# THESIS

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# ASSESSING THE EFFECTS OF THE CITY OF BUDAPEST ON THE MICROPLASTIC CONCENTRATION IN THE DANUBE

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## Abstract :

Plastic is one of the most versatile, durable and low cost material we know. It’s ubiquitous in our lives but unfortunately, also in the environment. Microplastics are small plastic pieces, smaller than 5mm. They have been identified as a growing threat as their number is rising, especially in water systems. Due to their tiny size, they are often mistaken for food by aquatic biota, and thus, they bioaccumulate along the food chain. They have been associated with a plethora of negative health effects, be it for corals, fish, birds or humans. The mismanaged plastic waste worldwide together with the Covid-19 pandemic is further feeding the fire of this ever growing microplastic pollution. In this study we will review the general problematic of microplastic pollution, before analysing the samples we took in the Danube river. The idea is to compare the samples from before and after the river has passed through the city of Budapest to see if it has an effect on the microplastic concentration and if so, to what extent.

## Összefoglalás:

A műanyag az egyik legsokoldalúbb, legtartósabb és legolcsóbb anyag, amit ismerünk. Mindenütt jelen van az életünkben, de sajnos a természetben is. A mikróműanyagok kisméretű, 5 mm-nél kisebb műanyagdarabok. Növekvő fenyegetésként azonosították őket, mivel számuk növekszik, különösen a vízrendszerekben. Apró méretük miatt a vízi élőlények gyakran összetévesztik őket táplálékkal, így biológiailag felhalmozódnak a táplálékláncban. A mikróműanyagokat számos negatív egészségügyi hatással hozták összefüggésbe, legyen szó korallokról, halakról, madarakról vagy emberekről. A világszerte rosszul kezelt műanyaghulladék és a Covid-19 világjárvány tovább táplálja ezt az egyre növekvő mikróműanyag-szennyezést. Ebben a tanulmányban áttekintjük a mikróműanyag-szennyezés általános problematikáját, mielőtt a Dunában vett mintákat elemeznénk. A felvetésem az volt, hogy a folyó Budapesten való áthaladása előtti és utáni mintákat összehasonlítom, hogy kiderüljön, van-e a fővárosnak hatása a mikróműanyag-koncentrációra, és ha igen, milyen mértékben.

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# 1 LIST OF ABBREVIATIONS

ALDFG : abandoned, lost or otherwise discarded fishing gear

BPA : bisphenol A

CH4 : Methane

CO2 : Carbon dioxide

DDT : dichloro-diphenyl trichloroethane

HDPE : High density polyethylene

LDPE : Low density polyethylene

MPs : Microplastics

MPW : mismanaged plastic waste

PET : Polyethylene terephthalate

POPs : persistent organic pollutants

PP : Polypropylene

PPEs : personal protective equipments

PS : Polystyrene

PVC : Polyvinyl chloride

UV : ultra violet

WHO : world health organization

# 2 INTRODUCTION

“The great problem of social chemistry we call politics, is to discover what desires of mankind may be gratified, and what must be supressed, if the highly complex compound, society, is to avoid decomposition.” Thomas Huxley,1871

We are now living in a plastic age. In 2019, Europe consumed no less than 50,7 million tons of that material we now see everywhere.(Johansen *et al.*, 2021) However the mass production of plastic items only started in the 1940s-1950s.

Plastic is a revolutionary material, that has changed our lives on a daily basis over the past decades; the term “plastics” describes synthetic polymers derived from oil or gas, by adding various chemicals (some 20 different types of plastics can be found, each with different properties). They allow us great technological advances as they are inexpensive, strong, non-corrosive, durable, lightweight and have high thermal and electrical insulation.(Thompson *et al.*, 2009)

But these wonderful properties also have their disadvantages. The problem really began with single-use plastics, one-time items made up of one of the most versatile and durable materials we know. This led to an enormous build-up of plastic waste all over the world. Between 1950 and 2015, 6.3 billion tonnes of plastic waste was generated, of which only 9% was recycled, the rest was either incinerated, buried in landfills or directly released into the environment.(Rhodes, 2018)

Plastic pollution comes in three difference sizes, known as macroplastics, microplastics and nanoplastics. Macroplastics are defined as having a size greater than 5mm. (LI et al., 2016) In addition to being an eyesore, they greatly affect our wildlife, which can get entangled in them or ingest them causing gut blockage or pseudo-satiation. (Miranda and Carvalho-Souza, 2016) The most detrimental macroplastics have been identified as ALDFG, meaning abandoned, lost or otherwise discarded fishing gear. This freely floating fishing gear leads to a phenomenon known as "ghost fishing", whereby they keep on catching a wide variety of wildlife. Although the actual amount of ALDFG is difficult to quantify, it has been estimated at 640'000 tons yearly, accounting for 10% of total marine debris. (Stelfox et al., 2016) These macroplastics can be degraded by UV light through a process called photodegradation, whereby the UV light from the sun causes oxidation of the polymer, leading to bond cleavage and therefore smaller plastic particles being formed, which then become microplastics.(Auta et al., 2017)

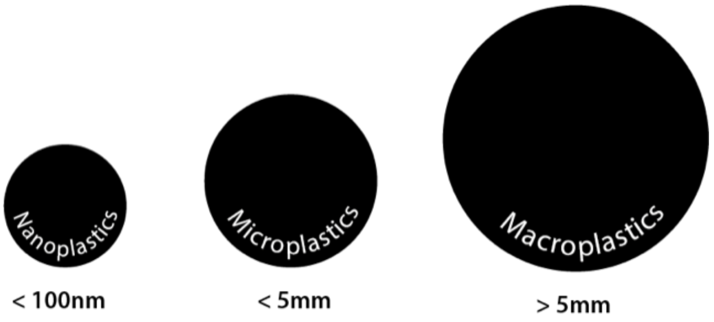

*Figure 1 : Different sizes of plastic pollution*

Microplastics have been found to be ubiquitous in all sorts of water systems be it rivers, lakes or oceans all around the globe.(Galvão *et al.*, 2020 ) They pose a growing threat to our ecosystems, their constant rise in number due to our ever growing plastic consumption and the fact that they cannot easily be removed has caught the attention of scientists all over the world. Microplastics are very small pieces of plastic, under 5mm, either originally this small (primary microplastics) or derived from bigger pieces of plastic (secondary microplastics).(Rhodes, 2018) Their small size makes it easy for the aquatic biota to mistake them for food, which can directly cause them harm or accumulate in the food chain, leading to a potential hazard to human health. Generally, the smaller the particle, the further it can get into the organism. Nanoplastics are considered hazardous because their tiny size (<100 nm) allows them to cross biological membranes, disrupting the functioning of blood cells and photosynthesis.(Carbery et al., 2018)

Moreover it has been found that toxic substances such as POPs ( persistent organic pollutants) are absorbed onto microplastics, which then "hitchhike" their way into the aquatic biota's digestive systems.(Bakir et al., 2014)

Although there are many sea water studies, this is not the case for freshwater systems, where studies are scarce. The principal objective of this thesis is to measure microplastic pollution of the Danube around Budapest. By measuring the extent of microplastic pollution upstream and downstream from the city, we shall also be able to estimate the possible effect of Budapest upon the river itself.

# 3 LITTERATURE REVIEW

## 3.1 Recycling and it's limitations

The low cost, convenience and durability of plastic materials explains why they are used so widely in our society. But the end-of-life of these materials are not so well managed and there is a lot of spill over into our environment. Plastic recycling is an economically marginal activity with recycling rates at about 14-18% at the world's level. What is left of the plastic waste is either incinerated (24%), disposed of in landfills or the natural environment (58-62%).(Mastellone, 2020)

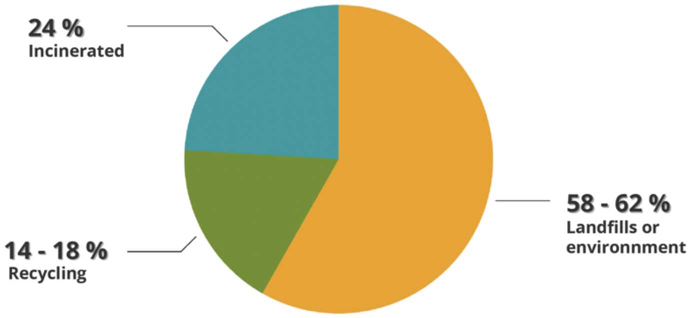

*Figure 2 : Different pathways for plastic waste*

Plastics are coded into 7 different families with symbols that can usually be found on packaging and bottles. Namely :

1) PET - Polyethylene terephthalate – is the most widely recycled type of plastic. It is what carbonated drink bottles are made of.

2) HDPE - High density polyethylene. Is one of the easiest plastic polymers to recycle, found in milk jugs or detergent bottles.

3) PVC - Polyvinyl chloride - is not recycled. Found in plumbing pipes, shower curtains as well as frames for windows and doors.

4) LDPE - Low density polyethylene, is found in garden furniture and floor tiles. It can be recycled.

5) PP - Polypropylene - is unfortunately not recycled, since recycling would be difficult and expensive. It is found in bottle caps, straws, yoghurt containers, plastic tables and chairs as well as car bumpers.

6) PS – Polystyrene - is unfortunately never recycled. It is found in take away food packaging, plastic table-wear, disposable cups and cutlery. Oddly enough polystyrene is mostly found in one-time use items.

7) Others, never recycled either.(Rhodes, 2018)

There are three different types of recycling: mechanical, chemical and thermal.

Mechanical recycling is the most common one. It is the process whereby plastics are grounded down to pieces of suitable sizes to be reprocessed. In chemical recycling, polymers are broken down into smaller molecules, then used to produce the monomers for new polymers or other petroleum products like waxes and paraffin. Thermal recycling both reduces the volume of the waste and serves as energy recovery in the form of heat. Thermal recycling can be further divided further into 3 types:

1. Pyrolysis (in the absence of oxygen)

2. Hydrogenation (high hydrogen or carbon monoxide environment)

3. Gasification (partial combustion with limited air supply)

Plastics can further be divided into thermoplastics and thermosets. Thermoplastics can be re-melted and thus - recycled , whilst thermosets cannot. PET, HDPE, PVC, LDPE, PP and PS are all thermoplastics. Examples of thermosets are epoxy resins such as those found in electrical insulation, melamide-formaldehyde resins that are heat-resistant surfaces found for example in kitchen worktops; and phenolics that are also heat-resistant and can be found in handles for pans, irons and toasters.(Goodship, 2007)

There are numerous additives in plastics such as calcium carbonate, which is a "filler", (it has a much lower cost than plastic polymers); pigments; glass fibers, to add stiffness and strenght; flame retardants, to add fire resistance; heat stabilisers; light stabilisers; plasticisers, which reduce viscosity; and foaming agents, to add lightness and stiffness.(Sendra *et al.*, 2021) Considering all of these, the possibilities of different combinations and percentages are enormous. This is the reason why recycling is not that easy. Combining different polymers that all have different melting points, all with additives giving them considerably different properties, creates a very non homogenous product that might have a lot of different properties scattered throughout it's volume and thus, is not suitable to be re-utilised. Because of this, sorting different types of plastics from each other is a crucial step in the recycling process. Sorting thermoplastics from thermosets is very important for obvious reasons because of the fact that thermosets cannot be melted. But in addition, different families of plastics like PET and PVC also have to be separated from each other because otherwise the end product would be of poor quality.(Goodship, 2007)

So the difficulty of the process, associated with the low economical attractivity of recycling, leads our society to have most of our waste discarded in landfills and the natural environment, or sent to other countries for processing. A lot of waste used to be sent to China for processing, but China banned 40 varieties of waste, including some plastics, in 2018 and another 16 items in 2019. Since many countries were accustomed to export their waste, they failed to develop their own treatment plants,which became highly inefficient, leading to an increase in untreated waste. This situation has, in turn, also raised the cost of recycling to unsustainable values.(Mastellone, 2020)

## 3.2 Microplastics and their sources

### 3.2.1 Primary microplastics

Microplastics are defined as particles of plastic under 5mm. However, 72% of microplastics in the environment are actually between 0,33 and 1 mm.(Wu *et al.*, 2019)

They can be either primary, secondary or tertiary (pellets used to make plastic goods).

Primary microplastics are originally manufactured to be this small, especially for their abrasive qualities.(Carbery et al., 2018) They can also be classified according to their shapes, namely : microbeads, which are mostly found in personal care products, nurdles, which are the pre-production pellets that will be used to manufacture various plastic objects, fibers, which come mainly from our synthetic clothing and are the most encountered shape of microplastic, foam, which comes from take-away food containers and drink cups and are non recyclable being made out of polystyrene and finally, fragments, which are secondary microplastics, derived from larger pieces by degradation and time.(Wu *et al.*, 2019)

Concerning microbeads,in our daily life, we encounter them in facial or body scrub cosmetics. These little microbeads are made of mainly polyethylene and they have been identified as an important source of microplastic pollution. Once used, they travel in the wastewater system and are most likely to escape the filtering system due to their very small size.(Fendall, Sewell, 2009) They can also be found in toothpaste, eyeshadows and other makeup products, deodorants, shaving cream, hair products, nail polish, synthetic clothing, insect repellent and even sunscreen, which directly escapes into the water when going for a swim after applying some. The average face scrub contains approximately 350'000 plastic microbeads.(Smulligan-Maldanis, 2014) Statistics have shown that in the US, 8 trillion plastic microbeads are reaching aquatic habitats per day.(Wu *et al.*, 2019) Representatives of plastic organisations from all over the world have announced a "Declaration for solutions on marine litter" during the 5th international marine debris conference in Honolulu in 2011. In 2015, 60 world plastic organisation signed the document, including international companies like Palmolive, Colgate, L'Oréal, Oral B, Procter and Gamble etc announcing they would stop using plastic microbeads in their products. In the US, Illinois was the first state to entirely ban the manufacture and sale of products containing plastic microbeads in 2014, effective since 2018-19, in reaction to the results of a research about microplastics in the Great Lakes. General public awareness is also extremely important as people can choose not to purchase and use products containing those microbeads once they know about the issue and if the information is out there and available.(Bhattacharya, 2016)

Another source of daily activity causing us to contribute to primary microplastic release in the environment is laundry. The washing of synthetic clothes made of polyester, acrylic and polyamide degrades them, creating microfibers that have been found to be an important source of microplastic in wastewater. A study, the first of its kind, has assessed the amount of microplastic fibers coming from the common laundry of a family of 4 people over a period of 2 months. Results have found that for an average washing load of 6kg of laundry, about 18'000'000 synthetic microfibers were released, out of which only 7% were larger than 500 micrometers (0,5mm), 40% were between 100 and 500 micrometers and 53% between 50 and 100 micrometers. The smaller the size, the less likely these fibers are to be efficiently filtered out of the water by the wastewater filtering systems.(Galvão *et al.*, 2020) Studies about the fate of microplastics in the wastewater treatment plants have revealed that the grease removal stage and sludge settling can trap microplastics into the sludge quite efficiently. However the extreme large amount of water treated everyday correlated with the microplastics that still manage to escape, renders wastewater treatment plants to still be a big source of microplastic in the environment. It was also found that microplastics can be resuspended and become airborne or pollute the terrestrial environment, during the treatment and disposal of the sludge itself.(Wu *et al.*, 2019) Primary microplastics are also used in air blasting technology. Small pieces of acrylic, melamine or polyester are blasted at machinery and boat hulls to remove paint and rust. Via this process these microplastics become contaminated with heavy metals. (Auta et al., 2017) Those heavy metals are also a huge problem for our aquatic ecosystems and human health due to their chronic toxicity and bioaccumulation. Heavy metals are elements that possess a large density and a high atomic mass. For exemple, Mercury (Hg), Cadmium (Cd) and lead (Pb) are toxic at minimal levels. These heavy metals can come either from natural sources such as volcanic eruptions and forest fires but they can also come from anthropogenic sources like mining, pesticides, fertilzers, herbicides as well as industrial and sewage water, inappropriate waste management and traffic pollution. They can enter the bodies of fisht hrough 3 routes, the gills, the body surface and the digestive tract where microplastics have been found to play a catalystic role. The effects on the fish themselves are mostly related to growth inhibition, in a world where population keeps on growing and the number of fish keeps on decreasing this becomes problematic. They are also known to bioaccumulate via the foodchain and on humans they have been linked to a series of negative health effects and diseases such as degenerative neurological processes leading to Alzheimer's and Parkinson's but also to muscle dystrophy, multiple sclerosis and depression to only cite a few.(Zaynab *et al.*, 2021)

### *3.2.2 Secondary microplastics*

Secondary microplastics are derived from macroplastic pieces. Over time, these larger plastic debris are exposed to a variety of physical, chemical and biological processes which leads to fragmentation. The UV radiation from the sun causes photodegradation which cleaves the matrix bonds, making plastic brittle. This phenomenon, associated with other environmental factors such as temperature and wind, waves or rain, releases microplastics into the environment. Both primary and secondary microplastics exist in the environment in high concentrations.(Smulligan-Maldanis, 2014) In the soil, it was found that low density polyethylene would take more than a 100 years to be mineralised. An interesting study was conducted in sea situation where plastic bags were immerged in real life conditions and assessed after 40 weeks. These plastic bags had only lost 2 % of their surface area in that time. It is also interesting to note that after a period of only 4 weeks, biofilms could be identified on all of the sample's surfaces together with macro-fouling organisms such as *Mytilus edulis* after 8 weeks. This process renders the plastic bags to be falsely identified as nutritious sources of food by the aquatic biota.(O'Brine and Thompson, 2010). So secondary microplastics take a substantial amount of time to be released into the environment but they are a constant and never ending source of the issue.

Another problematic source of secondary microplastic into the environment is the use of plastic mulch films in agriculture. These films are mostly made of polyethylene and they are used to help control weeds, keep the soil's moisture, which is particularly important in dry areas, as well as providing an ideal temperature and microclimate to promote growth for various vegetables. Although they have several really positive features, they have to be removed and changed after each harvest and they are known to become brittle and to fragment into microplastics. These will be left in the fields and damage the quality of the soil, particularly in China, where these plastic mulches are extremely thin, <10 micrometer and thus, very difficult to remove from the fields.(Flury and Narayan, 2021)

## 3.3 Fate of microplastics once in the environment

One of the biggest concerns about microplastics is the fact that their sizes are very similar to those of aquatic biota's food and thus they are very commonly ingested.(Waring et al., 2018) A wide range of organisms has been reported to ingest microplastics, from all trophic levels, namely, zooplankton, copepods, bivalves, mussels, shrimps, fishes, seabirds and whales.(Auta et al., 2017)

Several properties of microplastics come into the equation when they come to being ingested. Their size affects which species is more likely to ingest them but also their densities, determining whether they sink or float. Organisms feeding on surface waters will most likely ingest PS , PE and PP because having a specific density lower than that of water, they float. In contrast with more dense plastics that tend to sink and are mostly found in sediment, such as PET and PVC which are more likely to be ingested by benthic organisms. Another aspect that has recently been revealed to play a role in the ingestion of microplastic particles through chemoreceptive cues is biofouling. It has been found that a biofilm is created after a certain amount of time, on the surface of microplastics. When they breakdown, these biofilms produce a specific dimethyl sulfide odour that makes them smell like food and thus attracts organisms, fooling them into thinking that microplastics are in fact nutritious.(Carbery et al., 2018)

Once ingested these microplastic particles have been found to cause pathological stress, inflammation, increased immune activity, false satiation and reduced feeding activity, leading to poor development and reduced growth rate, reproductive complications, blocked enzyme production and oxidative stress.(Auta et al., 2017; Carbery et al., 2018) In a study involving *Mytilus edulis*, microplastics were found to start an inflammatory response at the tissue level and to disrupt the membrane stability of the digestive system. Particles were also translocated into the circulatory system where they were found to persist for as long as 48 days. In another study freshwater daphnia were fed microplastics which were shown to have translocated into cells and oil storage droplets (intracellular lipid storage). Japanese Medaka fish, fed Polyethylene, have exhibited bioaccumulation and liver stress response, such as glycogen depletion, fatty vacuolation and single cell necrosis. Another notable change in response to being fed microplastics was the appearance of early tumour formation.(Eerkes-Medrano et al., 2015)

Moreover, microplastics can also transfer between habitats. Their transfer from marine to terrestrial habitat has been documented in a field study where sea lions consumed fish contaminated with microplastics, which were later found in the scats of these sea lions, deposited on land.(Eerkes-Medrano et al., 2015) Seabirds are also widely affected by plastic pollution and seagulls living around the North Sea were estimated to have, on average, 30 pieces of plastic in their stomachs (macroplastic pieces). This has been linked to several reasons, the first being that they mistake floating debris for prey, secondly that they feed them to their nestlings and thirdly that they ingest prey that already contain microplastics in their own digestive systems, passing them to the next trophic level. Nowadays plastic debris are found in 90% of seabird's corpses, and is estimated to reach 99% by 2050. Furthermore, once these seabirds have died and their bodies have decayed, what remains is the much more long lived plastic pieces they have ingested during their lifetime. These plastics manage to outlive the birds as well as being transferred from sea to land, once again. A field study has also revealed a much less documented phenomenon, the passing of microplastics through a terrestrial food chain, from soil, to earthworms, to chickens and then, ultimately, to humans.(Rhodes, 2018)

These tiny particles also travel over long distances, in a study it was found that the sinking rate of marine particles vary between 10 and 150 m a day, meaning that it would take particles one month up to a year to reach the sea floor. The standard horizontal current being of 1m per second and a few centimeter per second from 1000m deep, thus sinking particles may travel from 1 kilometer if having a fast sinking rate and up to 35 kilometers if having a slow sinking rate. But this is only taking into account the particles that are sinking, not the floating ones, which can travel over much greater distances.(McDonnell *et al.*, 2015)

In addition, microplastics can also serve as floating substrates that organisms can use as so called rafts, managing to travel over long distances and presenting a threat to local biodiversity through the transport of alien species.(Avio et al., 2015) Invasive alien species (IAS) are described as any live specimen, plants, fungi or micro-organism who is found outside it's natural/original habitat and has negative impacts on the invaded ecosystem. They induce changes in the local community structure and balance, which, in turn, leads to a decline in endemic species and irreversible changes to the habitat. They tend to be resistant organisms and overtake while some other species are threatened to go extinct because of their presence.(Magliozzi *et al.*, 2020)

Another problematic feature related to microplastic pollution is the coral reef decline worldwide. The process called bleaching, has been attributed to a few different culprits, mostly the rise in ocean's temperature, in other words, global warming, but also to solar irradiance and diseases. Recently, microplastics too have been added to the list of culprits. The mechanism of bleaching can be described as a variety of processes whereby the coral undergoes the degeneration of zooxanthellae which, in fine, becomes detached from the coral. So to put it simply, it is the whitening of corals due to the loss of their symbiotic algae and/or pigments. An interesting study looked into the interactions between microplastics and corals. 6 small-polyp corals from the genera *Acropora*, *pocillopora* and *porites* were exposed to polyethylene particles (37-163 micrometers) at a concentration of around 4'000 particles per litre over a 4 week period. Feeding interactions such as ingestion and egestion were observed in all the species. More importantly, bleaching and tissue necrosis were found in 5 of the 6 specimens.(Rhodes, 2018)

Another study also confirmed the role that microplastics play in coral bleaching. Under laboratory conditions, the impact of LDPE pieces < 100 micrometers on the corals *acropora formosa* was investigated. The LDPE was ingested by the corals and only partially egested, plus it caused bleaching and necrosis. The worst sample showed bleaching on day 2 of the experiment and a 93,6% degree of bleaching by day 14. Microplastics play either a direct or indirect role in coral bleaching either by being ingested or by covering the surface of the coral thus interacting with the photosynthesis process.(Syakti *et al.*, 2019)

It has been proven that microplastics have a plethora of negative effects on coral health, among them, reduced growth rate, a decrease in the production of detoxifying and immunity enzymes, high mucus production, disruption of the coral's symbiosis relationships, tissue necrosis, low fertilization success, energy loss through taking in non nutritious elements that still require energy usage to be processed and egested, decreased skeletal growth, impaired food intake and photosynthesis and bleaching as well as increased exposure to toxic metabolites that might be sorbed onto microplastics. The indirect impact of microplastics attaching to the surface of corals has an important impact, indeed it was found that adhesion of microplastics is 40 times higher than their ingestion in corals, making corals sinks of microplastics in oceans probably due to their shapes and rugose quality. It's been found that >95% of corals in Maldivian reefs were contaminated with microplastics. The bleaching process is further exacerbated by the fact that microplastics have been identified as sources of bacteria that cannot survive free-floating in the water, such as *Vibrionaceae, Rhodobacteraceae* and *Flavobacteriaceae* which have been proven to induce bleaching in corals.(Soares *et al.*, 2020) . Since our coral reef health is in peril, further studies are needed to determine how much of a role microplastics have to play in this disastrous phenomenon.

## 3.4 POPs and other toxic metabolites

Even though plastic itself is considered biochemically inert, it has been proved to act as a vector for a cocktail of toxic contaminants. Some of these chemicals can either be additives, mixed with the plastic during manufacture, such as plasticizers like phtalates, flame retardants like polybrominated biphenyls (BPBs), stabilizers, antioxidants, antimicrobials and much more; or toxic contaminants can be absorbed into the microplastics from water.(Thompson *et al.*, 2009) The fact that organic xenobiotics are hydrophobic gives them an increased affinity to microplastics compared to the water. In addition, their high surface-to-volume ratio because of their tiny size combined with their non-polar surface facilitates the process and gives them the ability to attract and concentrate these contaminants up to 6 orders of magnitude greater than the surrounding water.(Carbery et al., 2018) They readily absorb contaminants such as POPS (persistent organic pollutants), heavy metals, organochlorine pesticides like DDT (dichloro-diphenyl trichloroethane), PAHs (polycyclic aromatic hydrocarbons), PCBs (polychlorinated biphenyls).(Auta et al., 2017) Such substances are known to be endocrine disruptors, mutagens and carcinogens. POPS have similar characteristics to microplastics which makes them problematic concerning the health of our ecosystems. They are chemicals that bioaccumulate readily, they are non degradable, they can travel over very long distances and they are toxic to a wide range of organisms including humans. As initially listed in the Stockholm Convention of the United Nations Environment Program (UNEP 2017), 12 chemicals were identified as the “dirty dozen”. Namely : Aldrin, Chlordane, Dichlorodiphenyltrichloroethane (DDT), dieldrin, endrin, heptachlor, mirex, toxaphene, hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs). In the following years more chemicals were added to that list.(Girones *et al.*, 2021) Their bioaccumulation into the food chain is of great concern and has been identified many times. Microplastics serve as vectors for these contaminants, which are released into the body of the organism that has ingested them under acidic stomach conditions. Contaminants thus enter the living organisms further and bioaccumulate in their tissues, making them even more of a threat to our ecosystem’s health. Furthermore, older plastic pellets have been found to exhibit higher concentrations of these toxic contaminants, suggesting that the time the plastic has spent in the environment prior to being ingested may play a role in how toxic it might be to the organism in question.(Carbery et al., 2018) That is the reason why it is thought that microplastics are more susceptible to become highly contaminated in estuaries, where the concentration of both toxic contaminants and microplastics themselves is higher, and residence time is longer.(Eerkes-Medrano et al., 2015)

A study involving marine mussels *Mytilus galloprovincialis*, proved the bioaccumulation of pyrene through the ingestion of contaminated microplastics. In the digestive glands, the concentration of pyrene was up to 3 times higher than in the original contaminated polymers, clearly demonstrating the bioaccumulation of this chemical in the tissues of the mussels and proving that via microplastic transport, toxic metabolites can enter organisms and accumulate in them. At the cellular level, alterations of immunological responses, neurotoxic effects, onset of genotoxicity and changes in gene expression were observed.(Avio et al., 2015) Another study has showed that microplastics readily absorb and accumulate metals from the surrounding water column.(Ashton et al., 2010) In the USA, a study has revealed that 95 % of adults had some BPA (bisphenol A) in their urine. BPA and phtalates, commonly found in plastics, are known endocrine disruptors, they have been correlated with lower fertility and disrupted sexual maturation. This is a vicious cycle because this BPA, once in the environment does not disappear but only circulates. If firstly added to some plastic, it then ends up in the water that humans either drink directly,or is absorbed by other animals. For example, fish could consume the plastic particles and when humans eat them, or drink contaminated water, it goes into their systems and also out through their urine and again into the sewage water systems. In another study, prenatal sheep were exposed to BPA, resulting in lower birth weight. In different fish species it leads to inhibition of egg hatching, as well as a decrease in body weight, tail and body length. To underline the known adverse effects of BPA, in 2018 the European Union has banned their use in items such as baby bottles and packaging of food of small children. It also has put in place a regulation for the limit of BPA in food packaging. As for phtalates, their use in children's toys has been restricted since 1999 in the European union, similar laws came in place in the USA in 2009.(Rhodes, 2018)

## 3.5 Human health

With all of these scientific research in mind, comes the question of human health. It is certain that further studies are required in this field but new research is constantly revealing some evidence on how microplastics might cause harm to the human species. Microplastics are recognised as a hazard, which by definition, according to the International Union of Pure and Applied Chemistry, is a set of inherent properties of a substance that upon production, usage or disposal enable it to cause adverse effects to organisms or the environment, depending on the degree of exposure. Exposure would be the concentration, duration and frequency of encountering those microplastics.(GESAMP report 2015)

It is thought that the exposure to microplastics can occur in 3 ways; ingestion, being the most important one, inhalation and dermal contact (although the latter has mostly been speculated about and requires further scientific investigations).(Prata et al., 2020)

Concerning the inhalation of microplastic particles, it is supported by the fact that microplastics have been found in mountain soils of Switzerland, far away from any form of industrialization, they have been identified to be airborne contaminants brought by wind. Some particles were also identified in human lung tissue.(Rhodes, 2018) Microplastics are released in the air by numerous sources but mostly by the abrasion of car tires, buildings, synthetic textiles and resuspension from dust deposits. One of the first microplastic air concentration study was done by Dris et al.2017, where they sampled and compared indoors and outdoors environments. The indoors results ranged between 1-60 fibers per m3, while outdoors was substantially lower ranging between 0,3 and 1,5 fibers per m3. The deposition rate of indoor fibers was numbered between 1586 and 11'130 fibers per m2 per day, leading to fiber accumulation in dust (190-670 fibers per mg). 33% of those fibers revealed to be mostly PP. Further studies need to be done as it is still unsure whether or not these fibers could be inhaled or mainly ingested through settled dust by hand to mouth contact, especially by young children. In all organisms microplastics are thought to produce particle toxicity, oxidative stress, chronic inflammation due to the inability of the immune system to get rid of these foreign particles, followed by an increased risk of neoplasia due to this chronic state of inflammation. Microplastics might also produce an intense release of chemotactic factors, leading to chronic inflammation, also known as dust overload. (Prata et al., 2020)

It is difficult to assess the effects of microplastics directly on humans because of ethical constrains, furthermore there is a need for strict biosecurity measures when handling human samples so studies on the subject are scarce. There is more information concerning the ingestion of microplastics and their potential effects on human health. There are different ways to ingest microplastics. They have been found in tap or bottled water(Danopoulos et al., 2020), soft drinks(Shruti et al., 2020), sea salt(Iñiguez et al.,2017) but more importantly in seafood and fish, where they are thought to bioaccumulate together with the chemicals they might transport. Seafood and small fish that are being consumed without taking out the digestive tract present a much higher risk, as the concentration of microplastics in the digestive tract is much higher than anywhere else in the body. Despite the fact that seafood has been identified as a source of microplastic contamination to humans, it is not yet routinely quantified nor regulated.(Carbery et al., 2018) In an interesting study done by Iñiguez et al.2017, 21 samples of table salt from Spain were purchased in the supermarket and tested for microplastics. The results were of between 50-280 MPs per kg, with the predominant polymer being PET, followed by PP, then PE. When it comes to seafood, mussels have been identified as a good bioindicator of microplastic concentration in the surrounding water due to their filter feeding mechanism. As they are eaten whole, they also represent a potential risk of microplastic and associated chemical intake to humans.(Mercogliano *et al.*, 2020) In a study done in Hong Kong, where the seafood consumption per capita is up to 3 times higher than the worldwide average, the green lipped mussel, *Perna viridis*, was collected form 5 different mariculture sites and tested for microplastics by automated Raman mapping (laser scans providing chemical and spatial information). All sites were positive for microplastics, with an average of 1,60-14,7 particles per mussel. The plastics were identified as PP, PS and PET. Through this study, it was estimated that by consuming *Perna viridis*, the average Hong Kong population could ingest about 10'380 pieces of MPs per person per year.(Ming-Lok Leung et al., 2021)

A Chinese study analysed the microplastic content of human faeces in 24 young men in Beijing using FTIR (Fourier transform infrared micro-spectroscopy). 23 of the fecal samples tested positive. The concentration of microplastics varied between 1 to 36 particles per gram. A qualitative analysis showed between 1 and 8 different types of polymer per sample with PP being the most abundant one (found in 95,8% of the samples).(N.Zhang et al., 2021) This study definitely proves the fact that we humans do ingest microplastics on a daily basis but it does not yet prove that these particles are not just passing through our digestive systems.

Furthermore, several studies have shown that exposure to microplastics alters the composition of the gut microbiota. The gut microbiota is a very important kind of microorganisms in the intestinal tract of animals and humans. They have several important physiological and biochemical functions such as growth and development by promoting tissue differentiation, digestion and absorption of nutrients, they stimulate the immune system thereby protecting the host from pathogens. Humans have 10 to the 14th bacterial cells in their microbiota, which is 10 times the amount of human cells. 70% of the microbiota is found in the colon. It is known that the chemicals transported on the surface of microplastics such as POPs, heavy metals, pesticides and plasticizers can cause dysbiosis leading to physiological dysfunctions.(Lu et al., 2019)

Neurotoxicity is another potential effect of microplastics that has been found. Indeed, particulate matter in general causes neurotoxicity through oxidative stress, activation of microglial cells in the brain and through circulating pro-inflammatory cytokines due to chronic inflammation processes, thereby increasing the risk of dementia and Alzheimer's disease.(Prata et al., 2020)

All of these studies and the fact that chemicals such as DDT, BPA, POPs and heavy metals, which, as previously stated, are known endocrine disruptors and carcinogens, can sorb onto microplastics and bioaccumulate through trophic levels, justifies that microplastic contamination is considered a health hazard. It was found that microplastics can cause several detrimental effects on human health mainly through inflammatory processes, leading to cancer, infertility and even chromosome alteration, to only name a few.(Chowdhury et al., 2021) Further studies on determining the concentration limits and negative effects are needed.

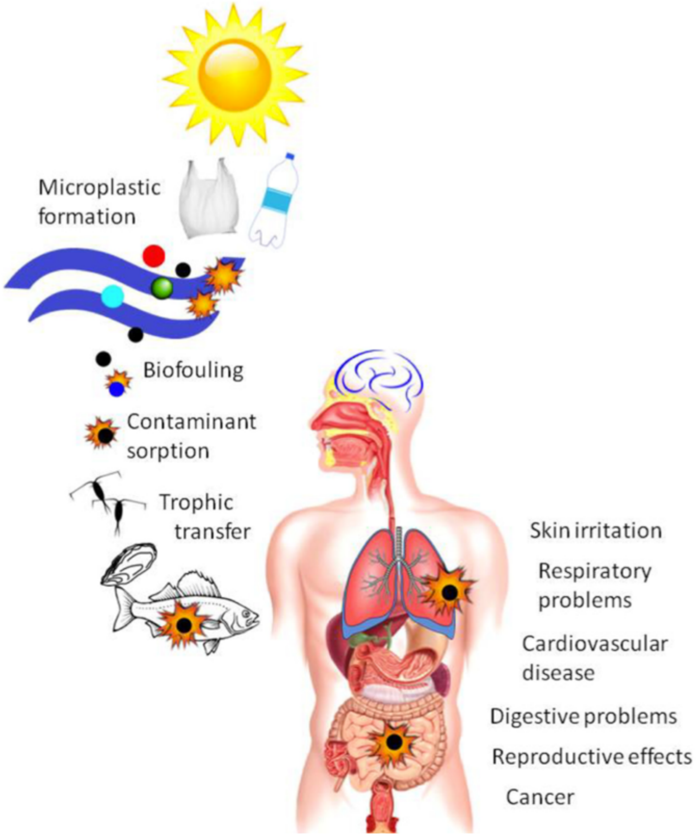

*Figure 3 : Bioaccumulation through trophic levels*

## 3.6 Freshwater systems, rivers and the Danube specifically

Although 88-95% of the plastic input into the oceans is via 10 major rivers, freshwater systems are still very poorly examined for microplastics.(Rhodes, 2018) In order to reduce the amount of plastic and microplastic entering the oceans, it is of utmost importance to determine where it comes from. Since rivers pass through centers of civilizations and industrialisation, it is suspected that they accumulate a great amount of plastic waste but also a great amount of toxic chemicals and contaminants, putting the ecosystems and river biota at great exposure risks.(Eerkes-Medrano et al., 2015) The concentration of microplastics in rivers is highly variable due to many factors such as, the human population density, the level of economic development of the area, the waste management system, as well as the weather and geography. Indeed it was observed that the concentration of microplastics in the Los Angeles river after a rainfall, was16 times higher than usual.(Wu *et al.*, 2019) In a study about mismanaged plastic waste (MPW), it was estimated that between 60 and 99 million metric tonnes of MPW were produced globally in 2015. Looking at a "business-as-usual" scenario, these numbers would triple to 155- 265 Mt a year by 2060. This projection was done without counting the exacerbating effects of the COVID-19 pandemic on the mismanaged plastic waste worldwide. They also demonstrated that 91% of this MPW was transported to oceans via rivers.(Lebreton and Andrady, 2019)

A study found that the sorption of DDT onto microplastics, an insecticide that is known to be an endocrine disruptor and carcinogen, is significantly higher in freshwater than in sea water.(Bakir et al., 2014) This is also an alarming point because humans depend on freshwater to drink. In a review of 12 studies on European drinking water, out of which 6 were tap water and 6 were bottled, all of them confirmed the presence of microplastic particles. The most prevalent polymer were PET and PP. The maximum amount reported for tap water was 628 microplastics per litre while it was as high as 4889 MPs per litre for bottled water. Extrapolating these findings, taking the maximum numbers found, this could mean that Europeans might consume as much as 458'000 microplastics from drinking tap water and 3'569'000 microplastics from drinking bottled water on a yearly basis.(Danopoulos et al.,2020)

But bottled water isn't the only beverage where microplastics were found, in fact a study looked into cold tea, energy drinks, soft drinks and beer and found that the microplastics found in these products mostly comes from the water components of them but also synthetic textiles and packaging fibers were identified. If we classify them in order of increasing concentration it looks like this : cold tea < energy drink < soft drink < beer.(Shruti et al., 2020)

Furthermore, it is feared by scientists that microplastics in urban rivers might serve as a downstream transport of unique bacterial assemblage, as they are known to be a good bacterial habitat and urban rivers are subject to sewage water input.(Lu et al., 2019)

The issue of landfill for plastic waste management should also be discussed here, as it presents a threat for groundwater contamination. Plastics degrade very slowly, it is estimated that it will take approximately 400 years for a plastic cup and 600 years for a fishing line to degrade. This is exacerbated by the fact that landfill environments are mostly anaerobic, thus not providing the sufficient amount of oxygen needed for thermooxidative degradation, rendering the process even slower. Whenever degradation does happen, waste generates secondary pollutants like volatile organic species (VOCs) such as benzene, toluene, xylene, trimethylbenzene isomers and ethylbenzene. These can be gaseous or discharge through leachate, which is the liquid emanating from landfills, both coming from liquid that was already present in the waste but also rain water, producing some kind of waste soup filled with toxic chemicals, contaminating the groundwater and flowing to the surrounding rivers. Furthermore landfilling takes up an enormous amount of land, which could otherwise be used in a productive manner such as for agriculture. (Rhodes, 2018)

In order to reduce the amount of plastic entering the ocean via rivers, it is crucial for us to understand where it comes from. The Danube specifically is a very interesting case, being Europe’s second largest river and the world’s most international river basin, featuring 19 countries, 800’000 km2 and approximately 81 million people. The Danube is also the main tributary to the Black Sea, with an input of 6444 m3 per second as mean flow. A survey was made over 2 years, from 2010 to 2012, about the Danube’s microplastic concentration. During both years of observation, it was found that during daytime, more plastic particles were floating around than fish larvae, with industrial raw materials accounting for 79% of the microplastics, which present a high availability of unsuitable and potentially harmful food items to the river’s biota. This 79 % is an enormous number and underlines the fact that further studies should be made to determine exactly where they come from and where the leakages are. The input of plastic litter delivered to the Black Sea by the Danube has been estimated in this study at 7,5 g per 1000m3 per second. This means a total entry of 48,2 g per second, 173,6 kg per hour, 4,2 t per day and a colossal 1533 t per year.(Lechner et al., 2014)

Leaky processing plants are a critical point of entry of microplastics into fresh water systems. Following this study of the Danube in 2010 and 2012, it was found that a substantial amount of plastics emerged from the plastic processing plant Borealis whose wastewater flows into the Schwechat river in Austria, which then joins the Danube. The problem however resides more in the political approach of the problem, as the threshold authorised by the Austrian government is generously high. Indeed, the upper limit authorised is set at 30 mg per litre, which means that the amount of plastics released depends on the flow rate of the sewer. Hypothetically speaking, taking the numbers of a heavy rainfall, the sewage flow rate would be of 100 L per second, meaning they could legally release 3 grams of microplastics per second, leading to 259,2 kg over a 24h period, which in turn leads to an enormous 94,5 t per year which approximately equals 2,7 million of 1,5L PET bottles, legally released into the river. However this is not only an Austrian issue, political awareness of the seriousness of plastic pollution is needed globally. Thankfully, since then, changes have been put in place to lower the quantities of released microplastics by Borealis.(Lechner and Ramler, 2015) There are so many plastic production sites and processing companies adjacent to rivers worldwide, thus the legal release of primary microplastics can be considered a global issue.

In a study done in 2021, the sedimentary microplastic concentration was looked at over a transect of the Danube, from Romania to the Black Sea. 38 samples were taken, all of them were found to be contaminated with microplastics. They were predominantly fibers, from this, it was concluded by the researchers that the microplastic pollution of the river mainly came from poorly treated wastewater or ineptly treated sewage sludge.(Pojar *et al.*, 2021)

Rivers are complicated sites to sample, as a lot of different factors come into the equation. Particle transport in rivers includes, the density of the particle itself, so whether it floats and adopts a pelagic route, versus if it sinks and adopts the benthic route, which is substantially slower. It also includes the river's flow velocity, which depends on the weather, seasonal variability and rainfalls (which might further contaminate the river by bringing pollutants from the land), the substrate type of the benthos and its topography, since heavy particles can accumulate at the bottom, as well as the water depth and the method of sampling.(Eerkes-Medrano et al., 2015)

### 3.7 Effect of COVID-19 pandemic on plastic pollution

Studies have predicted a twofold increase in plastic waste by 2030 and that by the year 2050, there will most likely be more microplastic than fish in our oceans.(Auta et al., 2017) However, with the COVID-19 pandemic, such predictions are very likely to be exacerbated.

Since December 2019, the SARS-coV-2, responsible for a respiratory syndrome otherwise known as COVID-19, has largely affected the world. The high contagiousness of the disease and it's spread via human contact and airborne droplets, has led to unprecedented measures worldwide such as the use of personal protective equipments (PPEs) (for the health workers in the front lines but also for the general population), social distancing, partial or total lockdown of cities/regions, closure of schools and universities, quarantine, reduced mobility and transport as well as reduced economic activities, as ways to flatten the epidemic curve. What started as a health crisis has also quickly become a social, economic and environmental threat.(Patricio Silva et al., 2021)

Despite the fact that the focus of people and governments should be on preserving health in this sanitary crisis, we should not forget about the long term impacts on our environment. The wide use of PPEs such as face masks and gloves, made of polymers such as polyethylene, PS, PP, polyester, which are derived from fossil-based material, generates enormous quantities of waste.(Rodriguez et al., 2021) To deal with the pandemic, the WHO has predicted a monthly demand of 89 million facial masks, 76 million gloves, 30 million gowns, 1,6 million goggles and 2,9 million hand sanitizer bottles, these being the numbers only for frontline workers.(Parashar and Hait, 2021) In China, the production of face masks increased to 116 million per day in February 2020, which is 12 times higher than usual. The global face mask market's value expanded from \$0,79 billion in 2019 to approximately \$166 billion in 2020, an increase by a factor of 210. An alarming study expressed that the inadequate management of only 1% of face masks globally could lead to 30'000-40'000 kg of mismanaged waste per day.(Chowdhury et al.,2021)

Even before the pandemic, waste management systems worldwide were unable to deal with all of the existing plastic waste, and now the surge in volume of waste from the pandemic threatens to overwhelm these systems some more. Moreover, plastic masks are made of a variety of different polymers mostly PP, polyethylene and PET. As previously stated, the recycling of such mixed polymers is extremely difficult, due to the different properties of such materials. This makes it almost impossible for waste management centers that are already overwhelmed by quantity to process these materials..(Mallick *et al.*, 2021)

Furthermore, fomites are recognised as a way of SARS-coV-2 transmission, leading to plastic products being often potentially contaminated and treated as hazardous waste, rendering it impossible to recycle them.(Klemes et al., 2020) Indeed, most recycling centers have closed during the pandemic, because of an increased risk of Covid-19 spread, for exemple in the UK, Spain and Italy, recycling has completely stopped to avoid taking any risk regarding the spread of the virus.(Mallick *et al.*, 2021)

In addition to the use of PPEs, the world has taken a big step back concerning the use of plastic bags, which had been banned from several countries. They are now, once again, widely used across the world to avoid cross contamination in groceries stores. The e-commerce has exploded with this pandemic, we are now able to order anything from home, be it groceries, dinner, drinks, clothes, electronics, everything is available for delivery. But deliveries come with a large amount of packaging, most of it being plastic. The battle against the virus has overshadowed the fight against plastic and other environmental policies.(Gorrasi et al., 2021)

On the level of the individual, the use of PPEs, carrying small plastic bottles of hand sanitizer, online shopping, using non reusable plastic bags, single use disinfecting wipes, on a daily basis, will drastically increase plastic waste. On a larger scale, the cost of virgin plastic manufacture has fallen, due to the plummeting oil and petroleum prices, as a result of reduced transport activities during lockdowns. Plastic manufacturing industries had a choice between recycling or manufacturing new virgin plastic and in the chaos of the pandemic, and the latter was the most economically viable option. So we are facing both an increase in manufacturing of new plastic items together with a decrease of plastic recycling. For example, the demand for recycled plastic in South-East Asian countries has declined by 30-40% since the fall in the oil prices were observed.(Parashar and Hait, 2021)

However, the pandemic has not only brought negative impacts on the environment. We could observe several positive effects such as a reduction in green house gases emissions and noise pollution (underwater too), the lockdowns led to a more quiet environment where nature and wildlife had more space to exist. But the impact of the plastic waste generated sadly overshadows those positives.(Mallick *et al.*, 2021)

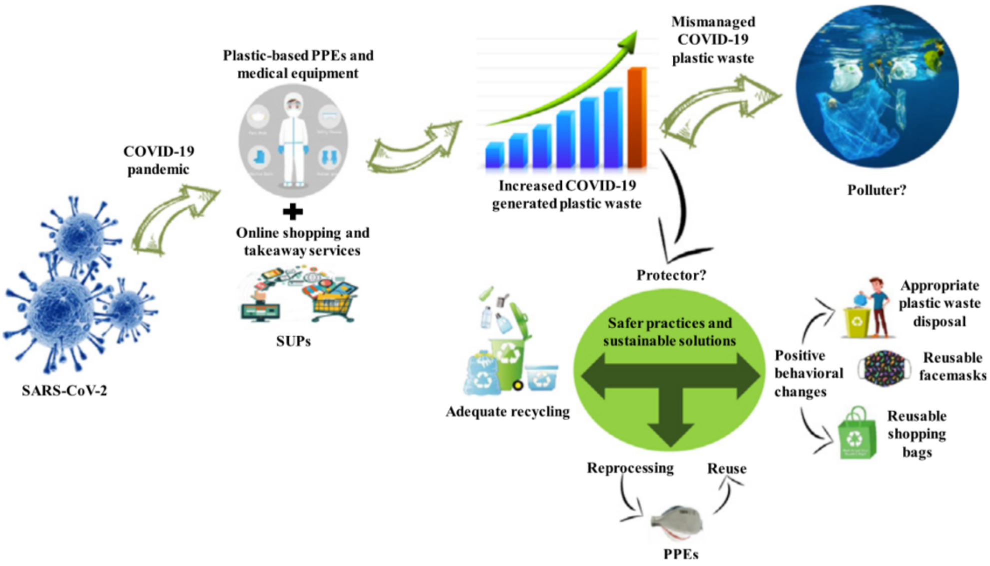

*Figure 4 : Effects of the Covid-19 pandemic*

# 4 AIM OF THE RESEARCH

I became aware of the problem of plastic pollution during an art gallery tour in Stockholm, where I saw the beautiful work of Mandy Barker, a brilliant British photographer who works hand in hand with scientists to stimulate an emotional response on the viewers and create awareness on the issue. It worked like a charm on me.

*Figure 5 : Refused by Mandy Barker*

This piece called "Refused" is from her series SOUP. It features marine plastic debris affected by the chewing and attempted ingestion by animals. SOUP stands for plastic debris suspended in the sea, especially refering to the Garbage Patch in the North Pacific Ocean. All the plastics she photographed in this series have been found on beaches across the. world during her travels.

There is a very low amount of data on the microplastic concentration of the Danube river. One of the most critical points to reduce our plastic waste is to understand where it comes from, data collection and knowledge of our freshwater systems is a key point in the process. In general, there is a positive correlation between the population density and the microplastic pollution of a site.(Wu *et al.*, 2019) That is the reason I found it interesting to have a look at the difference of microplastic concentration before and after the Danube passed through the city of Budapest. I am hoping that this study will provide useful information on the general state of the river, but also on whether or not the city of Budapest, which the Danube passes through, has a direct impact on the microplastic concentration of the river, and if so, to what extent.

# 5 METHODOLOGY

## 5.1 Sampling

First of all, two sampling sites were selected. One of them, about 22 km upstream (to the North) from Budapest : Dunakeszi-Horàny Ferry, coordinates corresponding to 47°39’30’’ N 19°07’09’’E.

The second sampling site is about 9 km downstream from Budapest (to the South), Dunafok Szabadidöpark, coordinates corresponding to 47°25’49’’ N 19°02’38’’ E.

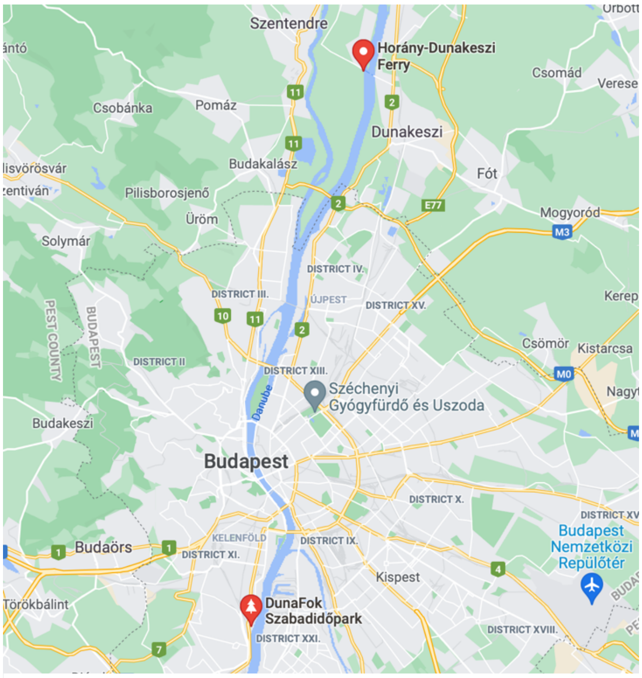

*Figure 6 : Sampling sites*

Microplastics are defined as plastic pieces under 5mm, but the size range remains very wide. We decided on targeting a smaller size range, between 60 and 190 micrometer, which is very likely to be ingested by aquatic organisms. A series of sample was taken on the 20th of November 2020 at both sites, then another series was sampled on the 3rd of February 2021.

15 m3 of Danube river water were filtered through a net, mesh sized 60 micrometers by horizontally circulating the net 40cm below the surface of the water. Then the sample was filtered through a 190 micrometer meshed sized plankton net by washing the first net with 10L distilled water. The filtered particles between 60 and 190 micrometers were again washed with 100ml distilled water making for the final volume of the sample. The samples were kept frozen until analysed.

*Figure 7 : Plankton net*

## 5.2 Microscopic analysis

Several methods are available to investigate microplastics in water bodies. We decided on using Nile red staining, which is specific to staining plastic particles. First, 10mg Nile red was dissolved in 10ml bidistilled water (double distilled water, having great purity and low conductivity, PH 7,1). After that 0,1ml of Danube river sample was mixed with 0,1ml of Nile red solution. Then, 1-2 droplets of the mixture was put under the cover slip of a bürker chamber of 25 times 200 micrometer squares and red colour stained particles were counted under an Olympus UV microscope with 130-160 x magnification. Then the average positive stained particles were calculated for 1 cubic meter of Danube river.

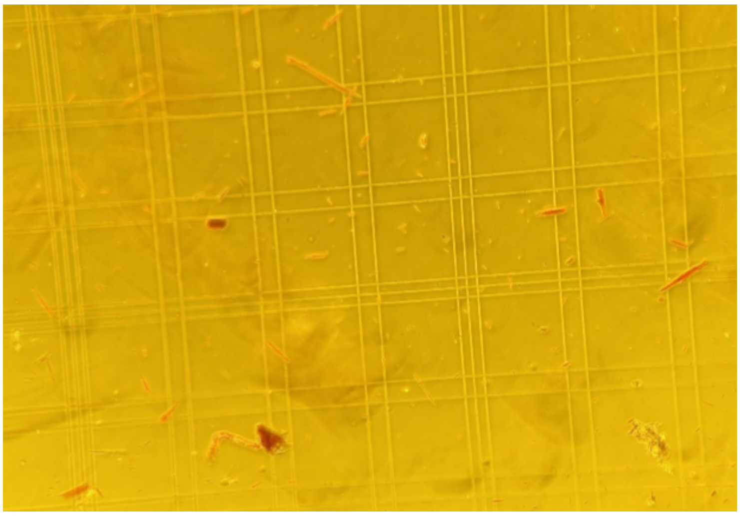

*Figure 8 : Microplastic particles stained in red under 130x magnification*

The results that we found were: From sample number 1, at Dunakeszi-Horàny Ferry on the 20th of November 2020, 38 particles per cubic meter were counted. From sample number 2, at Dunafok Szabadidöpark on the 20th of November 2020, 44 particles per cubic meter were counted. From sample number 3, at Dunakeszi-Horàny Ferry on the 3rd of February 2021, 27 particles per cubic meter were counted. From sample number 4, at Dunafok Szabadidöpark on the 3rd of February 2021, 37 particles per cubic meter were counted.

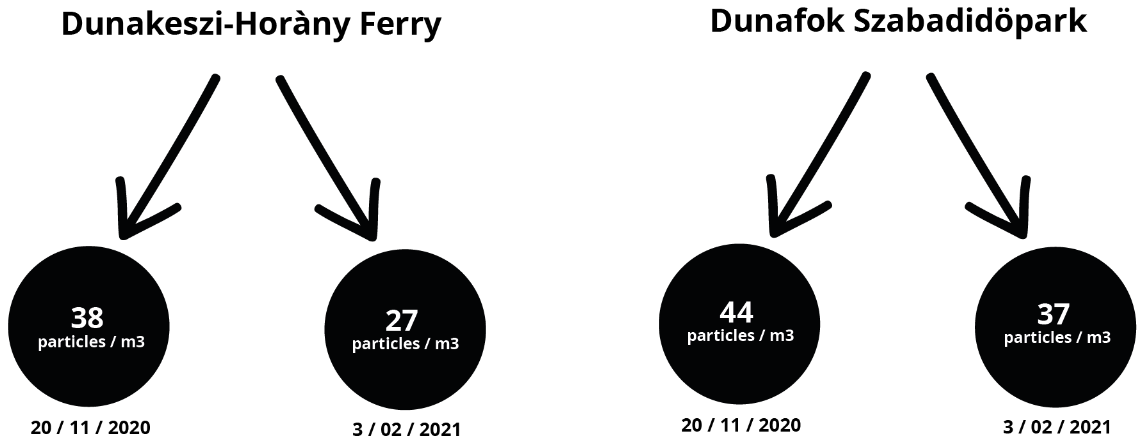

*Figure 9 : Results*

# 6 RESULTS

From the collected data of our samples, we can see that highest concentration of microplastic was found in sample number 2, at Dunafok Szabadidöpark on the 20th of November 2020 with a result of 44 particles per cubic meter. This sampling site is downstream from the city of Budapest and it can be compared with the result found at the upstream sampling site, at Dunakeszi-Horàny Ferry on the same date which was of 38 particles per cubic meter. Hence we can observe a 15,8 % increase in microplastic concentration through the city of Budapest.

Now looking at our second series of samples from the 3rd of February 2021, a concentration of 27 particles per cubic meters were found at the upstream sampling site of Dunakeszi-Horàny Ferry, which is the lowest concentration of microplastic we found in our samples. We can compare this result to the downstream sampling site of Dunafok Szabadidöpark which is of 37 particles per cubic meter. This time the increase is of 37% which is higher than the first series of samples.

So we observed a 15,8 % increase in microplastic concentration through the city of Budapest in November 2020 and a 37% increase in February 2021.

Furthermore we can compare the numbers from November 2020 with the ones from February 2021. If we compare the numbers from the upstream sampling site of Dunakeszi-Horàny Ferry from November 2020 that were of 38 particles per cubic meter to the sample from February 2021 where the result was of 27 particles per cubic meter, we can see a 28,9% decrease in microplastic concentration in a time lapse of 76 days. If we compare the results of the downstream sampling site of Dunafok Szabadidöpark within the same time lapse, with a first result from November 2020 of 44 particles per cubic meter and a second result of 37 particles per cubic meter in February 2021, we can observe a 16% decrease in microplastic concentration in the river. So we see that the concentration of microplastic in the upstream sampling site of Dunakeszi-Horàny Ferry decreased of 28,9% and that in the downstream sampling site of Dunafok Szabadidöpark it decreased of 16% in a 76 days time frame.

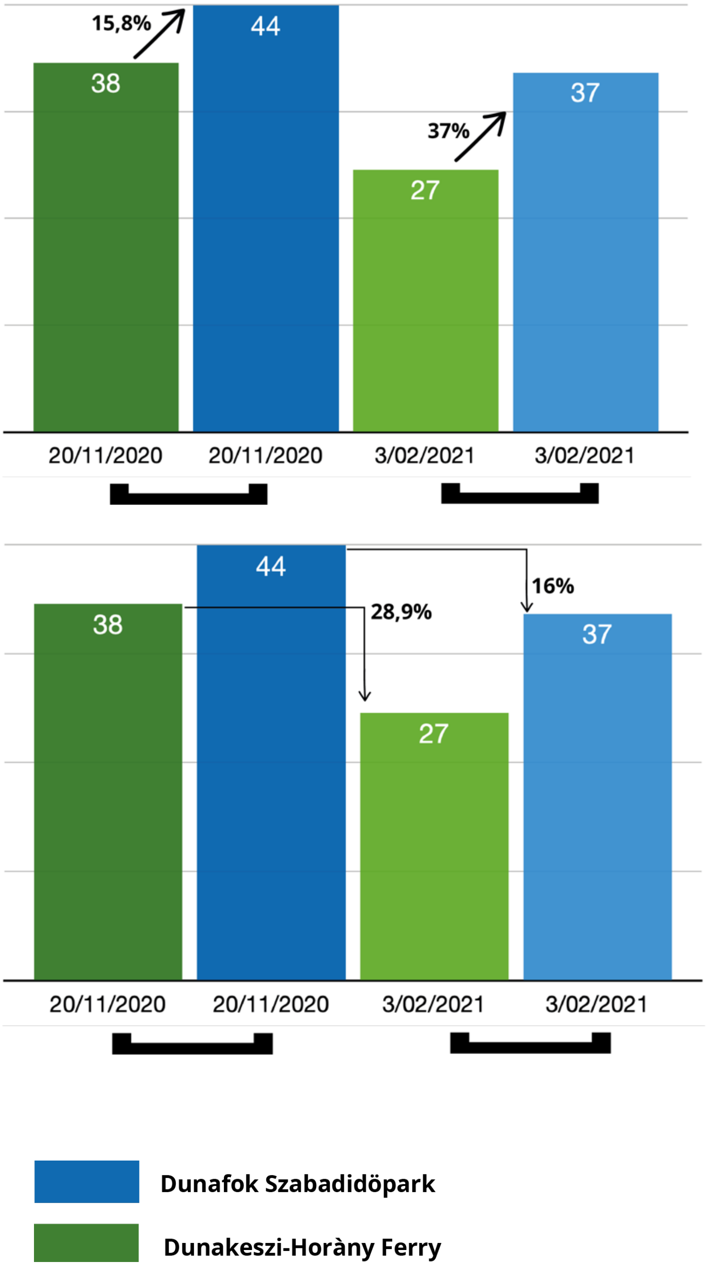

*Figure 10 : Data analysis*

# 7 DISCUSSION

From the numbers we analysed, we can observe that indeed, the city of Budapest does appear to influence and increase the concentration of microplastics found in the Danube river.

The numbers found at the downstream site of Dunafok Szabadidöpark were higher than the upstream numbers of Dunakeszi-Horàny Ferry both times. In November 2020, the increase in microplastic concentration induced by the passing through the city of Budapest was of 15,8% and in February 2021 it was of 37%.

It is interesting to note that the increase is higher in February 2021, thereby meaning that the city of Budapest had a greater influence on the microplastic concentration in the river, however the number of particles themselves were lower, meaning the river was less polluted at the time. Even though freshwater systems are particularly difficult to analyse because of how much currents, topography of the benthos and rainfalls influence results, and the fact that we do not have a lot of samples to work with, I think it is still safe to say that the fact that the Danube river passes right through the center of the city of Budapest increases the concentration of microplastics of the river and thereby, affects the health of the freshwater organisms downstream form the city.

The fact that the numbers of particles were lower in February 2021 could be due to a wide variety of events, but the one I find particularly interesting to reflect on would be the influence of the COVID-19 pandemic. Surely this health crisis has tremendously increased the amount of plastic waste produced, but it also has set the world on slow-motion for quite a while with the lockdowns. A lot of factories and work places closed down for some time or at least reduced their work load. This could be linked to the decrease in microplastic particles per cubic meter in the river, because of a decrease in primary producing sites of pollution such as factories along the river had themselves reduced their activities. As previously stated it was found that 79% of the Danube's microplastic pollution was industrial raw material.(Lechner et al., 2014)

Nevertheless during this time period of February 2021 we can still observe a larger relative increase in microplastic concentration as the river passes through the city of Budapest. If we formulate a hypotheis to explain this observation, I think this could be linked to the notable contrast between the upstream river basins and the city of Budapest at this specific time period. In the upstream area, the plastic pollution of the river is mainly linked to industrial activity, factories or rainfall draining water from Landfills etc, so the plastic pollution of the Danube would decline, reflecting the lower economic activity due to the Covid-19 pandemic. However, the city of Budapest itself would, in normal times, generate relatively less industrial plastic pollution and relatively more human plastic pollution than the upper river basins. It would therefore be a reasonable hypothesis to suggest that, due to the covid-19 pandemic and the slowing down of the economy, we see a general decrease in the Danube's plastic pollution, however this exacerbates the origin of human plastic pollution form the city of Budapest itslef. From the numbers we observe a 16% decrease in plastic particles in the dowstream sampling site, showing that there is less activity in the city, thus, less polluting the river, but still, the 37% increase in microplastic particles from the upstream to the downstream sampling site shows that the city is a substantial contributor to the river's plastic pollution.

# 8 SOLUTIONS , FURTHER STUDIES AND WAYS TO IMPROVE

In these times, it is of utmost importance to find sustainable solutions, using innovations, consumer awareness and political willingness. The issue of plastic pollution is a very complex one involving social, economic and technological aspects and cannot be approached by simplistic solutions.(Gorrasi et al., 2021)

For a better future, two points seem important to highlight: Better waste management infrastructures, including recycling at one end and a decrease in manufacture and usage of single use plastic at the other. Mismanaged plastic waste is one of the biggest issues and should be targeted as soon as possible if we want to reduce the disastrous projections that have been made. China and India are currently responsible for a third of MPW worldwide. The World Bank has declared that in China, 70 % of the municipal waste is presently mismanaged, as for India, it is no less than 85%. It is now crucial that countries and cities improve their waste management infrastructures. Furthermore, the issue of waste production is further exacerbated by the world population growth. For exemple, Africa's population is expected to reach 2,9 billion by 2060, which represents a 245% population growth from 2015. The global average for population growth is estimated at 138%.(Lebreton and Andrady, 2019) Wastewater treatment technology is thought to be one of the biggest challenges in order to decrease microplastic pollution. A study was done on a Canadian wastewater treatment plant, where the water inflow contained 1,76 billion microplastic particles annually, out of which 1,28 billion ends up in the primary sludge, 0,36 billion can be found in the secondary sludge and 0.03 billion ends up in rivers and finally to seas. It has been highlighted that improvement needs to be done on the tertiary wastewater treatment step, before those microplastics are released in rivers. It is also important to note that sludge is very commonly used as organic fertilizer, thereby releasing all of these microplastics in the soil.(Calero *et al.*, 2021)

To further feed the fire, is the COVID-19 pandemic, producing a huge amount of freshly made plastic and making humanity take a step back in its environmental considerations regarding plastic and waste management. In the EU, the ban on single-use plastics was under way for 2021 but the pandemic has put this project on hold.(Calero *et al.*, 2021) Now more than ever, we should remember the 10 R's, which stand for : Refuse-Reject, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.(Mallick *et al.*, 2021) We can no longer go on with a linear economy of produce, use and disposal, our "throw away" culture is outdated. A circular economy is essential nowadays, the goal being to reduce, reuse and recycle. But the transition to a circular economy needs to be done along the entire value chain of plastic, so that the design, production, use and disposal are all thought of together as one process. Otherwise, we will face problems like too many mixed polymers in the original designs, rendering it impossible to recycle, or non recyclable pieces mixed together in the municipal waste system thereby contaminating the polymers with organic and inorganic matter, leading to the downcycling of plastic, meaning that the recycled material will have a lower value than the original. The aim is to treat plastic waste as a precious source of new material thereby creating a closed loop with minimal actual waste production. Studies have mostly been focusing on the "end of life phase" of plastics, highlighting a knowledge gap in the rest of the value chain to create an efficient sustainable system of circular economy. We would need more studies looking into how we can improve the product designs, production and use, so that it can be more easily recycled and reused, at low cost.(Johansen *et al.*, 2021)

It is also important to identify the source of microplastic pollution, so that we can act on the problem before they reach oceans. For instance, an important source of primary microplastic pollution is the loss of preproduction plastic pellets by the industry. In the EU, 16'000 to 16'500 tonnes of these preproduction plastic pellets are lost to the environment every year. The initiative "Operation. Clean Sweep" (OCS) is a great example of what can be done to minimise microplastic pollution once the source has been identified. This voluntary program launched by PLASTICS (Plastic Industry Association) and the American Chemical Council, has the goal to prevent those preproduction plastic pellets to end up in the environment. For that, they are promoting the use of sieves in drains to prevent pellets from reaching the sewage water, the use of more resistant bags or switching to smaller packages instead of bulk loading to avoid the spillage of pellets during loading and transportation and a more efficient way of cleaning, like a vacuum to remove all the pellets. They also published instructions on best working procedures in order to avoid unnecessary pellet loss.(Calero *et al.*, 2021)

Another very important point is the public awareness. There is so much power in education and information, we should not forget about it. We cannot argue that the individual has only limited control over the issue, but still has some. What we need is *perception* of control as motivation. That means initiatives that provide individuals the ability to recycle their waste, or their fishing lines, thereby strenghtening their perception of control over the problem and encouraging this positive behaviour. Let's not forget about social media, which nowadays is an amazing tool to communicate ideas. For instance, it was used by the "Beat the microbead" project very efficiently, where the information about microbead use in cosmetics was shared and said to not be acceptable. It is also important that the motivation is intrinsic rather than extrinsic. The intrinsic motivation to have a certain behaviour, meaning that it is personally rewarding, will be more long lasting and can be spread to the individual's surrounding by enthusiasm. Whether the extrinsically motivated behaviour, for example the charges on plastic bags or fines on pollution are less effective, and also generates criminal behaviour such as illegal dumping of waste directly into the environment to avoid the payment, which is even worse.(GESAMP 2016)

Biodegradable plastics are also a promising alternative. Biodegradable plastics are made of polymers such as cellulose and starch, that can be converted by microbial action into CO2, CH4 and integrated into the microbial biomass. This can be done both in aerobic and anaerobic conditions. The full process consists of several steps, firstly we observe a microbial colonization of the plastic surface, then extracellular enzymatic depolymerization, followed by the uptake of those polymer fragments into the microbial cells, that will mineralize them through a respiration process. But an important detail is that, although biodegradable plastics readily degrade in composts, they might not do so in a natural environment. Indeed, in contrast with the popular idea that biodegradable plastics can degrade in the environment, leading to an increased risk of littering nature, their degradability relies on several factors that are meant to be met in industrial compost conditions. For biodegradable plastics to degrade > 90%, they need to be composted for 180 days at a temperature of around 58 C, which is rarely met in the natural environment. So in order for biodegradable plastics to be a successful strategy to combat plastic pollution, their "end of life" scenarios have to be carefully taken care of, as well as their primary source for manufacturing, making sure that they are also sustainable.(Flury and Narayan, 2021) From an economical point of view, the recycling of plastic remains quite unnattractive. We would need to find ways to render it more economically competitive, like setting taxes on the usage of virgin plastics for example, or on the contrary, incentive the use of recycled plastics.(Calero *et al.*, 2021)

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# 10 FIGURES REFERENCES

Figure 1 : Different sizes of plastic pollution, made by Alizée Curzon.

Figure 2 : Different pathways for plastic waste, made by Alizée Curzon.

Figure 3 : Bioaccumulation through trophic levels, Carbery M, O'Connor W, Thavamani P (2018) Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health, *Environment international 115*, pp. 400–409, doi:10.1016/j.envint.2018.03.007.

Figure 4 : Effects of the COVID-19 pandemic, Parashar N, Hait S (2021) Plastics in the time of COVID-19 pandemic: Protector or polluter?, *Science of the Total Environment 759*, 144274, doi:10.1016/j.scitotenv.2020.144274.

Figure 5 : Refused by Mandy Barker, Mandy Barker, https://www.mandy-barker.com/soup-2

Figure 6 : Sampling sites, google maps

Figure 7 : Plankton net, picture

Figure 8 : Microplastic particles stained in red under 130x magnification, picture

Figure 9 : Results, made by Alizée Curzon

Figure 10 : Data analysis, made by. Alizée Curzon

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