2.2 Shape of meso-plastics and macro-plastics

Different shapes of Plastic particles (fragment, fiber, film, sphere, and foam) of various quantities across sampling locations were recorded as shown in figure4. Fragment type of shape of meso and macro plastics were recorded as the dominant shape in sediment samples. The second most abundant type of shape was fiber. Sphere was the third most abundant shape as shown in figure 6. Foam was the fourth most abundant shape. Film was the least and last recorded shape of meso and macro plastics. The current result of dominant shape was similar with (Harith *et al.*, 2022). In TikurWuha site different shape types was recorded as Shawn in figure4 which is 12.24%, 40.825%, 28.57%, 8.16%, and 10.20% was sphere, fragment, fiber, film and foam respectively. Fragment was recorded as the most dominant shape and second most dominant shape was recorded as fiber, sphere was recorded as the third most dominant shape fourth and fifth shape was foam and film.

In Fiker Hayike site different shape types was recorded as Shawn in figure4 which is15.38%, 53.85%, 19.23%, 3.83%, and 7.69%, was sphere, fragment, fiber, film and foam respectively. Fragment was recorded as the most dominant shape and second most dominant shape was recorded as fiber, sphere was recorded as the third most dominant shape fourth and fifth shape was foam and film. In Amora Gedel site different shape types was recorded as Shawn in figure5 which is13.33%, 48.89%, 24.44%, 6.67%, and 6.67%, was sphere, fragment, fiber, film and foam respectively. Fragment was recorded as the most dominant shape and second most dominant shape was recorded as fiber, sphere was recorded as the third most dominant shape and foam and film was recorded as the same.

In Referral site different shape types was recorded as Shawn in figure5 which is14.71%, 17.65%, 50.00%, 11.76%, and 5.88%, was sphere, fragment, fiber, film and foam respectively. Fiber was recorded as the most dominant shape and second most dominant shape was recorded as fragment, sphere was recorded as the third most dominant shape and fourth and fifth shape was film and foam. In Loke site different shape types was recorded as Shawn in figure4 which is6.98%, 44.19%, 30.23%, 13.95%, and 4.65%, was sphere, fragment, fiber, film and foam respectively. Fragment was recorded as the most dominant shape and second most dominant shape was recorded as fiber, film was recorded as the third most dominant shape and fourth and fifth shape was sphere and foam.

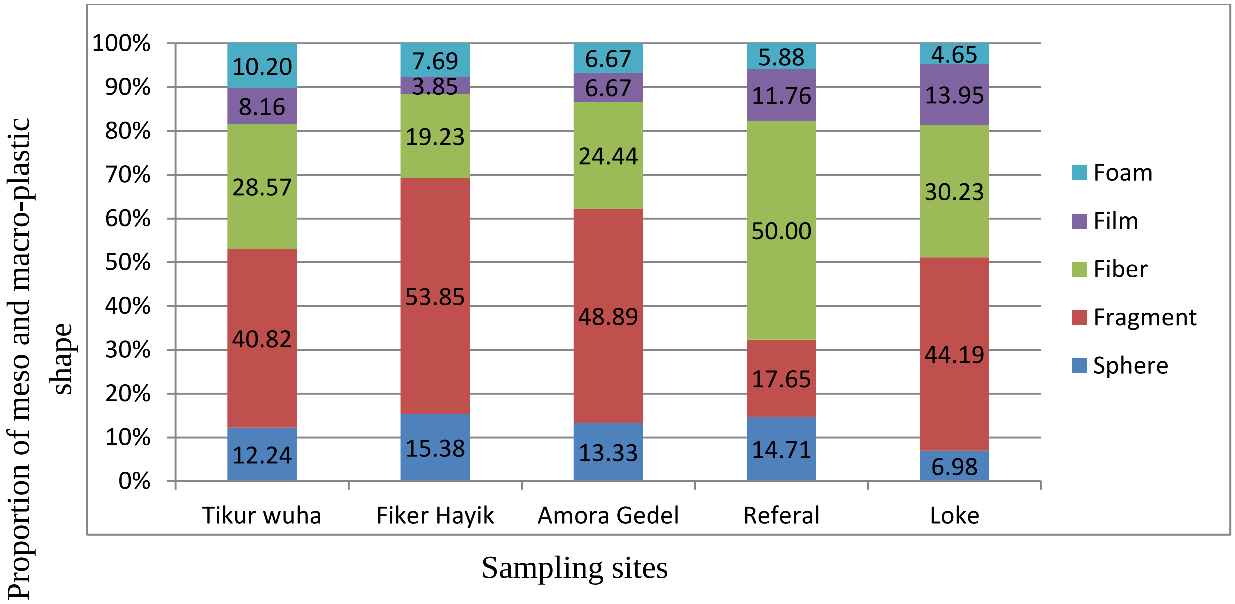

Figure 4 shape of meso and macro-plastics in the sediment sample of Lake Hawassa

4.2.3 Color of plastics

4.2.3.1 Color of micro-plastics

In the present study, various colors were recorded across all sampling locations white, black, yellow, green, red, and blue as shown in Figure 5. The most common color of MPs identified in the sediment sample was white (49.2%), followed by black (29.4%), and yellow (7.6%), the remaining four hues accounted for green (6.5%), red (4.6%) and blue (2.5%) MPs found in the sediment of the lake. The current result of high white color was compatible with Merga *et al.*, 2020 and Sun *et al.*, 2021). Similarly this study result is an agreement with the study conducted by (Zhang *et al.*, 2018; Zhao *et al.*, 2020).

Black was the second most prominent color this study, despite the fact that Reinold *et al.*, 2021 identified yellow as the dominant color of MPs. The predominance of white-colored MPs may be related to the types and quantities of plastics (MPs) utilized locally (Zhou *et al.*, 2020). Furthermore, on-site inspections revealed that Lake Shoreline vegetable such as tomato production was prevalent, and growers used white plastic objects to support these plants; hence, the current white color dominance of MPs may be ascribed to such human actions. Similarly, the existence of degraded plastic items could be linked to the second and the third dominance of black and yellow MPs respectively, since Liu *et al.*, 2019) discovered that yellow MPs are the outcome of degraded products. The colored micro-plastics taken as food were further degraded and the color additives were removed

(Wright *et al.*, 2013). Color has additionally been perceived as a decent mark of residence time for micro-plastics on the ocean surface, and of the level of weathering (Rodríguez-Seijo and Pereira, 2016). The level of yellowing or darkening is a great extent because of the expanded carbonyl functional group lists responsible for the degree of aging or degradation (Stolte *et al.*, 2015). The color of the micro-plastic particles is an important factor enhancing the likelihood of ingestion by the aquatic organisms for resembling their target prey. Some commercial fish species (Selvam *et al.*, 2021) and their larvae may target tiny zooplankton and they have a higher chance of ingesting white and yellow MPs as they are visual predators (Zhao *et al.*, 2015).

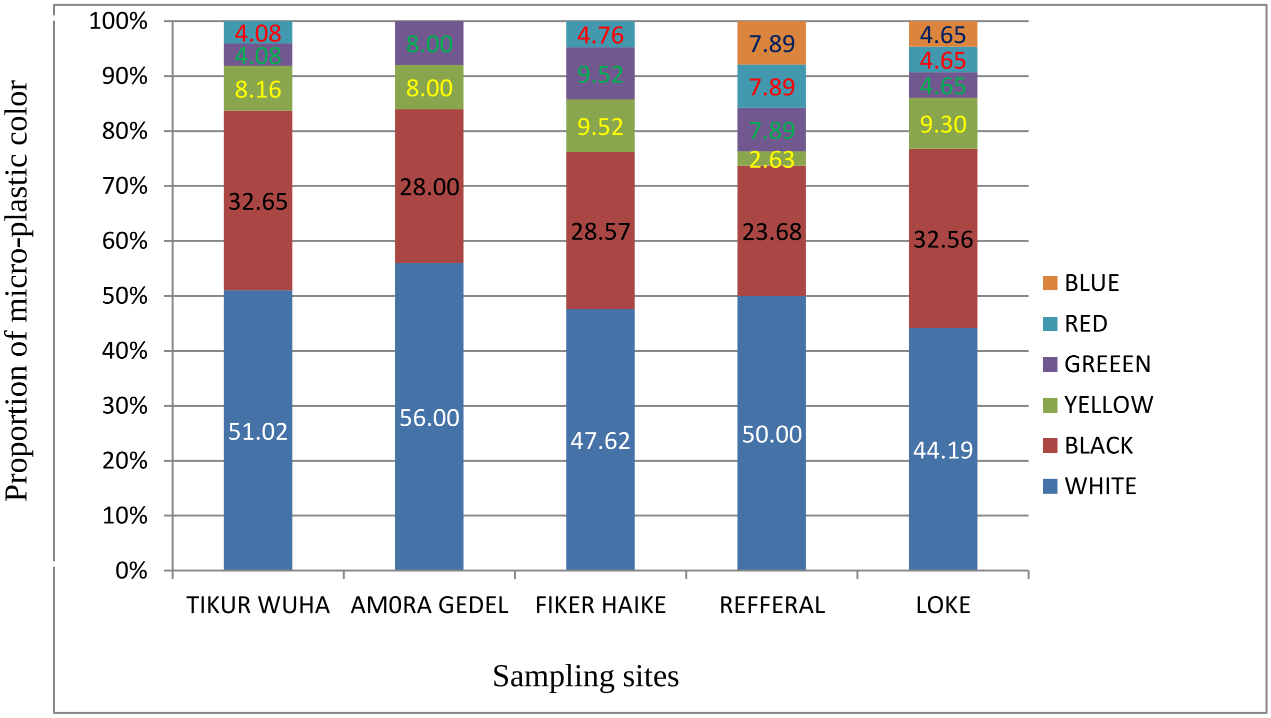

Figure 5 Color of micro-plastics in sediment sample from Lake Hawassa

4.2.3.2 Color of meso-plastics and macro- plastics

In the present study, five types of colors were recorded across all sampling locations as shown in figure6. Black colored meso and macro plastics were recorded as the most frequently dominant type of color along the all study sites except in Amora Gedel and Fiker Hayik in this two site white color was recorded as dominant color and also most in the rest of the sites white color was recorded as the second most dominant color, yellow and green colors was equal in number and the least one was red color as shown in figure 6. The current result of high black color was not compatible with (Harith *et al.*, 2022). Clear plastics seemed to be due to the breakdown process where the plastic wastes were exposed to the UV radiation and mechanical stress caused by the wave movement at the beach (Lechthaler *et al.*, 2020).

In Tikur Wuha site color of meso and macro-plastics was recorded which is 30.77%, 61.54%, and 7.69% was white, black and yellow respectively in this site black color was recorded the most dominant color compared with the white and yellow.

In Fiker Hayik site site the color of meso and macro-plastics was recorded which is 44.44 %, 33.33%, and 11.11% and 11.11% was white, black yellow and red respectively in this site white color was recorded the most dominant color compared with the black, yellow and red. In Amora Gedel site the color of meso and macro-plastics was recorded which is 40.91%, 31.82%, 9.09% and 8.18% was white, black yellow and red respectively in this site white color was recorded the most dominant color compared with the black, yellow and red. Second most dominant color was recorded black.

In Referral site the color of meso and macro-plastics was recorded which is 29.63%,55.56 %, 11.11% and11.11 % was white, black yellow and red respectively in this site black color was recorded the most dominant color compared with the white, yellow and red. Second most dominant color was recorded white and also yellow and red was recorded as the same. In Loke site the color of meso and macro-plastics was recorded which is 33.33%, 45.83%, 4.17% 4.17% and 12.50% was white, black yellow red and green respectively in this site black color was recorded the most dominant color compared with the white, yellow red and green. Second most dominant color was recorded white and third most abundant color was green and also yellow and red was recorded as the same.

The color of the micro-plastic particles is an important factor enhancing the likelihood of ingestion by the aquatic organisms for resembling their target prey. Some commercial fish species (Selvam *et al.*, 2021) and their larvae may target tiny zooplankton and they have a higher chance of ingesting white and yellow MPs as they are visual predators (Zhao *et al.*, 2015).

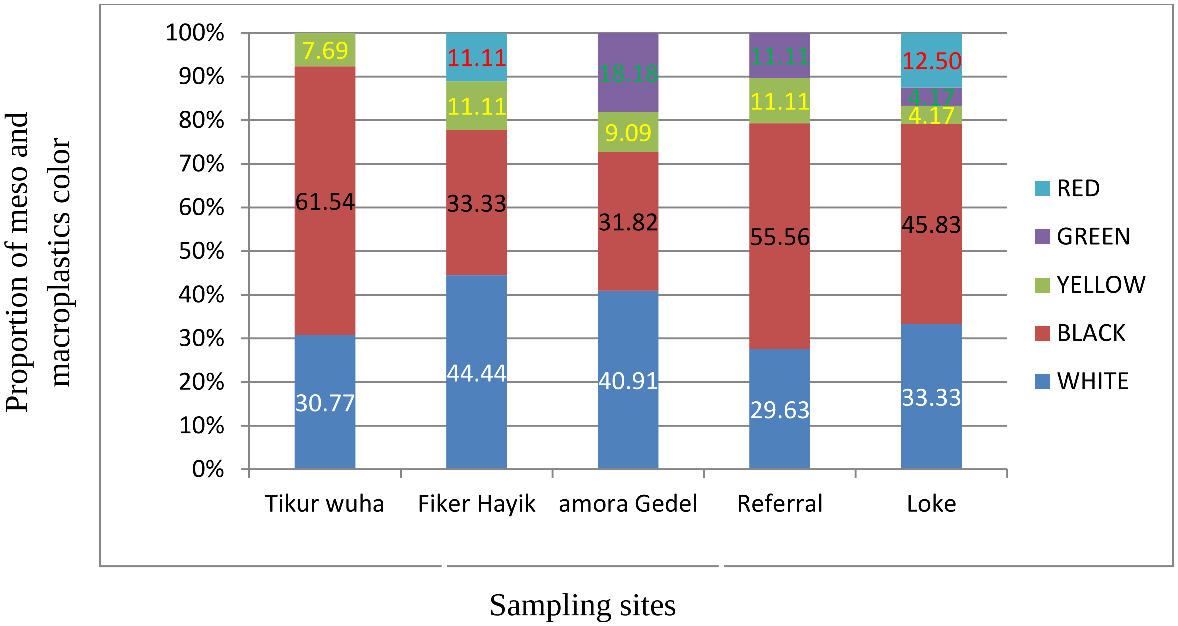

Figure 6 color of meso and macroplastics in the sediment sample from Lake Hawassa

5 CONCLUSION and RECOMMENDATIONS

5.1 Conclusion

Our study assessed micro-plastics and Meso and macro plastics pollution in the sediment of Lake Hawassa, a rift valley Lake in Ethiopia. MPs were found at all sites sampled in this study, indicating high prevalence of this emerging pollutant. All sediment samples contained micro-plastics, with a mean concentration of 160-326.6 particles item per kg dry sediment. The highest abundance of MP is at Tikure Wuha site (326.6 item/kg), while the lowest abundance is at the Fikir Hayik site (160 item/kg).The most abundant type of MPs in sediment samples was fragments, which are mainly derived from thicker plastic products that are degraded into MPs when discarded materials larger than 5 mm are not removed from shoreline.

Based on the size of the highest abundance of micro-plastic particles, particles in size 0.25-0.5mm was the prevalence size and at all study sites 0.25-0.5mm plastic particle sizes were most abundant particle size except Loke site. Generally in all sites, the frequency of micro-plastics increased with a decrease in size class. White colored micro-plastics were recorded as the most frequently dominant type of particles along the all study sites samples. The proportion of white particles in sediment was significantly higher than other plastic colors. The proportion of white colored MPs was recorded as 49.23% flowed by black color accounting 29.44%. The presence of large amounts of micro meso and macro plastics in the sediment suggests human activities and municipal sewage are the main sources of micro-plastic pollution, and human activities increase the accumulation of MPs in the environment, thereby increasing the pollution risk of MPs. Micro-plastics distributed to Lake Hawassa from the different source and activities for this reason micro-plastics entered to Lake Hawassa.

5.2 Recommendations

Based on the study results, the researcher forwards the following recommendations.

1 The occurrence of plastics in the shore sediments of Lake Hawassa alarms the need for further studies in the biota and associated public health risk assessments.

2 In order to bring significant change in plastics waste management practice of the town, the city administration should implement the existing laws, regulations and guiding manuals of plastics waste management. Besides this; specific technical guidelines focuses on Hawassa city actual situation need to be produced by cooperation with the municipal experts and environmental experts.

3 Promote waste reduction methods through the 3Rs: (Reduce, Reuse, and Recycle) the 3R methods should be promoted and implemented to significantly reduce the amount of plastics waste at source of generation which is to be disposed of at final disposal sites, thereby ,and reducing public health, aquatic organisms and environmental risks.

4 Plastic pollution in Ethiopian aquatic ecosystems was not fully explored. Therefore, it necessitates the technical collaboration of environmental researchers, institutions, and stake holder organizations to find a way to fill this huge paucity of information.

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