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MICROPLASTIC IDENTIFICATION-REMOVAL AND STUDYING ABOUT ITS BACK WASHING EFFICIENCY

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Lists of Abbreviation

ABS: Acrylonitrile butadiene styrene

BPA: bisphenol A

DDT: dichloro-diphenyl-trichloro ethane

ECHA: European Chemical Agency

EPS: expanded polystyrene

HCH: hexachloro-cyclohexane

HDPE: high-density polyethylene

LDPE: Low-density polyethylene

MPs: Microplastics

NOAA: The National Ocean and Atmosphere Administration

nd: non-detection

N/A: non-applicable

PA: polyamides

PAN: Homopolymeric Polyacrylonitrile

PAHs: Polycyclic Aromatic Hydrocarbons

PBDE: Polybrominated diphenyl ether

PC: polycarbonate

PCB: poly-chlorinated biphenyls

PE: polyethylene

PEG: polyethyleneglycol

PET: polyethylene terephthalate

PMMA: polymethyl methacrylate

PP: polypropylene

PS: polystyrene

PS-E: expanded polystyrene

PSU: polyarylsulfone

PUR: polyurethanes

PVA: polyvinyl alcohol

PVC: polyvinylchloride

PEMRG: Plastic Europe Market Research Group

REACH: Registration, Evaluation, Authorization, and Restriction of Chemicals

RSF: rapid sand filter

SAPEA: Science Advice for Policy by European Academies

SD: standard deviation

TPE: thermoplastics elastomers

TBBPA: Tetrabromobisphenol A

UNEP: The United Nation of Environmental Programme

UV: ultraviolet

WWTP: wastewater treatment plant

Chapter I: INTRODUCTION

1. Introduction

Plastic is an organic polymer from fossil fuels like natural gas, oil, or coal. In the modern age, the first plastic created became known as "Bakelite" in 1907. Because of the numerous advantages of plastics, such as their low cost, versatility, lightweight, and resistance, global production in 1950 increased from 0.35 million metric tons to 348 million metric tons in 2017. The global population continues to rise annually, and this tremendous growth has increased the quantity of trash deposited by humans. With almost 240 million tons of plastic consumed yearly, rushed lifestyles necessitate readily disposable goods such as cans or bottles. The gradual accumulation of these items has increased worldwide plastic pollution (Rillig 2012, Verla et al. 2019). Significantly, these plastics get high, potentially degrading into smaller debris sizes in the term of secondary microplastics from the shredding and weathering conditions.

Microplastics (MPs) have been identified as causing chronic toxicity in organisms due to their accumulation (Li et al. 2018) and have even been associated with sublethal effects such as a decreased number of offspring and smaller body size in Daphnids (Schwarzer et al. 2022), and metabolism disruption in fish (Qiao et al. 2019). In particular, microplastics indicate a severe hazard for human health due to their potential to absorb organic pollutants such as dichloro-diphenyl-trichloro ethane (DDT), hexachloro-cyclohexane (HCH) and polychlorinated biphenyls (PCB) (Hidalgo-Ruz et al. 2012). MPs can explore the human body through the digestive or respiratory systems. As a result, the impact of microplastic contamination on the environment is receiving increased attention in society.

Microplastics have been spread throughout the world in recent years. Microplastic abundance has been reported in soil biota (Cheng et al. 2021), saltwater (Karami et al. 2017), water surface, and agricultural soil (Silori et al. 2023). Furthermore, MPs are ubiquitous across the marine ecosystem, reaching even the most isolated aquatic environments, such as the deep sea. In 2019, an overwhelming concentration of MPs was observed in the sediment at depths ranging from 200 to 600 meters (Choy et al. 2019), in addition to at a depth of 1176 to 4844 meters (Van Cauwenberghe et al. 2013).

Moreover, wastewater treatment plants (WWTPs) are considered the primary receptors of terrestrial microplastics before reaching the natural water systems (Sun et al. 2019). On the other hand, microplastics found in municipal wastewater are frequently the result of regular human life activities. For example, an abrasion from clothing during the laundry process, as well as exposure to chemicals and detergents, cause the breakdown of synthetic fibres into smaller microfibers (Napper & Thompson 2016, Browne et al. 2015), also personal care products such as toothpaste, cleanser, and shower gel (Magni et al. 2019).

Objective

In WWTPs, a rapid sand filter is considered one of the best-performed methods among other water treatment equipment. In order to ensure and to reduce the number of microplastics entering the natural aquatic system, this study aims to identify MPs and determine the effectiveness and capacity of RSF to remove MPs together to analyse the back washing efficiency in the cleaning process after each batch.

Chapter II: LITERATURE REVIEW

2.1.General knowledge about microplastics

Microplastics are synthesized materials made up of solid particles under 5 millimetres. Furthermore, microplastics are defined as materials that are insoluble in water and non-biodegradable (Verschoor 2015). According to (Hartmann et al. 2015), various definitions of microplastics are used in academia, with discrepancies mainly about the size ranges covered in the term. In 2017, the National Ocean and Atmosphere Administration (NOAA) defined microplastics as plastically debris material with all shapes and sizes that are less than 5 mm are called microplastics.

The British Scientist Professor Richard Thompson and his team researched plastic pollution and published their seminal paper in 2004 when they first introduced and described the term "Microplastics" into the world-representing the tiny particles of plastics and their accumulation in the environment through the article names "Lost at Sea: Where Is All the Plastics?" (Thompson et al. 2004). Long chains of polymeric molecules made from organic and inorganic essential elements such as carbon, silicon, and hydrogen combine to generate microplastics. Typically, these resources are derived from oil, coal, and natural gas (Shah et al. 2008).

2.2.Classification criteria of plastic pollutants

Microplastics are not biodegradable. As a result, microplastic particles aggregate and resist the environment. Microplastics have been discovered in a wide range of environments, including both marine and freshwater ecosystems. Therefore, microplastics were classified into various categories due to the purpose of the study.

2.2.1. Origin or source of plastic

In 2010 Plastics Europe Market Research Group (PEMRG) announced that 192 coastal countries produced roughly 275 million tons of plastic pollution, comparable to the world's entire plastic material production. Moreover, up to 12.7 million tons of discarded plastic are anticipated to approach the oceans yearly (Jambeck et al. 2015). Plastics have a wide range of uses and applications. Hence the sources of microplastic vary greatly. Currently, microplastics are categorized into two extensively different classifications: primary and secondary microplastics (Laskar & Kumar 2019).

Primary microplastics are mainly utilized for commercial use and are directly discharged into the environment in the form of tiny plastic particles. A significant proportion of these particles are caused by the laundry of synthetic fabrics and the abrasion of tires when driving. They tend to be generated by the roughness of large plastic items during manufactured usage or maintenance, such as tire erosion when driving or synthetic textile abrasion while washing. Primary microplastics can be added voluntarily to products such as scouring agents or microbeads in personal care products (shower gels, creams), as well as microfibers shed or plastic fibres from textiles, fish traps, and so on (fishing industry). Land-based activities cause overwhelming primary microplastic losses (98%). In comparison, maritime operations generate just 2%. Most discharges to the oceans are caused by product usage (49%) or product maintenance (28%). These plastics enter the ocean primarily by road runoff (66%), wastewater treatment systems (25%), and wind transfer (7%) (Boucher & Friot 2017, Rogers 2022).

In agricultural fields where plastic mulching is practised, an abundant plastic material would be available; in other cases, incidental plastic debris would be the starting material. Degrading into tiny plastic pieces and smaller plastic fragments once it is exposed to the environment (Rogers 2022). This contrasts with secondary microplastics that generally originate from the degradation of large plastic, particularly indiscriminate disposal of macroplastic waste or trash, such as plastic bags and bottles, by exposure to environmental conditions and factors, mainly the sun's radiation and ocean waves (Rogers 2022) or inside the soil profile (Cole et al. 2011).

2.2.2. Shape

The shape of microplastics is an essential feature in their characterization. The form of microplastics influences their removal effectiveness in wastewater treatment plants (WWTPs) (McCormick et al. 2014). Through a global examination of microplastics' characteristics and removal in 38 WWTPs in 11 countries, nine shapes of microplastics were discovered in the influent and effluent of the WWTPs. Fibres, pellets, fragments, and films were the most widely detected microplastics in wastewater; their highest occurrence was 91.32%, 70.38%, 65.43%, and 21.36%, respectively (Bayo et al. 2020, Hidayaturrahman & Lee 2019, Lares et al. 2018). Moreover, other microplastic shapes, such as foams, particles, ellipses, lines, and flakes, were also detected in the WWTPs (Liu et al. 2021), as shown in Table.1. Following a study of 50 pieces of literature on microplastics in drinking water, freshwater, and wastewater, monitoring has been carried out in numerous areas in Asia, Australia, Europe, and North America. Fragments, fibres, film, foam, and pellets were the most frequently reported shapes (Koelmans et al. 2019).

Table 1. Show the most abundance of various shapes of MPs in 38 WWTPs along 11 countries globally (Liu et al. 2021).

Shape	Influent (particle l^{-1})	Influent (particle l^{-1})	Detection times
Fibre	$0.22 - 4.60 \times 10^3$	nd – 35.00	12
Fragment	$0.25 – 3.40 \times 10^3$	nd – 80.00	11
Film	$0.06 – 1.30 \times 10^3$	nd – 12.00	9
Pellet	$0.01 – 2.21 \times 10^4$	$0.22 – 1.33 \times 10^3$	7
Foam	nd – 2.33	nd	4
Particle	$\text{nd} – 2.91 \times 10^2$	nd – 10.00	3
Ellipse	0.36	nd	1
Line	0.12	0.12	1
Flake	0.92	nd	1

*nd means on-detection

Textile production and consumption are expanding due to population increase and fast fashion. The total microplastic daily loads in each size fraction emitted in the effluent for the three WWTPs, and fibres accounted for an average of 75% or more in all samples. Many studies have seen fibres dominate the effluent microplastic or microliter profile (e.g., 61-89% of all microplastic in treated effluents were fibres) (Michielssen et al. 2016). Moreover, the source of the microplastic fibres was identified as domestic washings. Because of the growing quantity of washing and textile use, fibre identification has become more common (Cesa et al. 2020; Liu et al. 2021). Fibre fragments emitted from clothes and household textiles while washing, drying, and wearing are considered a new form of pollution and a health hazard (Prince Periyasamy & Tehrani-Bagha 2022).

2.2.3. Size

The size of microplastics is significant because it influences their behaviour and interactions with biological organisms. Smaller microplastics can be consumed by plankton, but larger microplastics can constitute a physical threat to more giant creatures like fish and marine animals. The biological consequences of microplastics vary according to their size, with smaller sizes having a higher impact on organisms at the cellular level (Lusher 2015). More significant microplastics (2-5 mm) may take longer to pass through creatures' stomachs. They may be stuck in the digestive system, extending exposure to adsorbed toxins (Rochman 2015). Moreover, the size of microplastics can influence their capacity to flow across various environments, such as water or sediment, and their tendency to aggregate in certain regions. The study of microplastic size helps us to have better knowledge and insight into their fate in the environment.

This study focused on removing MPs from the outlet in 4 municipal wastewater treatment plants operating various advanced final-stage treatment technologies. The examination of two WWTPs in Eastern China discovered that the influent MPs of those plants were composed of MPs with prominent sizes of >500 mm (40%) and 62.5-125 mm (29%) (Lv et al. 2019). It derived an even higher prevalence of small size fractions, with 70% in the effluent in the size range of 20-100 m and >95% in the size range of 20-300 m. (Talvitie et al. 2017). As a result, we may assume that the smaller the size, the less efficient the elimination procedure.

2.2.4. Polymer types (composition) and density

Microplastics are also called hydrocarbon chemicals which are consisted of Carbon and Hydrogen atom bond gathering in a long polymer chain (Rogers 2022).

Plastic materials may be categorized into several classes based on their qualities: bioplastics, biodegradable plastics, technical plastics, epoxy resins, expanded polystyrene (EPS), fluoropolymers, polyolefins, polystyrene, polyurethanes (PUR), polyvinylchloride (PVC), polyethylene (PE), and polypropylene (PP) among others. The polymer identification must be established to ensure reliable evaluation of plastic particles, theoretically using (micro) Fourier-Transform infrared spectroscopy (FT-IR) or Raman spectroscopy, pyrolysis-GCMS, or TGA-GCMS analytical techniques (Hermsen et al. 2018, Mintenig et al. 2018).

Table 2. Chemical components of some widely use polymers with its SPI code.

SPI code	**Chemical name**	**Abbreviation**	**Chemical formula**
1	Polyethylene Terephthalate	PETE (PET)	$(C_{10}H_8O_4)_n$
2	High-Density Polyethylene	HDPE	$(C_2H_4)n$
3	Polyvinyl Chloride	PVC	$(CH_2=CHCl)_n$
4	Low-Density Polyethylene	LDPE	$(CH_2\text{- }CH2)_n$
5	Polypropylene	PP	$[CH_2\text{-}CH(CH_3)]_n$
6	Polystyrene	PS	$(C_8H_8)_n$
7	Other	N/A	-

On the other hand, based on the chemical compositions of plastic polymer, microplastic can correspondingly be divided into two distinct categories. The first group belongs to plastic, which comprises polymers with only aliphatic (linear) carbon atoms in their backbone chains. While all of the above polymers mention in Table 2. belong to this class. The former, thermoplastics, are a class of reversible polymers whose shape can be easily changed by varying temperatures, e.g. polycarbonate (PC), expanded polystyrene (PS-E), polypropylene (PP), polyarylsulfone (PSU), polystyrene (PS), thermoplastic elastomers (TPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), polyamides (PA), polymethyl methacrylate (PMMA) and fluoropolymer, which are more typical in the environment. For example, consider the structure of polypropylene, which has a pendant methyl group connected to every other carbon atom (CH_3) (Rodriguez & Ferdinand 2023) Figure 1. a.

The other category of plastics is made up of heterochain polymers. In addition to the carbon chain, these compounds contain oxygen, nitrogen, or sulfur atoms in their backbone chains. Thermosets, on the other hand, are a kind of plastic that's unable to be reversed when subjected to heat. Epoxy resins, vinyl ester, polyurethane (PUR), urea-formaldehyde, acrylic resin, silicone, melamine resin, phenolic resins, phenol-formaldehyde, and unsaturated polyester, for example, go through a chemical transition that results in a three-dimensional network, making them rigid. An example, polycarbonate molecules contain two aromatic (benzene) rings (Rodriguez & Ferdinand 2023) Figure 1. b.

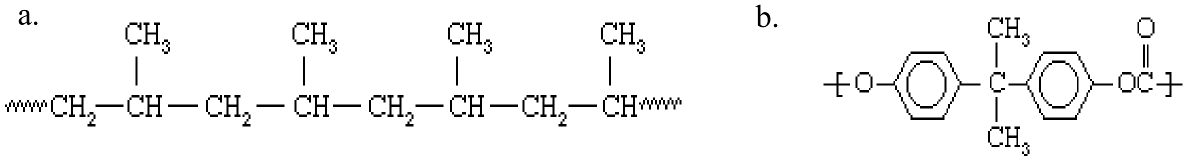

Figure 1. Showing the chemical compositions of plastic polymer in two different type. a: Chemical structure of Polypropylene (thermoplastics); b. Chemical structure of Polycarbonate molecule (Thermosets).

Microplastics (MPs) are currently one of the most significant marine pollution issues. MPs transport throughout the water column, with the polymer type's density and the water flow's direction, depth, and velocities determining their distribution. The density of various polymer types can be found below in Table 3. (Borges-Ramrez et al. 2020). The quantity of microplastics in fish gastrointestinal tracts is mainly related to the depth of the environment in which each species eats. The density of the substance determines the presence and depth of these MPs in the water column. The density of the material used to make microplastics is essential in determining their destiny in marine fish ecosystems.

Plastic usage has become widely spread according to its capacity to changeable shape and is easy to manufacture in diverse forms, especially at an affordable price. The purpose of usage depends on polymer composition and density, even for daily human activities or industrial use. Some examples of polymer uses are shown in Table 4.

Table 3. The typical density of Polymer (gram per cubic centimetre) (Borges-Ramrez et al. 2020)

Name	Abbreviation	Typical density
Expanded Polystyrene	EPS	0.02
Polypropylene	PP	0.89
Polyethylene	PE	0.96
Acrylonitrile-butadiene-	ABS	1.05
Polystyrene	PS	1.06
Polyamide (Nylon)	PA	1.14
Polymethyl methacrylate	PMMA	1.18
Polycarbonate	PC	1.21
Cellulose Acetate	CA	1.3
Polyvinyl chloride	PVC	1.39
Polyethylene terephthalate	PET	1.39
Polytetrafluoroethylene	PTFE	2.2

Table 4. The usage exemplification of some common polymer type observed by the United Nations Environmental Programme (UNEP) 2015

Polymer type	Example of common uses
PE	Packaging, containers, pipes
PET	Containers, bottles, clothing
PVC	Pipes, electric cable insulation, construction
PP	Packaging, containers, furniture, pipes
PS	Food packaging

2.3.Solubility

A substance's solubility is the amount of that substance required to make a saturated solution in a given amount of solvent at a specific temperature.

Polymer solubility is influenced by polarity, molecular weight, branching, cross-linking degree, and crystallinity. Water dissolves polar macromolecules such as polyethyleneglycol (PEG), polyacrylamide, and polyvinyl alcohol (PVA). On the other hand, non-polar polymers or polymers with low polarities, such as polystyrene, polyvinyl chloride etc., are weakly soluble in water (Verschoor 2015).

Another critical aspect of the study of microplastic solubilization is its polymer's solubility. According to the REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) guidelines provided by the European Chemical Agency (ECHA), a material is considered poorly soluble if its water solubility is less than 1 mg/L at 20 °C. As a result, most traditional polymers are weakly soluble in water, but other synthetic polymers dissolve quickly in water. e.g., PVA or low molecular weight PEG (Hartmann et al. 2019).

2.4.Degradability

Polymers are a large class of materials composed of repeated units of smaller molecules referred to as monomers. Polymers can have natural origins, such as lignin from tree branches. Synthetic polymers are those that humans create from naturally existing components. Polyester and polystyrene are two examples. Polymers are beneficial in numerous applications due to their strength and durability.

The environment has a detrimental impact on the service life of polymers used in outdoor applications. One major disadvantage of polymers is that they disintegrate when exposed to high temperatures or are utilized in outdoor applications. The phrase degradation of macromolecules refers to any processes that result in a decrease in polymer characteristics. It may eventually comprise physical processes such as polymer recrystallization or protein structural denaturation. Chemical processes associated with degradation may decrease average molar mass according to macromolecular chain bond scission or increase molar mass due to cross-linking, turning the polymer insoluble (Yousif & Haddad 2013).

Although the smallest micro-particle identified in the oceans at the moment is 1.6 m in diameter, microplastics are thought to deteriorate further to become nanoplastics (Galgani et al. 2010). The polymer degradation rate, r_d, is the differential mass loss per unit of time:

$$r_d = -\frac{dm}{dt} = k.SA$$

Since degradation proceeds mostly on exposed surfaces, we assume that the degradation rate is proportional to the surface area SA and that the constant rate k has a dimension of kg/s.m^2. As a result, the rate of degradation is affected not only by the intrinsic properties of the plastics (polymer type, molecular weight, fillers, etc.) and climatic parameters such as temperature, presence of moisture and air, etc., in addition to extrinsic properties such as the material's size and shape (Chamas et al. 2020).

2.4.1. Chemical/Photodegradation

Photodegradation is the disintegration of a photodegradable molecule induced by photon absorption, precisely wavelengths prevalent in sunlight such as infrared radiation, ultraviolet (UV) light and visible light. Some types of electromagnetic radiation, on the other hand, can produce photodegradation. Photodegradation involves photodissociation, which occurs when photons break apart molecules into smaller pieces. It also involves the change in the form of a molecule that causes it to be irreversibly changed, such as denaturing proteins and adding additional atoms or molecules. Oxidation is a frequent photodegradation process. Photodegradation can occur in the absence of oxygen (chain breaking or cross-linking) and in the presence of oxygen (photooxidative). UV light and other catalysts (or both) generate photooxidative deterioration, which can be accelerated at high temperatures (Yousif & Haddad 2013).

Figure 2. Degraded transformation (Hemwichian et al. 2021)

Several materials can degrade, particularly when exposed to sunlight or UV radiation. Exposure to sunlight over an extended time can stimulate the photodegradation of plastics; ultraviolet radiation in sunlight promotes oxidation of the polymer matrix, resulting in bond cleavage (Andrady 2011, Barnes et al. 2009, Browne et al. 2007, Moore 2008, Rios et al. 2007) showing in Figure 2. UV light induces photooxidative degradation, which results in the breaking of polymer chains, the production of free radicals, and the reduction of molecular weight, leading to the deterioration of mechanical characteristics and the formation of unusable materials after an undetermined period (Cole et al. 2011). As a result of this degradation, additives meant to improve durability and corrosion resistance may leach out of the polymers (Talsness et al. 2009).

The cold haline circumstances of the sea environment are expected to prevent this photooxidation; however, plastic debris on beaches has high oxygen availability and direct exposure to sunlight, so it will degrade quickly, turning brittle, forming cracks, and "yellowing." (Andrady 2011, Barnes et al. 2009, Moore 2008). When their structural integrity deteriorates, these polymeric materials become more vulnerable to fragmentation caused by abrasion, wave action, and turbulence (Barnes et al. 2009, Browne et al. 2007). This process continues, with fragments shrinking over time until they reach the size of microplastics (Fendall & Sewell 2009, Rios et al. 2007, Ryan et al. 2009).

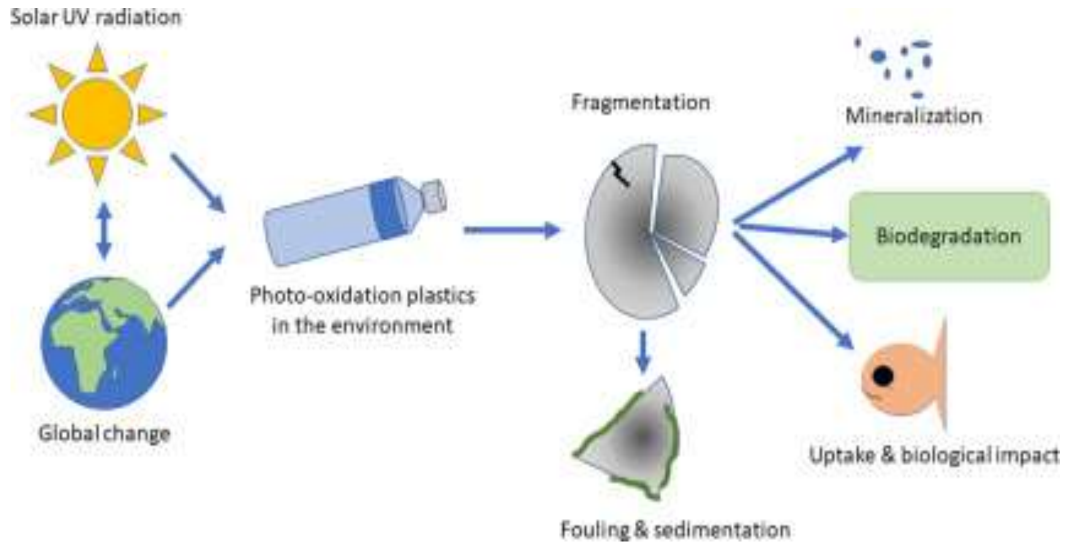

Figure 3. Oxidation and fragmentation procedure of plastics due to UV radiation explosion (Adrady et al. 2022)

There are three main steps of photodegradation: initiation, propagation and termination.

- Initiation is the process of free radical formation.
- Propagation step is the reaction of free polymer radicals with oxygen, the production of polymer oxy- and peroxy-radicals and secondary polymer radical.
- Termination step is the radicals formed in the degradation of polymers can be terminated by multiple combinations of two polymer radicals, which form inactive products resulting in chain scission.

2.4.2. Mechanical erosion or physical degradation

Mechanical degradation of microplastic litter proceeds mainly through abrasion, which occurs when the particles come into contact with both biological and artificial materials in aquatic and terrestrial environments. Natural objects include silt grains, shells, and woody debris. In contrast, anthropogenic materials include other plastic particles and strewn rubbish, manufactured obstacles (e.g., seawalls, groynes), and vehicles (e.g., boats, automobiles). Additional mechanical degradation mechanisms under consideration include temperature variations and wet or dry cycles (Klein et al. 2018).

Mechanical abrasion of microplastics results obtained in rounded particles (low sharpness of particle edges), which resembles the morphological characteristics of natural sediment grains subjected to long transport lengths or repetitive abrasion in high energy conditions. These patterns are widespread on natural sedimentary quartz grains in littoral (shoreline) zones where grain-to-grain collisions are common (Vos et al. 2014). The latter entailed filling bottles with sand with plastic strips and spinning the bottles at a steady speed for 24 hours. The plastic lost 14% of its weight, represented by produced microplastics undetectable to the naked eye. This experiment demonstrates that mechanical abrasion may cause polymer deterioration (Corcoran 2022).

Mechanical deterioration is a significant component in the decomposition of plastics in the aquatic environment. The recalcitrant matter is subsequently shredded into smaller particle sizes by friction forces generated during movement across various environmental conditions (Klein et al. 2018). Mechanical degradation's degree varied according to polymer type. PP and PE particles demonstrated that they carry a low risk of deteriorating due to mechanical weathering alone. At the same time, PS-E is potentially broken into multiple smaller pieces due to frictional forces alone (Song et al. 2017).

Mechanical degradation primarily relates to macroscopic phenomena driven by shear forces. As a result of these factors, macro radical formation is as follows in Figure 4. a. In the absence of oxygen, such radicals can recombine. Peroxy radicals can develop in the presence of oxygen, leading to the deterioration of polymeric chains, shown in Figure 4. b. (Yousif & Haddad 2013).

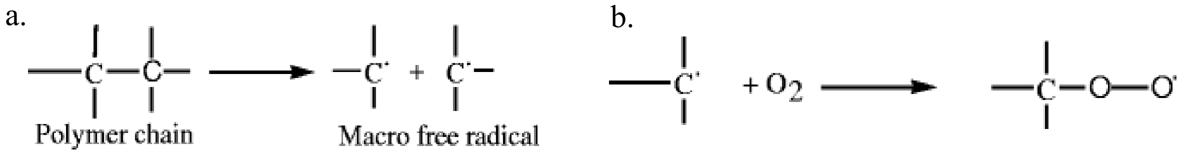

Figure 4. Mechanical degradation process of polymer in molecular level. a: polymer degradation influenced by shear forces. b. polymer degradation in the present of oxygen affected by peroxy radicals.

Mechanical weathering of microplastics in the water column can also occur when particles are under shear stress pressures. Mechanical stirring, pumping, and ultrasonic irradiation were utilized in order to subject PE microbeads from a facial cleanser to shear stress conditions. The result indicated that under low shear stress, microplastics are broken down into nanoplastics, introducing a higher amount of plastic particles into the environment (Enfrin et al. 2020).

2.4.3. Bio-degradation

Biological degradation is defined as the biological metabolic breakdown of complex organic matter into another carbon dioxide, methane, water, minerals, and new biomass. This process is accomplished by the enzymatic activity of certain microorganisms, specifically bacteria and fungi, which colonize the plastic's surface and secrete a biofilm of specialized enzymes. The expelled enzymes divide the long polymer chains into small fragments, carried into the microorganism's interior via tunnel proteins in the cell wall and metabolized (Kliem et al. 2020).

Various environmental factors influence biological degradation, including the prevailing physical-chemical conditions, the activity of existing microorganisms, and the material qualities of the examined plastic component. The virtual environments, however, may be summarized. Composting environments provide the best degrading conditions. There is a wide microbial variety with high activity in the home and industrial composting operations, especially with an adequate oxygen supply. In the latter scenario, high temperatures promote microbes' activity even further. Several microorganisms are still abundant in the soil and sewage sludge, although temperatures are vulnerable to substantial regional fluctuations. Since water offers considerable dilution, aqueous environments (fresh and seawater) have the lowest biological activity. In landfills, biological degradation occurs at a slower rate and with the exclusion of oxygen and is highly dependent on the manner of operation. Bacillus cereus subgroup A and Bacillus sphericus GC subgroup IV are marine bio-organisms capable of degrading secondary microplastic for prolonged exposure to these organisms.

The weight loss of the thermally treated HDPE and LDPE samples was about 9% and 19%, respectively. Weight loss of un-pretreated starch-blended LDPE was 25% with B. cereus. Besides, the tensile strength of thermally pretreated LDPE, HDPE, and un-pretreated starch-blended LDPE decreased by 27%, 14.8%, and 30.5%, respectively, with B sphericus, at pH 7.5 and temperature 30 °C with the polymer as the sole carbon source (Sudhakar et al. 2008).

2.5.The occurrence of microplastics

The study discovered that basic routines might produce microplastics in our daily lives, such as scissoring with scissors, ripping with our hands, cutting with knives, or twisting manually open plastic containers/bags/tapes/caps. These methods can produce 0.46-250 plastic particles per centimetre. Many factors, such as stiffness, thickness, anisotropy, plastic material density, and microplastic size, determine its quantity (Sobhani et al. 2020).

Micro-Raman spectroscopy was used to investigate 17 saltwater brands from eight different countries. Microplastics were non-existent in one brand, whereas others included 1 to 10 MPs/Kg of salt. Plastic polymers comprised 41.6% of the 72 isolated particles, while pigments comprised 23.6%. The particle size (mean standard deviation) was $515 \pm 171 \mu$m. Polypropylene (40.0%) and polyethylene (33.3%) were the most prevalent plastic polymers. MPs were mainly in the form of fragments (63.8%), filaments (25.6%), and films (10.6%) (Karami et al. 2017).

The reviews of the event and the abundance of MPs in coastal sediments and agricultural soil of three major Asian countries, India, China, and Japan, were studied. A significant concentration of MPs has been recorded from these countries, which affirms its strong presence and subsequent environmental impacts. Concentrations such as 73,100 MPs/kg in Indian coastal sediments and 42,960 particles/kg in the agricultural soil of China are solid testimony (Silori et al. 2023).

Microplastics are ubiquitous and distributed throughout the marine environment, with concentrations highest towards coasts and in mid-ocean gyres. Microplastic ingestion has been seen in a wide range of marine species, which may facilitate the transmission of chemical additives or hydrophobic waterborne contaminants to biota (Cole et al. 2011). In the level of the deep pelagic zone (5-1000m), water samples were collected surrounding Monterey Bay, which discovered the presence of microplastic particles. Moreover, between depths ranging from 200-600m, the highest abundance of microplastics was found. Pelagic red crabs (Pleuroncodes planipes) and giant larvaceans (Bathochordaeus stygius) showed that microplastic particles readily flow from the environment into coupled water column and seafloor food webs (Choy et al. 2019).

Recent research discovered low-energy mudflats had high quantities of microplastics (ranging from 0.58 to 2116 items/kg) (Lo et al. 2018). Microplastic particles have also reached the most remote aquatic environment areas, such as the deep sea. Based on the sediments collected from depths between 1176 and 4844 m, 0 to 400 particles/m of microplastics were detected (Van Cauwenberghe et al. 2013). Marti et al. 2017 was discovered floating on the water surface at a limited concentration (1.1 g/km^2). In contrast, the number of microplastics on beaches ranged from 27 to 5595 particles/m^2 (Fok & Cheung 2015, Hidalgo-Ruz & Thiel 2013).

PET fibre fragments are commonly found in the environment, and the contamination in the ocean is in the order of PET > PAN > PP > PA. The order in globally detected polymers in these studies is PE ≈ PP > PS > PVC > PET, which probably reflects the global plastic demand and a higher tendency for PVC and PET to settle due to their higher densities (Koelmans et al. 2019).

Twenty-four benthic sediment samples were collected from four study sites located along the northeastern and eastern shores of Hong Kong. Microplastic concentrations ranged from 169 ± 48 to 221 ± 45 items/kg, and the mean concentration of microplastics in the seabed sediments was 189 ± 50 items/kg, comparable to similar studies in other regions. It showed that polyethylene (PE) and polyethylene terephthalate (PET) comprised the majority of polymer types, contributing 45.3% and 29.3%, respectively (Cheang et al. 2018).

Besides, evidence of micro and nano plastics in the air has just been reported. These micro and nano plastics suspended in indoor and outdoor air are the consequence of daily behaviours such as opening a plastic container, detachment of microfibers from textile clothing, or tire wear, all of which contribute to particulate matter in ambient air. Due to atmospheric deposition, these particles arrive on land, in aquatic ecosystems, or in remote areas where micro and nano plastics have been detected in snow from diverse locales (Bergmann et al. 2019).

2.6.Fate and pathway of microplastics

In order to find the solution to microplastic pollution, understand the source, distribution, and fate of MPs. Wastewater treatment plants, sizeable plastic fragmentation, solid waste management, aquaculture, runoff, agriculture, commercial fishing, or industrial factories (among many others) are generators of micro- and nano-plastics pollution, which can be potentially hazardous to biota as macroplastic, secondary microplastics, and, even after long-term deterioration, nanoplastics (Derraik 2002, Domenech & Marcos 2021).

Plastic particles in lakes and rivers can originate from various sources, including tributaries, on-water activities, tourism, and inappropriate disposal of unused or abandoned plastic wastes from terrestrial sources. Storm-water events, rainfall drainage, floods, and wind can also gather and carry MPs spread or created on land to freshwater habitats. MPs are abundant in freshwater systems, exhibiting a vertical distribution throughout the water column and a top-down distribution gradient, even in benthic locations. Plastic density influences organic matter and pollutant partitioning in surface water, the water column, and sediments. Polymers having a higher density than water are expected to sink. Low-density micro- and nano-plastics are regularly found on the surface of seas, rivers, and oceans (Jambeck et al. 2015, Rillig et al. 2017). So far, some research has found that low-density polymers are accumulated on the substrates of aquatic basins due to biofouling by bacteria, algae, and other species.

Nevertheless, microplastics may be carried by wind and water once in the environment, influencing their geographical distribution. They may eventually end up in the marine environment because of the progressive breakdown of huge polymers or sewage overflow from residential and commercial sources. Moreover, density may also alter these contaminants' buoyancy and vertical dispersion. As a result, microplastics are widely spread in both marine- and freshwater systems, creating a significant hazard to aquatic life. Additionally, trophic transfer and biomagnification mechanisms are feasible routes for microplastics to enter humans (Elizalde-Velázquez & Gómez-Oliván 2021).

In addition, crops irrigated with contaminated water remain a potential route of human micro/nano-plastic particle exposure by consumption. Agricultural activities use contaminated water to raise crops, and microorganisms constantly decompose plastics in crop-growing soils. Furthermore, agricultural items form the foundation of the livestock husbandry diet. Consequently, crops, animal-derived food products, and drinking water are all sources of micro/nano-plastic particles for humans through ingestion (Corradini et al. 2019, Ru et al. 2020).

2.7.Effect of Microplastics on environmental- and eco-system

Because of two significant factors, microplastics provide a novel set of issues. They are tiny enough to be taken up by biota and so accumulate in the food chain, and they may also absorb toxic chemicals on their surfaces, enriching them on these particles (Rillig 2012).

Polluting plastics are biochemically inert owing to their enormous molecular size and have the potential to cause significant environmental harm. Microplastics transfer hazardous compounds into the environment by functioning as a vector. It is well known that microplastics may adsorb harmful chemicals such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). In comparison, the concentration of hydrophobic pollutants on microplastics can be a million times that observed in surrounding seawater. Besides that, they may remain in the environment for an extended period and accumulate in open oceans, sedimentary ecosystems, soil, and plant tissues (Verla et al. 2019).

2.7.1. Effect of microplastics on freshwater and marine species

Organisms can consume MPs depending on their quantity and particle size, the existence of natural prey, and the organism's physiological and behavioural characteristics. Indeed, the size of particles that may be caught is determined by the physiology and morphology of the organism. Numerous studies have observed microplastics in different trophic levels of the marine and freshwater food webs (Setälä et al. 2014). Microplastic ingestion has been seen in various marine species, which may enable the transfer of chemical additives or hydrophobic water-borne contaminants to biota (Cole et al. 2011). The health implications of their existence in animals include that they impede their digestive tract, which may result in the animal's mortality or alter its eating habits.

Compared to various forms of PS, chronic exposure of D. magna to 6 m PS beads (at low and high concentrations) demonstrated substantial unfavourable impacts on morphology and life history parameters. For PS fragments, there were only minor adverse impacts on offspring numbers. As a result, our findings indicate to shape-dependent toxicity of MP particles, with spherical particles appearing to be the most hazardous to Daphnids. Although the reported sub-lethal effects, such as a decreased number of offspring and smaller body size, appear to be mild, persistent exposure to MP with potentially harmful qualities may influence Daphnia's fitness in nature. As a result, even moderate impacts of chronic MPs exposure may result in cascade effects from lower to higher trophic levels, resulting in slow ecological alterations (Schwarzer et al. 2022).

Microplastic aggregation generates a variety of harmful consequences in the fish gut, including mucosal damage, increased permeability, inflammation, and metabolism disruption. Additionally, microplastics stimulated dysbiosis in the gut microbiota and alterations in particular bacteria (Qiao et al. 2019). During the chronic exposure to pristine primary microplastics and secondary microplastics of three Clodecorans (Jaikumar et al. 2019) observed that the reproductive output of all species declined.

They verified the detrimental effects resulting from the physical toxicity of polyvinyl chloride microplastics, which resulted in a shortened hatching time and higher teratogenic effects on aquatic embryos, as well as modification of genes involved in hypoxia-response and cardiac development (Xia et al. 2022). On the other hand, real-time oxygen fluctuations indicated that hypoxia generated by increased primary microplastic adsorption to the chorion surface contributes to the toxicological reactions of this material compared to secondary microplastics.

The coral reef ecosystem is recognized as one of the world's most sophisticated and productive marine ecosystems. It is thought to preserve diverse marine animals while providing human ecosystem services. Pesticides, trace metals, and petroleum hydrocarbons were discovered in coral reefs, affecting many creatures in the system. For example, the herbicide glyphosate, combined with high temperatures, can cause the bleaching of scleratinian (hard) corals (Amid et al. 2018).

2.7.2. Effect of microplastics on soil species (territorial)

Micro- and nano-plastics are classified as emergent and widespread soil contaminant that influences the behaviour of pollutants and can potentially threaten organisms. When earthworms are exposed to toxins or their intestinal environment changes, the microbial community's stability can be interrupted. As a result, the composition and structure of the earthworm gut microbiota have been identified as an essential indication of contaminants. The antioxidant enzyme activities of earthworms revealed that MPs caused significant oxidative stress. The higher the concentration of MPs, the more noticeable the limitation on the growth rate (Liu et al. 2022). In M. Guillelmi, exposure to HDPE and PP microplastics did not result in gut microbiota dysbiosis. On the other hand, PP microplastics drastically decreased bacterial diversity and changed bacterial community structure in the soil (Cheng et al. 2021).

Earthworms are the most studied group of creatures. While some studies found an influence of PE beads (looking at earthworm mortality), others found no adverse effects using the same experimental method with identical earthworm species. Microplastics did not affect isopod-eating behaviour (crustaceans in soil). According to SAPEA (Science Advice for Policy by European Academies), there needs to be more experimental research on soil biota in 2019.

2.7.3. Effect of microplastics on human health

Polymers, particularly micro/nano-plastics, are becoming more widely recognised as possible human health risk factors. Large plastics continuously degrade in the environment, producing many microplastics and nanoplastics that spread through the air, land, and oceans. As a result, people are exposed to micro/nano-plastics in various ways, including ingestion, inhalation, and dermal exposure (Domenech & Marcos 2021). MPs have the potential to contaminate drinking water, accumulate in the food chain, and generate hazardous compounds that can cause disease, including some cancers. Micro/nano-plastics can potentially cause acute toxicity, (sub)chronic toxicity, carcinogenicity, genotoxicity, and developmental toxicity (Yuan et al. 2022). While those who solely drink bottled water to accomplish their daily water requirements may swallow an additional 90000 microplastics annually (Cox et al. 2019).

Certain fibrous MPs are inhalable. Polycyclic Aromatic Hydrocarbons (PAHs) and other pollutants may desorb and cause primary and secondary genotoxicity. Most of these are expected to be eliminated by mucociliary clearance; however, some may stay in the lung, generating localised biological reactions such as inflammation, particularly in those with limited clearance processes. In contrast, plastic and its additives (dyes, plasticisers) may cause reproductive toxicity, carcinogenicity, and mutagenicity (Gasperi et al. 2018).

Humans have been exposed to plastic components such as phthalates, bisphenol A (BPA), polybrominated diphenyl ethers (PBDE), and tetrabromobisphenol A (TBBPA). In addition to their use in plastics, these compounds have the unintended property of altering the endocrine system. These substances are discovered in high amounts in the human body, and concentrations in young children, a population more vulnerable to exogenous insults, are often higher, highlighting the need to reduce exposure to these compounds (Talsness et al. 2009).

The consequences following prenatal exposure of male rats to phthalates exhibit a significant resemblance to the testicular dysgenesis syndrome in humans. BPA concentrations in the foetal mouse within the range of unconjugated BPA levels found in human foetal blood produced effects in animal tests. Lastly, thyroid hormones are required for optimal brain development and reproduction.

2.8.Microplastic removal rate

The effectiveness of water treatment systems was reviewed, with initial treatment of wastewater treatment plants found to remove 16.5 to 98.4% of microplastics. Secondary wastewater treatment plant microplastics removal efficiency ranges from 78.1 to 100%, with stage-wise efficiency ranging from 7% (activated sludge) to 99.9% (membrane reactor). The tertiary treatment eliminates 87.3 to 99.9% of the entire microplastics (Tang & Hadibarata 2021).

MPs removal from the discharge point in four distinct municipal wastewater treatment facilities using various advanced final-stage treatment techniques was investigated. The research includes a membrane bioreactor for treating primary wastewater and other tertiary treatment methods. As it turned out, RSF demonstrated remarkable performance, eliminating 97% of MPs after treatment, while dissolved air flotation is roughly 95% (Talvitie et al. 2017).

Microplastic particles and microplastic fibres were analysed for removal purposes. The samples were filtered via a 10 µm stainless steel cartridge filter. Sand filtering in the final treatment phase of PVC manufacturing reaches its high capacity in eradicating 99.2%-99.9% of the contaminants (Wolff et al. 2021). The sand filter removed microplastics of all polymer kinds, shapes, and sizes with excellent efficiency (up to 100%), confirming the usefulness of this well-developed and regularly used technology for removing microplastics from wastewater (Umar et al. 2023). The project accomplishes to enhance the effectiveness of microplastic removal in wastewater treatment plants by incorporating biochar into sand filtering systems. Removal efficacy was greater than 95%, well beyond the 60-80% attained by unmodified sand filtering systems. Another experimental study investigated microplastic removal's capability using magnesium/zinc-modified magnetic charcoal adsorbents (Mg/Zn-MBCs). When polystyrene microspheres were extracted from an aqueous solution using Mg-MBC, Zn-MBC, and MBC, removal efficiencies of 98.75%, 99.46%, and 94.80% were obtained, respectively (Wang et al. 2021). With a removal effectiveness of nearly 100%, the iron-modified biochar exceeded the raw biochar by a substantial margin (Singh et al. 2021). The top-performing membrane material for long-term residential system applications was discovered to be cellulose acetate with comparable mass removal efficiency (Pizzichetti et al. 2021).

Fibres and microplastics with big particle sizes (0.5-5 mm) were easily distinguished by primary settling in a study of the characteristics and removal of microplastics in 38 WWTPs in 11 countries globally. PE and microplastics with tiny particle sizes (<0.5 mm) were easily retained in activated sludge and by bacteria in WWTPs. Interactions between microplastics and membrane porosities and surfaces made microplastics readily adsorbed onto the membrane surface in membrane filtration technology. Although some of the microplastic removals by the above technologies eventually got a high performance, the filter-based treatment technique achieved the highest microplastic removal efficiency (Liu et al. 2021).

2.9.Back washing (back flushing) process and efficiency

Sand porosity may get blocked over time according to tiny colloidal particles, reducing the efficacy of the filter bed since the higher layers remove the majority of the rejected particles. As a result, tiny particles must be removed from the pore spaces of the sand. Filter back washing is a well-known method for removing microscopic particles. The degree of turbidity and particle count endpoint decreases, which improves water quality (Kramer et al. 2021). When the influent water contains more than 150 NTU, the back wash Filter has about 1.1 times the turbidity removal effectiveness of the down-flow Filter (regular filtration). In the same operating circumstances, the back washing process has a higher average filtering efficiency than the down-flow Filter (Hasan et al. 2020). As a result, the optimisation filter back washing technique was successful.

Chapter III: METHODS OF THE STUDIES

3.1. Sampling

3.1.1. Water samples

In this study, water samples utilised in the system were created in 3 ranges of different turbidity at various times, as called case "A", "B", and "C".

The wastewater samples used in this experiment were artificially created from microplastic particles collected while shredding a ground mineral water bottle I bought from Spar. The clean artificial MPs were mixed with distilled water and represented as Case "A". Based on the most abundant MPs types diverted to water bodies were PET particles (Lv et al. 2019).

Since the majority of MPs entering WWTPs originate from domestic washings. The increased quantity of washing and textile usage resulted in the identification of fibres becoming increasingly prevalent (Cesa et al. 2020). Thus, in case "B", the water sample was taken during the washing process in the washing machine of some of my clothes.

During the same washing process with the same machine in case "B", the rinsed water was collected and used in this study as the water sample in case "C".

Regarding cases "B" and "C", the washing methods were done on a Zanussi ZWQ5102 machine. The program used is washing synthetic clothes at 30°C, with the total amount of water used in the thorough washing procedure being 46 litres. The wash cycle was black and dark blue clothes. The materials of washed clothes are cotton, viscose, elastane, polyamide, and polyester, and the type of washed clothes are bras, pyjamas, socks, panties, trousers and cardigans. All the clothes I used here are trying to get close to the similarity of common wild usage in humans daily.

3.1.2. Soil sample

To fill our column, the soil sample was obtained from Kiskunhalas, as shown in Figure 5. which locates in the southeast of Hungary using a spade and a soil sample was taken at the beginning of April 2023. The total weight of the collected sample was 5 kg, and it was stored in a glass container to avoid further contamination.

The sample was dried and homogenised after bringing to the laboratory in Gödöllő.

Figure 5. The soil sampling site in Kiskunhalas city, the southeast of Hungary.

3.1.3. Experiment

- **Pre-treated phase**

Before the experiment starts, the column filling (soil sample, Figure 6. a) must be treated by washing with distilled water to prevent any pollution or suspended materials from contaminating the sand sample. Due to it can cause an inaccuracy in the experiment.

- After washing a sand sample several times, the pre-settling process was applied. The sand sample settled for an hour in a separating funnel during this procedure.
- After 1 hour, the funnel is opened and separated from the sediment part. This sediment was put as a sand sample in the column.
- The average particle size of the sand is 100-300 µm shown in Figure 6. b. (Sembiring et al. 2021) The smaller grain used in the rapid sand filter showed a higher efficiency in removal rate, especially with micrometre level.
- There were a total of 9 columns used. Each column's length is 11.2 cm, diameter 1.7 cm and volume 25.42 cm^3.
- Each experiment used one column.

- Due to the difference in size range and shape of the sand particles, in each column stored the minor difference in mass of sand such as in Case "A" the mass of the filled sand in the column is (m_{A1} = 39.0602g; m_{A2} = 38.9982g; m_{A3} = 39.0204g), Case "B" (m_{B1} = 38.9242g; m_{B2} = 39.0123g; m_{B3} = 39.0212g) and Case "C" (m_{C1} = 38.9173g; m_{C2} = 39.0014g; m_{C3} = 39.0242g), which number 1, 2, and 3 are indicating the repeated time in each case.

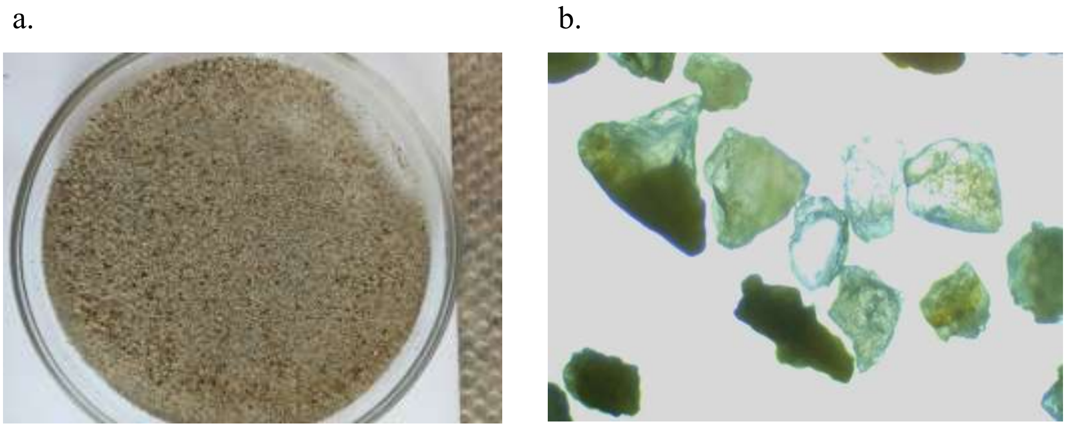

Figure 6. The soil sample utilized in column filling. a. sand particle visual size from naked eyes; b. the visual size from microscope.

- **Removal phase**

- After finishing filling the columns, the experiment could start.
- The water sample (500ml) was passed through the column (by gravity) with the assistance of a low-pressure pump (Jasco PU-980 Pump) 2-3 Bar.
- Then, a post-sedimentation in a separating funnel and filtrate was accomplished, and the cleaned water was collected at the output.
- The breaker was placed and covered by filtration paper at the column outlet. This filtrated paper was made from cellulose acetate with MN619G type.
- After filtering, the paper was placed on a 1-1 Petri dish and transferred to a drying oven (LP-321 (200l)); which temperature was set to 45-50°C for an hour to eliminate the moisture.
- After drying, the paper was cooled down with the assistance of an exicator.
- I then filled the column from the bottom to displace the air until the first drop of water appeared at the top of the column. The back washing phase follows this.

- **Back washing phase**

- In the Back washing process, a compressor had to be connected to the column's lower part, and a low-pressure pump was used.
- Then Set the pressurised system with 1-3 Bar and 0.5 ml/min Flow rate.
- 500 ml of distilled water was pumped and collected the liquid from the top (Back wash outlet). This process is different from the typical operational setting.
- Then did post-sedimentation in a separating funnel, filtrated it with filter paper, dried and let it cool down (all the steps mentioned here have been done by following the procedure I did in the removal phase).
- After the process ended, the residue was retained in the column.

- **Final examination**

The three experiments (case "A", case "B", and case "C") were done in 3 replications. A new column was applied to each experimental batch. At the same time, all the filter papers were measured before and after filtration.

Finally, a microscopic examination was performed on the filter papers. Visual analysis was carried out using a microscope (BTC, BIM 312T) equipped with WF 4x-10x magnification objectives and a camera (Toupcam). Images were acquired using ToupView software (version 3.2) by connecting the microscope to the laptop.

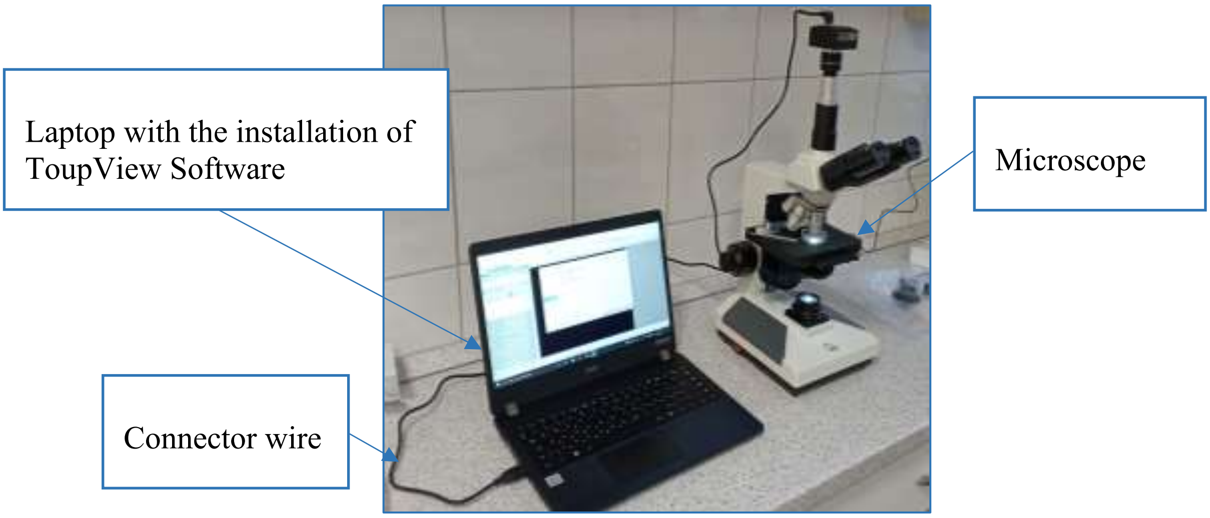

Figure 7. visual analysis on suspended particles collected from the filter paper.

3.2. Methods

3.2.1. Rapid sand filter technique

Rapid Sand Filter (RSF) is a widespread water filtration technology. RSFs use coarse and fine sand as a filtration media to eliminate fine suspended particulates from turbulent water.

RSFs are made up of a tank or basin which contains the filter media and has gravel support at the bottom, which allows the fluid to pass through the media vertically 40 times faster than Slow Sand Filters, an underdrain system that captures filtered water and injects back wash water, and troughs that run along the top of the filter (Coerver et al. 2021). In this research, the filtered and back wash outlets are directed to breakers with filter papers on top to remove suspended particles from the water.

RSFs remove particles from the water primarily by physical processes, the most significant of which is adsorption, while sedimentation and straining also play an essential part. The most common filtering medium is sand, which should be reasonably similar in size with an effective range of 0.4-1.2 mm. The effectiveness of removal using RSF for plastic particles depending on the Effective Size filter media 0.39 mm and 0.68 mm were 97.7% and 94.3%, respectively (Sembiring et al. 2021).

3.2.2. Inspection

The filter papers were examined under a microscope equipped with a Toupcam camera. ToupView software was implemented to capture the images for visual examination.

3.2.3. Removal rate and back washing efficiency measurement

Filter papers were measured by the analytical balance (SCALTEC SBC 31). (Von Sperling et al. 2020) the removal rate can be by the input minus output concentration (equal to the $m_{remaining}$ in the column) and divided by the input concentration as shown in (3.3).

$$\Delta m = m_{af_1} - m_{org_1} = m_{ef_1} \qquad (3.1)$$

$$m_{PET} - m_{ef_1} = m_{remaining} \qquad (3.2)$$

$$\boxed{\textbf{Removal rate \%} = \frac{m_{remaining} \times 100}{m_{PET}} \qquad \textbf{(3.3)}}$$

The Back washing efficiency (E_{BW}) can be calculated by the following steps:

Followed the (3.1) equation: $\Delta m = m_{af_2} - m_{org_2} = m_{ef_2}$ (3.4)

From equation (1) and (2) => $m_{remaining} - m_{ef_2} = m_{residue}$ (3.5)

The back washing efficiency, $\boldsymbol{E_{BW}\% = \frac{m_{ef_2} \times 100}{m_{remaining}}}$ **(3.6)**

* The subscripted number 1 and 2 are used to represent the removal phase and the back wash phase, respectively.

Chapter IV: RESULTS AND EVALUATION OF RESULTS

4. Results and evaluation of results

After all, the data were collected. The Excel software was applied to commit the calculation process. In this study, I obtained the following results for three parallel experiments of 3 experimental batches and concluded the results in three tables (Tables 5., 6, and 7) below.

In case "A", the examinations began using the artificial sample from a water bottle, shredding particles combined in distilled water medium. The results of 3 replicate measurements can be observed in Table 5. The MP removal rate of RSF is between 1.6-6.7% and 70.8-88.2% in the back wash. The average removal effectiveness is 4.3±2.6%, regarding a tiny amount of MPs removed. On the other hand, the average back washing efficiency is 79.7±8.7%.

Table 5. Removal and Back wash results in case "A"

	$m_{original}$ filter paper [g]	m_{after} filter paper [g]	$m_{influent}$ of MPs [g]	$m_{effluent}$ of MPs [g]	$m_{remained}$ in column [g]	removal rate [%]
REMOVAL	0.4953	0.5191	0.0250	0.0238	0.0012	4.8
	0.4958	0.5273	0.0320	0.0315	0.0005	1.6
	0.4967	0.5303	0.0360	0.0336	0.0024	6.7
	Average			0.0296	0.0014	4.3
	SD			0.0052	0.0009	2.6
BACKWASH	0.4943	0.4954	-	0.0011	0.0001	88.2
	0.4958	0.4962	-	0.0004	0.0001	80.0
	0.4971	0.4988	-	0.0017	0.0007	70.8
	Average			0.0011	0.0003	79.7
	SD			0.0007	0.0003	8.7

SD* means Standard Deviation

Figure 8. shows an LED micrograph of PET particles collected from the filter paper after filtration has been done. The magnification is 10x, and the average particle size is between 30-50 µm. Due to the plastic bottle being shredded by using a grater, most of the microplastic shapes were formed as flake and fibre shapes.

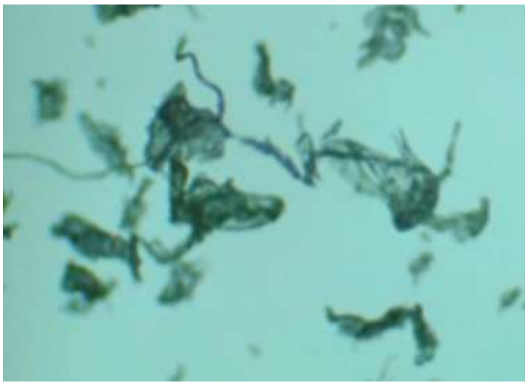

Figure 8. PET particles was detected at the effluent.

In case "B", the experiments began using the wastewater sample taken from the washing process in a washing machine. The results of three replicate measurements are shown in Table 6. The MP removal rate of RSF is between 6.4-20.7% and 90.0-92.2% in the back wash. It means the average removal effectiveness is 13.1±7.2%. Inversely, the average back washing efficiency is 91.1±1.1%.

Table 6. Removal and Back wash results in case "B"

	m_{original} filter paper [g]	m_{after} filter paper [g]	m_{influent} of MPs [g]	m_{effluent} of suspended	m_{remained} in column [g]	removal rate [%]
REMOVAL	0.4953	0.6348	0.1588	0.1395	0.0193	12.2
	0.4971	0.6573	0.1712	0.1602	0.0110	6.4
	0.4948	0.6263	0.1659	0.1315	0.0344	20.7
	Average			0.1437	0.0215	**13.1**
	SD			0.0148	0.0118	**7.2**
BACKWASH	0.4951	0.5127	-	0.0176	0.0017	91.2
	0.4940	0.5039	-	0.0099	0.0011	90.0
	0.4968	0.5285	-	0.0317	0.0027	92.2
	Average			0.0197	0.0018	**91.1**
	SD			0.0111	0.0008	**1.1**

The effluent was re-filtrated by filter paper and examined for microplastic identification purposes. This examination utilised the LED with 10x magnification. LED micrographs show in Figure 9. With regard to my supervisor's experience of working associated with microplastic identification, we can guess that these suspended particles (shown in Figure 9.) are of fibre microplastics, with an average length of 30-50 µm.

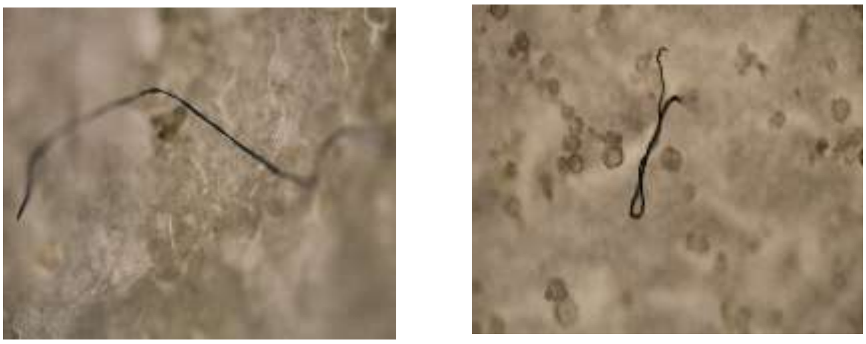

Figure 9. Detected fibers in the washing water.

In case "C", the experiments began using the wastewater sample from rinsing water after the laundry. The results of 3 replicate measurements are shown in Table 7. The MP removal rate of RSF is between 1.3-4.0% and 85.6-95.4% in the back wash. It means the average removal effectiveness is 2.6±1.4%. Inversely, the average back washing efficiency is slightly high at 90.1±4.9 %.

Table 7. Removal and Back wash results in case "C"

	m_{original} filter paper [g]	m_{after} filter paper [g]	m_{influent} of MPs [g]	m_{effluent} of suspended	m_{remained} in column [g]	removal rate [%]
REMOVAL	0.4949	0.5989	0.1154	0.104	0.0114	2.3
	0.4972	0.5867	0.1096	0.0895	0.0201	4.0
	0.4985	0.6041	0.1121	0.1056	0.0065	1.3
	Average			0.0997	0.0126	2.6
	SD			0.0089	0.0068	1.4
BACKWASH	0.4962	0.5064	-	0.0102	0.0012	89.5
	0.4951	0.5123	-	0.0172	0.0029	85.6
	0.4973	0.5035	-	0.0062	0.0003	95.4
	Average			0.0112	0.0014	90.1
	SD			0.0056	0.0013	4.9

The wastewater was treated with a sand filter medium, and the effluent was re-filtrated by filter paper and examined for microplastic identification purposes. Figure 10. Shows the occurrence of microplastics in fibre shape, average length: 30-50 µm.

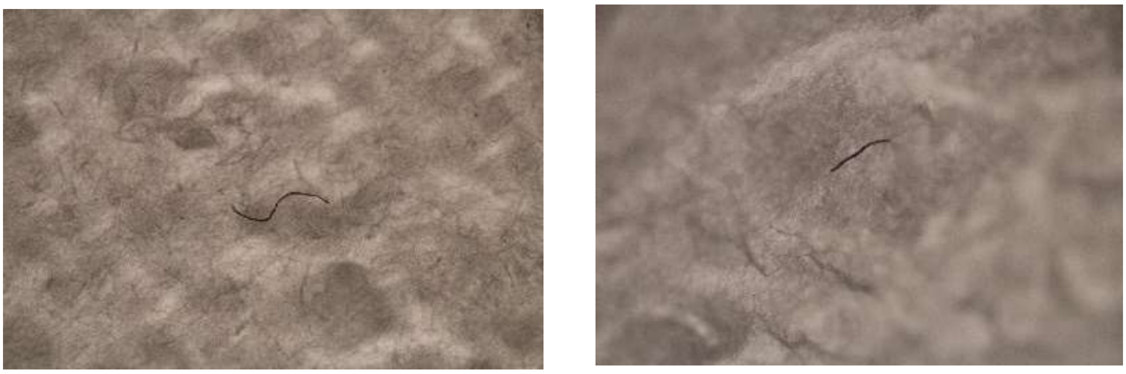

Figure 10. Detected fibres in the rising water.

As we can observe the results in the three tables above (Tables 5., 6., and 7.), we can sum up that the microplastic removal rate in all cases is relatively low compared to Sembiring et al. 2021, which received high removal rate approximately 85% and 95% via effective sand size 0.39mm and 0.68mm, respectively. It is significant to note that the effective size of the 0.39mm and 0.68 mm filter media was mainly only able to hold MPs that had a size of ≥ 200 μm. While the MPs detected in this study are more than 4-6 times smaller, between 30-50 μm size range. Besides, (Crittenden et al. 2012) show the association of the particle diameter to grain diameter ratio if it is more than 0.15; a tightly closed arrangement would generate strain, allowing smaller particles to flow through the filter media. A study about advanced wastewater treatment systems exhibited a high performance of MP removal (greater than 20 μm) at 97% (Talvitie et al. 2017). However, reaching that high removal percentage also requires a primary, secondary and tertiary treatment process.

In back wash process obtained high effectiveness with the mean value of these 3 cases is approximately 86.96% and reaching the highest point at 95.4% of the cleaning procedure in the last experiment in Case "C".

Chapter V: CONCLUTION AND RECOMMENDATIONS

5. Conclusion and recommendations

The effectiveness of microplastic removal by rapid sand filter and the efficiency of its back wash were evaluated in this study, according to the microplastic fibres originating from domestic washings. The samples of this study were collected from the laundry process and the mixture of PET particles and distilled water in the laboratory. Altogether the increasing amount of washing and textile consumption resulted in the more frequent detection of fibres.

As the results obtained after the wastewater treatment by utilising RSF indicated, the microplastic removal amount is minimal. It might influence by MP size, which is smaller than 50 µm compared to the medium sand size of around 100-300 µm. Inversely, the back washing process achieved a moderately high removal amount of the clogging MPs. The average back wash in all 3 cases is 86.96%.

Further studies must be conducted on the proper sand filter size to range the suitable porosity between the grain filter media and microplastic size. However, there is an absence of studies that fulfilled microplastic removal by single media or single treatment. Therefore, in microplastic elimination purpose might acquire to apply secondary and tertiary treatments. Otherwise, human health risk assessment due to microplastic exposure should be more concerned.

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ABSTRACT OF THESIS

MICROPLASTIC IDENTIFICATION-REMOVAL AND STUDYING ABOUT ITS BACK WASHING EFFICIENCY

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Microplastics have been detected in several environments, such as in the air, terrestrial, surface water, river lake, or deep ocean. Wastewater treatment plants (WWTPs) are mentioned to be the main pathway of microplastics into the natural waterways. Besides, the rapid sand filter (RSF) is one of the conventional water purifiers that can be an alternative treatment for removing MPPs after several configuration processes (pre-sedimentation, coagulation-flocculation, and sedimentation).

In order this study aims to determine the effectiveness of RSF in removing microplastic particles with 100-300 μm effective size grain filter media. The artificial samples were made from water bottle shredding particles combined in distilled water medium and wastewater collected from the domestic laundry process. The average removal efficiency of MPs was 4.3±2.6 %, 13.1±7.2 %, and 2.6±1.4 % in case "A", "B", and "C", respectively. In contrast, the efficiency of back wash in each case was 79.7±8.7%, 91.1±1.1 %, and 90.1±4.9 % in Cases “A”, “B”, and “C”, respectively. The detected MPs in this experiment are majority fibre and flake shapes with tiny sizes around 30-50 μm.

The result observation obviously shows that the size of MPs essentially affects removal effectiveness on wastewater treatment by using a rapid sand filter.

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STUDENT DECLARATION

Signed below, Vongsiry Savity, Student of the Szent istvan Campus of the Hungarian University of Agriculture and Life Science, at the BSc Course of Environmental Engineering declare that the present Thesis is my own work and I have used the cited and quoted literature in accordance with the relevant legal and ethical Campus/Institute/Course and my Thesis will be available at the Host Department/Institute and in the repository of the university in accordance with the relevant legal and ethical rules.

Confidential data are presented in the thesis: yes [✓ no*]

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Student

SUPERVISOR'S DECLARATION

As primary supervisor of author of this thesis, I hereby declare that review of the thesis was done thoroughly; student was informed and guided on the method of citing literature sources in the dissertation, attention was drawn on the important of using literature data in accordance with the relevant legal and ethical rules.

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Approval of this thesis for oral defense on Final Examination: [✓ approved] not approved*

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