MBMUN'25

STUDY GUIDE

UNDER- SECRETARY-GENERAL:
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WHO

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1. Letter from the Secretary General

Honourable Delegates, Esteemed Advisors, and Distinguished Guests,

My name is Bersun Akkaya. As the Secretary-General, it is with great pride, immense joy, and a privilege that I welcome you to the long-anticipated revival of MBMUN, now with its new iteration. This conference is the revival of a conference rooted in tradition and now reconstructed for a new generation of thinkers and changemakers.

The preparation of this conference has been an odyssey. Alongside an exceptional team of organizational and academic teams, we have devoted countless hours fueled by passion and purpose to ensure that MBMUN'25 embodies not only excellence in diplomacy, but with a genuine commitment to dialogue, cooperation, and meaningful progress to be a platform for meaningful discourse, a forum where today's youth can engage with the complexities of a rapidly changing world. It is our utmost pleasure to bring together young minds in a time defined by uncertainty, environmental collapse, contested sovereignties, technological upheaval, and a shifting global order nor only to discuss but also to share and develop their ideas with the critical tools of diplomacy, ethics, and global citizenship in a collaborative atmosphere. This year's theme draws inspiration from one of history's most noble civilizations: the Roman Empire. It invites participants to examine the durability of power and the fragility of institutions. Under the motto Per Aspera Ad Astra "Through Hardships to the Stars" we call upon you to rise above challenges and to reach intellectually and morally, toward something greater. Each of our ten deliberately selected committees has been formed to combine academic depth with contemporary relevance ranging from historical reenactments to futuristic policy dilemmas, public health to international security, and from post-Soviet sovereignty to the legal dilemmas in orbital militarization. From historical simulation in the Roman Senate to the timeless ethical conflict of the 12 Angry Men, we aim to reflect the diversity of the United Nations and the multidisciplinary challenges that confront our period. Each agenda item was chosen not only to echo global urgency but also to foster intellectual relevance creating a space where rhetoric meets responsibility. Model United Nations is not merely a conference, it is a living classroom, a training ground for leadership, a crucible where global awareness is tested, and a stage where youth diplomacy is celebrated. In this regard, whether your voice resonates through heated debate or takes shape in silent diplomacy, never forget that your presence here has meaning. I invite and encourage all my delegates to research boldly, question fearlessly, and above all, remain deeply committed to the principles of respect, empathy, and curiosity for the rest of their lives..

Aim to reach the moon even if you could not reach the moon, you will find your place among the stars, may the light of the stars be your beacon that enlightens your path to knowledge. On behalf of the entire MBMUN'25 Secretariat, I look forward to welcoming you to leave a mark far beyond its closing ceremony.

Cordially,

Bersun AKKAYA, The Secretary General of MBMUN'25

2. Letter from the Under-Secretary-General

In our committee, we have such an important topic that is affecting many people, even more than you would think. Thus, we are expecting every single member of the committee to express their thoughts on it. Position papers are expected but not mandatory. However, it will be taken into consideration when deciding awards. For the resolution paper, only and only delegates are responsible for writing it. The academic team will give instructions and guidance but that will be it. Failing to provide at least one resolution paper by the end of the committee will also result in the committee's failure. One other thing that will lead to a failure is usage of artificial intelligence. Once the committee starts, usage of AI is strictly prohibited. You should not be scared though, we are pretty sure we will complete this committee with great success.

We wish to thank the Secretariat for the opportunity and. We cannot wait to meet you all in person and start the committee. If you have any questions or wishes you can contact us via the email address below. See you soon!

Elif Çakır,
Under-Secretary General of WHO
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3. **Letters from Academic Assistant**

Dear Participants,

First of all, I would like to welcome you all to the MBMUN'25 WHO committee.

I am Mustafa Aslan, an 11th grade student at Bahçeşehir Aspendos Campus, and I am honored to serve as the academic assistant of the committee.

I have been attending Model United Nations conferences in Antalya and many other cities for the last two years. This is my nineteenth conference, and I am very glad to be sharing it with you.

I would like to thank Bersun Akkaya, the best secretary general in the universe, for giving me the chance to make this committee. Her efforts are endless to make this conference happen.

Besides these, I don't want you to have any questions about the committee before the conference, so I would like you to contact me from my contact information below, even for the tiniest thing you want to ask.

Apart from these, we have added all the necessary information in the committee to the study guide as an academic team. I wish you all success in advance.

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4. Introduction

4.1. Introduction to the Committee

Founded in 1948, WHO is the United Nations agency that connects nations, partners and people to promote health, keep the world safe and serve the vulnerable – so everyone, everywhere can attain the highest level of health. WHO leads global efforts to expand universal health coverage. WHO directs and coordinates the world's response to health emergencies and promotes healthier lives – from pregnancy care through old age. Their Triple Billion targets outline an ambitious plan for the world to achieve good health for all using science-based policies and programmes.

From longstanding Geneva headquarters to working with 194 Member States across 6 regions and on the ground in 150+ locations, the WHO works to improve everyone's ability to enjoy good health and well-being. Collaboration is at the heart of all WHO does. From governments and civil society to international organizations, foundations, advocates, researchers and health workers, WHO mobilizes every part of society to advance the health and security of all.

WHO's work remains firmly rooted in the basic principles of the right to health and well-being for all people, as outlined in their 1948 Constitution. The World Health Assembly is the decision-making body of WHO and is attended by delegations from all Member States. They are committed to the principle of accountability – a core value for an organization that is entrusted by countries and other donors to use limited resources effectively to protect and improve global health.(who.int)

4.2. Introduction to the Agenda

From the Philippines to the Arctic, plastic is everywhere. It takes a variety of forms, from synthetic fishing nets to single-use items like water bottles and trash bags.

If all plastic waste in the ocean were collected, it would fill 5 million shipping containers. Put another way, there is enough plastic in the ocean to stretch 30,000 kilometers (18,640 miles) if placed end to end. That's the equivalent of a trip from New York City to Sydney, Australia.

And because plastic is not at all biodegradable, it simply breaks apart into smaller and smaller pieces over time, creating what's known as micro- or nanoplastics. "It's completely indestructible," says Agustina Besada, co-founder and CEO of Unplastify, an organization based in Buenos Aires, Argentina, committed to ending plastic pollution. "To me, that's a problem of systemic design."(unfoundation.org)

i.Definition and Origin of Microplastics

Microplastics are small plastic pieces less than five millimeters long which can be harmful to our ocean and aquatic life.

Despite being tiny in size, microplastics and nanoplastics pose a massive threat to human health and the health of vital ecosystems. “These microplastics act as little sponges and come with a lot of different chemicals that get absorbed,” Besada explains. “All these [affect] our health system [and can cause] endocrine alterations.” They also infiltrate and contaminate every part of the planet, from everyday things like our clothing and laundry to remarkable places like the summit of Mount Everest or the depths of the ocean.

Microplastics come from a variety of sources, including from larger plastic debris that degrades into smaller and smaller pieces. In addition, microbeads, a type of microplastic, are very tiny pieces of manufactured polyethylene plastic that are added as exfoliants to health and beauty products, such as some cleansers and toothpastes. These tiny particles easily pass through water filtration systems and end up in the ocean and Great Lakes, posing a potential threat to aquatic life.

Microbeads are not a recent problem. According to the United Nations Environment Programme, plastic microbeads first appeared in personal care products about fifty years ago, with plastics increasingly replacing natural ingredients. As recently as 2012, this issue was still relatively unknown, with an abundance of products containing plastic microbeads on the market and not a lot of awareness on the part of consumers. (oceanservice.noaa.gov)

ii.Sources and Global Distribution of Microplastics

There are many ways in which plastics can be released into the environment, either as primary microplastics or as larger plastic materials (‘macroplastics’) that break down to form microplastics.
Primary microplastics, such as microbeads from household products, can be found in wastewater and subsequently discharged into rivers, while Nurdles can be lost in freshwater during manufacturing processes. Examples of secondary sources of microplastics include intentional releases (illegal dumping) mismanaged waste (litter) or unintentional losses (e.g. loss of fishing gear and ship cargo). The magnitude of the different sources and pathways of microplastic releasevaries between terrestrial freshwater and marine environments.

All plastic is manufactured on land and, other than maritime or fishing uses, it is also where the majority of plastic is used in consumer products. The pathways for release of waste consumer products to land include direct littering and inefficient waste management e.g. loss during the waste disposal chain, industrial spillages, or release from landfill sites.

Modern agricultural practices make use of plastic in a variety of ways including as mulches, which can degrade in situ, in addition to bale twine and wrapping which can be improperly disposed of. These items can degrade to form secondary microplastics within the environment.

Microplastics may also be released directly to land along with sewage sludge applied to agricultural land as a fertiliser. Wastewater treatment plants are quite effective at removing microplastic particles from the wastewater stream, often with ~99% removal, and many of these particles will settle to the sludge. It is estimated that throughout Europe, between 125–850 tons of microplastics per million inhabitants are added annually to agricultural soils as a result of sewage sludge application.

Horton et al. calculated that 473,000–910,000 metric tonnes of plastic waste is retained within European continental environments (terrestrial and freshwater) annually, which includes microplastics derived from sewage sludge, in addition to predicted inputs of litter and inadequately managed waste. Where plastics are not transported from land to rivers or the sea, this could lead to massive accumulation. However, few studies have investigated abundance of microplastics within terrestrial environments, or linked abundance to input pathways, therefore it is not currently possible to directly link accumulation with specific environmental characteristics or anthropogenic activities.

In the marine environment The presence and abundance of microplastics within the oceans have been widely studied. Sources of microplastics to marine environments are widespread, as oceans are generally considered to be the ultimate sink for all plastic within the environment.

In addition to the inputs from rivers, plastics will also enter oceans directly via mismanaged maritime or fishing waste, including abandoned fishing gear, accidental cargo loss and illegal dumping. This will most likely be in the form of macroplastic waste that will degrade to form microplastics within the marine environment.

Microplastics have been found to be widespread throughout various locations and within marine organisms worldwide, with ocean currents leading to specific areas of accumulation such as the well-known ‘Great Pacific Garbage Patch’.

Models have been developed to investigate transport processes and fate of microplastics within the oceans, which may also add to our understanding of the processes that influence microplastic transport within freshwater environments.

Transport Process

It is widely considered that the ocean represents a sink for a large proportion of microplastics, with the terrestrial and freshwater environments acting as important sources and pathways for microplastics to the sea. Due to their lightweight nature and potential for widespread dispersal it is also likely that air currents act as a means of particulate transport, contributing to microplastic contamination on land and within aquatic systems. A number of studies have provided evidence for macro and microplastic litter reaching oceans from rivers, with particles often originating on land. However, it is increasingly becoming recognised that far from being merely conveyor belts for waste plastic, freshwaters and soils can act as sinks themselves, retaining much of the microplastic pollution that they receive.

In some cases, due to the proximity and scale of plastic inputs, certain terrestrial and freshwater areas could actually accumulate microplastics at higher concentrations than in the ocean. For future understanding of microplastic pollution within the environment it will therefore be important to link sources, particle behaviours and transport mechanisms, to understand how and where microplastics will accumulate.

Agricultural soils may be an important source for microplastics to rivers through the application of sewage sludge as fertiliser, although it is likely that a high proportion will also be retained. A study on microplastic retention within soils found synthetic fibres derived from sewage sludge retained within treated agricultural soil up to 15 years after the last sludge application. This study also suggested that accumulation hotspots can occur even at depth, with fibres found at more than 25 cm depth in areas where downward drainage flow through the soil was high. Retention within soils will be further facilitated by processes such as bioturbation which will draw particles away from the surface and into the deeper layers of the soil. Agricultural and forest soils are more likely to retain particles than urban land due to permeable soils and lower rates of overland flow.

Where particles do enter rivers, they will be subject to the same transport processes which mobilise other sediments, such as sand and silt, in channels. In simple terms, the faster a river flows the more energy it has, and thus it can entrain and transport a greater volume of particles. However, in the case of microplastics, most rivers are likely to be supply-limited with respect to transport, meaning rivers will be capable of transporting all plastics that are delivered to them. Despite the buoyancy of many plastics, where river energy drops, for example in slow-moving sections of water, it is likely that microplastics will settle out along with sinking sediment particles. Additionally, this sediment deposition may aid in the burial of microplastic particles, whether microplastics are simultaneously deposited or are already present within the sediment. It is therefore likely that on their journey throughout the freshwater environment, many particles will also be retained within sediments. Within lakes where sediment accumulation rates are high, it has been suggested that retention and incorporation of microplastics into sediments could lead to burial and long-term preservation within the sediment.

The density and shape of microplastic particles will have important effects on their transport and retention in sediments. Although many polymer particles have low densities, so are buoyant and will float, there are also many types of polymer that are denser than water and so will naturally sink. Dense plastics include commonly used polymers such as polyvinyl chloride (PVC), polyethylene terephthalate (PET) and nylon, in addition to polymer composites such as those found in paints. The density of plastic polymers is also not constant, with the growth of microalgae on particles (biofouling) increasing their density, leading to them sinking and being deposited in sediments. Additionally, size and shape play a role in retention of microplastics within sediments, with irregularly shaped particles having highly complex settling mechanics compared to spherical particles. For buoyant particles, those which are irregularly-shaped are most likely to be drawn down from the surface of the water and be retained underwater, rather than return to the surface, compared to spherical particles. In river bed sediments, larger microplastic particles have been found to be more likely to be retained. However, previous work on comparable sediment particles has shown that shape may have a greater influence than size, with larger plate-like particles more likely to be mobilised in preference to finer, spherical particles. This difference in particle behaviours dependent on size, shape and density illustrates the complexity in predicting and modelling microplastic fate and transport in river environments.

It is clear from the research published to date that microplastics are abundant and widespread across the globe, and that their rate of input is increasing. The main concern with this is the potential damage that microplastics may cause to ecosystems. Large-scale macroplastic waste has been prominent within the global media in contributing to the deaths of numerous marine animals including whales, turtles and seabirds.

A variety of studies have also shown harm by microplastics to a wide variety of smaller aquatic organisms including zooplankton and large invertebrates including mussels and crabs and fish larvae. Harm may occur as a result of physical damage due to clogging of the gut or gills, or internal lacerations following ingestion due to sharp edges. Damage to organisms and populations at lower trophic levels has the potential for knock-on effects in food webs, either due to reduced populations of smaller organisms leading to a reduced food source, or due to predators ingesting large numbers of contaminated prey and concentrating microplastics in their own bodies.

Additionally, toxicity or bioaccumulation of chemicals associated with the plastics may occur, for example organic pollutants sorbed to plastics may become available to organisms following ingestion, while plasticiser chemicals can leach out within the environment.

Microplastics may have implications for soil ecosystem function, for example experimental studies have shown effects of microplastics on reproduction of earthworms – a key organism for nutrient cycling and aeration within soils. This will be especially pertinent for agricultural areas given the likely prevalence of microplastics on agricultural land. The resultant chemical or particulate toxic effects to organisms could have detrimental impacts on agricultural productivity.

Recently, concerns have been raised about the possible consequences of widespread microplastic pollution on human health, with microplastics highly likely to be ingested or inhaled on a regular basis. The potential for health implications has been highlighted by workers in textile industries suffering respiratory disorders following inhalation of synthetic particulate matter, although this has not yet been directly compared to the effects of non-polymeric dust such as cotton fibres, which may be similarly inhaled. As little clinical data is available on short or long-term health effects of this microplastic exposure, this remains a priority research question to be addressed.

5. Understanding the Threat of Microplastics

i. Exposure Pathways: Inhalation, Ingestion, and Dermal Contact

Human consumption of micro- and nano-plastics (MNPs) occurs mainly through three exposure routes(air inhalation, ingestion, and dermal penetration) having distinct mechanisms and corresponding health implications. All three routes enable internalization of MNPs with potential translocation to other organs and tissues. Ingestional exposure is caused by food and drink contamination: microplastics are detected in seafood, packaged drinks, table salt, sugar, honey, milk, beer, and vegetables, with estimates of hundreds to hundreds of thousands of particles being consumed by each person annually. Ingested microplastics are expected to cross the gastrointestinal lining through endocytosis and persorption processes, having the potential for entering systemic circulation. This exposure is also evidence-linked with inflammatory gut, microbiota derangement, metabolic disorder, and uptake in blood and organ tissue. In-door and out-door aerosolization of MNPs through inhalation takes place because of sources like textile fibers, tire wear, urban dust, and aged plastics, with indoor air levels between 1–60 fibers/m^3 and out-door deposition from hundreds per m^2 per day. Meta-analytical evidence shows that adults ingest 100–170 particles/day and children ingest 80–130. Animal and cell models predict inhalation exposure to elicit lung inflammation, oxidative stress, epithelial barrier injury, asthma, COPD, and other respiratory disease pathologies. Of specific mention, in the COVID-19 pandemic setting, disposable masks have been reported to release microplastic fibers of diameter ~300 nm to a few millimeters during typical exhalation. Cutaneous contact, less well studied, cannot be ruled out. Microbeads in cosmetics and personal care products and rag fibers of synthetic material leading to cumulative dust may be in contact with skin in general; nanoplastics (<100 nm) would penetrate intact skin via pores, follicles, or damaged tissue. Preliminary work suggests larger particles are stuck on the surface but that the smaller particles penetrate the stratum corneum and induce local inflammation or oxidative stress. The biological impacts of such exposures include particle deposition in lung, gut, blood, liver, placenta, and fetal tissue and disturbance of organ homeostasis and induction of inflammation, cytotoxicity, endocrine disruption, and reproductive toxicity. Systematic review of nearly 3,000 publications verifies associations between inhaled microplastic exposure and respiratory, gastrointestinal, and reproductive illness and potential associations with colon cancer and decreased fertility. Despite the new findings, nonetheless, there remains an urgent requirement for standardized high-resolution analytical procedures to assess MNP exposure and clarify dose–response relationships in field settings. New research frontiers are to define translocation processes, long-term effects on health, sensitive subpopulations (e.g., infants, pregnant women), and interactive effects of toxic additives or adsorbed contaminants. Inhalation, ingestion, blending, and dermal absorption are exposure routes that are coupled and enable microplastic entry into the human body. Evidence is proven to enter protective barriers and cause damaging cellular and physiological effects. Interdisciplinary research through analytical chemistry, toxicology, epidemiology, and policy is necessary to improve risk assessments and advice policy and regulation against microplastic exposure.

ii.Bioaccumulation in Ecosystems and Food Chains

Bioaccumulation is an instantaneous process in all organisms throughout the organism's life, wherein substances of different organic and inorganic origin are accumulated. Bioaccumulation impacts are a function of the chemical properties of the substances and also the biological properties of the organisms. In general, bioaccumulation is not achievable without exposure, which is a function of factors including behavior, bioavailability, bioaccessibility, and absorption. These are organism-specific conditions like size, diet, genetics, hormones, and sex. Uptake is direct environmental contact(air, water, soil)or indirectly through the food web, with the ingestion of tainted food causing chemical accumulation.

In plants, uptake pathways are typically roots (water and soil), and leaves (air and water), while in animals, uptake can take place through respiratory, digestive, and dermal channels. Long-term body burden of pollutants is a consequence of a dynamic balance between absorption, distribution, metabolism, and excretion. Distribution of chemicals within an organism is not symmetrical and is influenced by tissue, species, and chemical characteristics. Metabolism comprises biotransformation of drugs into metabolites, typically decomposition to lower molecules or complete mineralization to CO_2, water, and nutrients. Storage takes place in specialized tissues like adipose tissue and bones, whereas excretion routes in animals comprise urine, feces, saliva, lactation, sweat, and respiration, but in plants excretion is mainly via the leaf surface.

Bioaccumulation traces intricate food chains, the concentration of chemicals within tissue being greater in those organisms in higher trophic positions; it is a process that depends on food habit-, geographic location-, and metabolic processes. Bioaccumulated chemicals are metabolically converted to more toxic derivatives of the original compounds; e.g., inorganic mercury is methylated to the more toxic methylmercury. Bio Accumulated substance persistence is a function of their metabolic half-life and stability of binding into cellular compartments.

Chemical elimination typically occurs through first-order kinetics and may be differentiated into fast pools (those that are gone in hours to days), slow pools (months), and unassimilated gut contents (animals' days).

Bioaccumulation in aquatic ecosystems depends on such parameters as biomass to water volume ratios, chemical concentration, and the period of sampling and is greatly influenced by seasonal temperature fluctuations. Water chemistry is critical in controlling the incorporation of chemicals into aquatic food chains, beginning with primary producers such as phytoplankton and aquatic plants and continuing upwards through higher trophic levels by ingestion in invertebrates and fish. Chemicals may be introduced into organisms either through direct uptake from water through membranes using ion channels, pumps, and active or passive transport systems or indirectly through ingestion of food that is contaminated. Assimilation efficiency, or the proportion of ingested chemical taken up into tissues, differs by organism group and the food consumed.

Terrestrial animals bioaccumulate chemicals mainly by diet with minor contributions from dermal and respiratory pathways, except in soil animals where dermal uptake plays a major role. Terrestrial animals have, in comparison to aquatic animals, an order of magnitude lower bioaccumulation levels. Mammals and birds achieve dynamic equilibrium levels such that rates of uptake and excretion are equal and tissue concentrations stabilize. Time of equilibrium depends on chemical characteristics, species, and extent of food contaminants. Worth mentioning, algal cells are capable of concentrating toxic metals 100 to 1000 times more than other species.

Bioaccumulation testing consists of food chain or integrated ecosystem and compartmentalized organism-level bioassays. Single variables such as size, age, sex, and weight define bioaccumulation and make quantitative interpretation difficult. Standard procedures with similar individuals and matrices in mind are the key to reproducible results. Chemically measured levels of chemicals provide exposure but correlations between biomarkers, both invasive and non-invasive,are required to quantify total body burden. Bioaccumulation testing enables the identification and removal of exposure sources, temporal monitoring trends, assessment of regulatory effectiveness, and investigation of association between exposure and disease or abnormality. Bioaccumulation testing guides legislation, particularly in order to restrict persistent, bioaccumulative, and toxic chemicals (PBTs), necessitating biodegradability testing prior to market authorization. Chemicals failing biodegradability tests or showing bioaccumulation potential with unproven mammalian safety are prospective candidates for restriction or ban.

Bioaccumulation of inorganics and organometallics are generally determined with static fish or sediment tests. Fish tests expose organisms such as rainbow trout or common carp to sublethal concentrations of chemicals (1/100 to 1/1000 of LC50) for one to two months or until steady-state levels are reached. Bioconcentration factors (BCFs) greater than 1000 are cause for concern. Benthic organisms such as Chironomus and Lumbriculus are used for sediment toxicity and contribute to sediment exposure risk assessment.

Bioaccumulation models, which vary from empirical to mechanistic, steady-state to dynamic mass-balance, are species and chemical predictive models with environmental inputs and kinetic rate constants. Biomonitoring research of biomarkers of exposure and effect is required to expose trends in exposure and reduce health risk. Chemicals that are monitored regularly include toxic metals (Pb, Cd), polycyclic aromatic hydrocarbon (PAH) metabolites, persistent organic pollutants (POPs), and volatile organic compounds (VOCs). Epidemiologic biomonitoring shows increased metal and PAH bioaccumulation in children and women who live in industrial areas; urban dwellers have greater lead burdens than rural citizens.

Hair, as a nonintrusive biomatrix for monitoring, has excellent sequestration of metals and excellent correlations with liver, kidney, and environmental soil content. As hair is developed over extended periods and contains elements at one to two times concentration in other tissues, it is useful in indicating chronic exposure.

Organic bioaccumulative compounds like organochlorines concentrate in body fat. Apex aquatic predators, birds, and mammals are the responsible causes of maximum susceptibility as a result of trophic biomagnification. They metabolize and eliminate the contaminants to some extent (e.g., through lactation), with consequent persistence of body burden.

Toxic metals are among the earliest known bioaccumulative toxic substances that have managed to remain in human environments because of anthropogenic mobilization. Bioaccumulation of toxic metals is especially undesirable because nonessential toxic metals resemble essential elements, usurping their transport routes and interfering with cellular processes. For instance, cesium ions look chemically similar to potassium and are transported into plant cells through potassium channels. Organometallic compounds are lipophilic molecules that accumulate from aqueous and dietary sources, and biomagnification is based on hydrophobicity, aqueous chemistry (pH, complexing agents), and the ability of organisms for elimination. Mercury, industrially released to aquatic environments, is bio methylated in sediments and biomagnified via food chains to result in human exposure causing damage to the central nervous system.

Experimentally, bioaccumulation makes toxicological and ecotoxicological experimentation feasible, with quantitation of dose-response and measurement of thresholds possible. Hyperaccumulating species, species that can tolerate and store large quantities of pollutants,are applied for bioremediation and wastewater treatment, with microorganisms commonly being the optimal bioaccumulators because of their minute size and adaptational detoxification processes, such as metallothionein synthesis. Organisms that are small-sized have greater bioaccumulation capacity.

Metall alloy implants (e.g., stainless steel, titanium, nickel-titanium) can bioaccumulate carcinogenic, mutagenic, and allergenic metals such as cadmium, chromium, and nickel in the human body over prolonged periods of implantation, leading to further bioaccumulation issues.

Regulatory frameworks classify persistent, bioaccumulative, and toxic chemicals (PBTs) as dioxins, lead compounds, mercury compounds, and polycyclic aromatic hydrocarbons (PAHs) and some such examples are heptachlor and polychlorinated biphenyls. PBT chemicals are classified by environmental persistence, food chain bioaccumulation, and toxicity and hence they are ecosystem and human health risks. Regulation evaluation is met through the experimental testing of persistence, bioaccumulation, and toxicity against standards such as the European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

In brief, bioaccumulation is a metabolic control process whereby the living organisms take up and sequester chemicals from the surroundings, either directly from such media as water or soil, or indirectly by consumption of food. Bioaccumulation is dependent upon chemical characteristic, environmental characteristic, and organismic characteristic. Organisms have developed compensatory metabolic pathways in an attempt to prevent over-accumulation, i.e., excretory pathways and biochemical sequestration. Bioaccumulation can be qualitatively determined by biomonitoring and bioindicator studies to serve as a basis for pollution prevention, environmental policy, and practice such as bioremediation by hyperaccumulating plants and microorganisms. Because of this discovery, development of biomonitoring methods and reference values is difficult based on heterogeneity of biological as well as of environmental constituents.Keratinized tissues and hair are convenient, noninvasive chemical exposure biomarkers for long-term chemical exposure and evidence of long-term systemic bioaccumulation. Lastly, a database of bioaccumulation phenomena is the basis of an assessment of environmental and human health risk and in the development of effective regulative and cleanup strategies for reducing persistent environmental pollutants.

iii. Detection of Microplastics in Human Tissues and Fluids

Microplastics, small plastic fragments measuring less than five millimeters in length, are a fresh environmental and public health issue based on their prevalence in ecosystems and suspected toxicological effect on living organisms, including humans. Although MPs have been largely documented to take place in marine animals and marine environments, it is only in recent years that scientists have ventured into the occurrence of MPs in human bodily fluids and tissues. The present study aims to gather the latest scientific evidence of microplastics in human body fluids and tissues, identify their possible routes of entry, enumerate the methods employed in detecting them, and discuss the newly emerging health hazards and knowledge gaps.

Microplastics have been found in all human systems of digestive, cardiovascular, endocrine, integumentary, lymphatic, respiratory, reproductive, and urinary systems. MPs enter the digestive system via ingestion with activities varying from disturbance of microbiome to physical injury, deposition in the liver, and migration to neighboring organs. For example, cirrhotic liver tissue contained more MP concentration than regular tissue. Whereas there is well-documented toxicity effects in marine organisms, there are no well-documented direct health effects in human subjects. Nonetheless, in-vitro experiments confirm genotoxicity and cytotoxicity, particularly on the cardiovascular system, where MPs lead to micronucleation and DNA damage. Of particular interest is endocrine-disrupting activity in MPs. Due to their nanometric dimensions, they can cross the placenta and other endocrine-regulating organs and transport endocrine-disrupting chemicals bisphenol-A (BPA) and phthalates. These interactions would be likely to alter maternal-fetal communication, immune cell traffic, and hormonal signals. Also, MPs on hair, saliva, and skin would be most likely because of air or object and surface direct contamination with clothing or veils. Interestingly, despite being exposed at greater levels, hand skin has lower MP deposition perhaps because of washing in routine.

In the lymph system, MPs have been isolated in spleen tissues, and that does raise some question about their role as vectors for environmental toxins. Spleen function effect effects are speculative, but the potential for MPs to have adsorbed toxics is definite. MPs are primarily absorbed with respiratory exposure by inhalation of air-borne fibres. Microfibre particles may be lodged in the respiratory tract and have the potential to induce chronic inflammation, granuloma, and fibrosis. Lung ground-glass nodules would be anticipated to demonstrate chronic microfibre deposition.

Not even the reproductive system is spared. MPs have been separated in human semen and reported to impair male fertility. Mice and murine models treated with polystyrene MPs over extended periods have been associated with testosterone inhibition and sperm quality decline. More disconcerting is the finding that nanoplastics seem more injurious than large MPs. Concurrently, non-contaminated whole kidney tissues, exposure in experimental design led to injury and inflammation to human kidney cell and mouse model mitochondria, indicating latent nephrotoxicity potential.

At the cellular level, MPs provoke oxidative stress through the formation of reactive oxygen species (ROS), challenging mitochondrial integrity, and triggering lipid peroxidation. Exposure of model digestive systems to polyvinyl chloride MPs triggered cell stress-related genes. These pathways are aimed at signaling the toxicological significance of MPs, though causalties particular to humans are yet to be resolved.

MPs are separated from human samples using different analytical methods with their own sets of strengths and weaknesses. The samples are usually digested using potassium hydroxide (KOH), hydrogen peroxide (H2O2), nitric acid (HNO3), and zinc chloride (ZnCl2), which can be combined with catalysts like Fenton's reagent or sodium hydroxide. KOH is especially useful for digesting organic tissue. TRIS buffer, SDS, CaCl2, and protease are less conventional means to more specialist forms of tissue. Optical microscopy is still the standard for first-level MP identification, other specialist methods like Raman spectroscopy, FTIR, Py-GC/MS, SEM-EDX, and LDIR being applied to examine polymer composition and fine morphological detail.

One of the most important issues facing MP research is control over contaminants. Blanks are infrequently applied in limited studies, and environmental contamination in these studies will affect outcomes as well. Blanks must be able to emulate experimental protocols for recovering atmospheric MPs and chemical contaminants. Reproducible, reliable data demand adequate contamination controls.

In summary, microplastics have been detected in more than half of human organ systems and in various biological fluids at with possible harms to human health. Point of entry channels and morphological features become increasingly recognizable though, while associations with some disease still remain weak because of limitations under prevailing methodological circumstances and lack of longitudinal data. Standardized protocols and contaminant control efficacy must be maintained in follow-up studies. More cross-disciplinary research will be undertaken to differentiate the long-term health impacts of MPs and provide public health policy for exposure control.

6. Assessing Toxicological Risks

It is important to know the toxicological implications of micro- and nanoplastics (MNPs) on human health because they are surrounding us all over the environment and tissues. MNPs consist of heterogeneous physicochemical features (size, shape, polymer kind, charge) that control their interaction with biological systems and their toxicity. Particles with a size below 20 µm can cross biological barriers, and particles with a size below 100 nm can reach systemic circulation, with distal organ penetration. Toxic mechanisms described in animal and in vitro experiments include inflammation, oxidative stress, cytotoxicity, genotoxicity, genotoxicity, and endocrine disruption. Some have reported that polystyrene nanoparticles induce liver oxidative damage in rodents and microfibers caused respiratory epithelial disruption. Surprisingly, MNPs can act as a vector for co-associated impurities such as phthalates, bisphenols, and heavy metals to boost their toxicity profile. Empirical evidence confirms MNP deposition within the human lungs, gut, blood, liver, placenta, and fetal tissue. The evidence is substantiated by biomonitoring evidence demonstrating microplastic in human feces and in placental tissues and suggesting both ingestion and inhalation routes lead to systemic distribution. Despite such an appreciation, there are still knowledge gaps. Quantitative dose (response data, especially concerning low-level chronic human exposure, are limited) as is data on sensitive subgroups of the population such as infants and pregnant women. Harmonized analysis techniques to quantitate MNPs in the biological environment are still in infancy phases. Such non-harmonization prevents repeat risk assessment.

i. Chemical Pollutants Carried by Microplastics

Microplastics (MPs) are manufactured polymer particles of small diameter and less than 5 mm in size. MP is becoming increasingly prevalent in freshwater environments. MPs' "vector effect," that they are vectors for chemical and biological pollutants, has turned out to be one of the most important environment issues. MPs have been found to adsorb other persistent organic pollutants (POPs), heavy metals, pharmaceuticals, and microbial pathogens and hence influence many ecological and biological processes. MPs' interaction with the pollutants is a complex physicochemical one that needs to be researched in order to reveal their activity on the environment and on human health.

Chemical Contaminants on Microplastics MPs adsorb hydrophobic organic contaminants (HOCs) like polycyclic aromatic hydrocarbons (PAHs), perfluoroalkyl compounds (PAFs), and pesticides like dichlorodiphenyltrichloroethane (DDT). The adsorption is governed by van der Waals forces, hydrogen bonding, and hydrophobic forces. These operations are kind of polymer, surface area, and even environmentally condition-specific like salinity and pH. Polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) adsorbed POPs and their levels on MP surfaces were 106 times greater than in the ambient bodies of water.

Gas chromatography-mass spectrometry (GC-MS) and gas chromatography with electron capture detection (GC-ECD) have been utilized to quantify POPs such as DDT, PCBs, PBDEs, PAHs, and HCHs. PCBs have been found as 126.13 ng/g in Japan, 14.52 ng/g in Portugal, 39.90 ng/g in Chile, and 159.67 ng/g in Hong Kong. DDT has varied as much as 156.01 ng/g. While some simulation models of desorption have suggested that MPs play a very minor part to play in chemical bioaccumulation, increased pH and temperature in the gut significantly enhance desorption rates. Desorption rates of DEHP and DDT are 30 times greater under laboratory-conditioned conditions in the gut and are linked with increased concentrations of POPs in tissues in aquatic animals fed on contaminated MPs.

Pharmaceuticals Non-steroidal anti-inflammatory drugs (NSAIDs) and antibiotics are ubiquitous in freshwater. Their behavior and fate in terms of MPs are also of increasing interest because MPs can potentially serve as transport media. Sorption is chiefly caused by hydrophobicity of the compounds (Kow), polymer characteristics of MPs, and environmental factors. The research has demonstrated that PE and polyamide MPs exhibit favorable drug affinities for ibuprofen, naproxen, and certain antibiotics. Maximum sorption capacity of polyamide MPs ranged between 756 L/kg upon dissolution in water, whereas propranolol and sertraline desorption was 4% and 8%, respectively. Experimental evidence regarding MP-pharmaceutical interaction under environmentally relevant conditions has not been illustrated with a focus on polar and aged polymers like polyacrylics.

Heavy metals such as chromium (Cr), lead (Pb), cadmium (Cd), and mercury (Hg) are most abundantly present on MPs because these elements have very high surface-area-to-volume and functional groups such as C–O and N–H on the plastic surface. Metal content has been reported by research work to reach up to 8216 nmol/kg in MP samples taken from Mediterranean beaches. PE and PVC polymers have strong metal adsorptivity. Methods used to study the quantification of these metals include Fourier-transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM), energy-dispersive spectroscopy (EDS), inductively coupled plasma mass spectrometry (ICP-MS), and nanoscale secondary ion mass spectrometry (NanoSIMS). Photo-oxidation and biofilm formation enhance MPs' metal adsorption capability significantly. Long-term transport processes of metals by MPs are not well studied.

Microbial Colonisation and Biological Agents MPs are biofilm growth substrates and sites of microbial colonisation that enable both adsorption of chemical pollutants and proliferation of resistant pathogens and genes. Pathogenic Vibrio alginolyticus were isolated from MPs via scanning electron microscopy and high-throughput sequencing. Microbial communities are geographically and seasonally variable and showed variability between MP polymer types. MPs have been shown to harbor fecal indicator bacteria and toxigenic algal species, and there is limited field evidence of viral carriage. Viruses have been reported to become incorporated into biofilm extracellular polymeric substances (EPS) such that viruses do have a role to play as a vector.

Antibiotic Resistance Genes (ARGs) MPs are now massive reservoirs and transmission locations of antibiotic resistance genes (ARGs) and antibiotic-resistant bacteria (ARBs). The presence of up to 5000 times greater levels of ARGs on MPs than in co-occurring planktonic bacterial communities has been reported by research. MP biofilm facilitates horizontal and vertical gene transfer and increases the transfer of the resistance traits. It has been established in laboratory studies that MPs' biofilm-plasmid uptake is greater compared to free-living bacterial cultures. It has also been established that MPs hold higher levels of mobile genetic elements like Class 1 integrons, indicating the human health risk in such contact.

Vertebrates and Invertebrates Even though negligible studies on MPs being a carrier for vertebrates, it is actually a fact that various invertebrates like molluscs, bryozoans, and hydroids inhabit MPs. Organisms make use of MPs as an anchorage primarily in turbulent water environments. SEM analyses have established diverse types of organisms like barnacles, dinoflagellates, and coccidia on the surface of MP. Biofilm development is a significant characteristic of larval settlement appeal, as demonstrated by experiments that have proved to establish bacteria to play a role in mediating invertebrate larval settlement. MPs, however, have been scarcely analyzed as mediators of vertebrate dispersal, and one among the knowledge gaps remaining that are yet unfulfilled is discussed below.

Ecological and Human Health Impacts The vectoring function of MPs is more active than physical injury; they enable the transmission of chemical pollutants and microbial communities and affect ecosystem functioning and can have a potential impact on health in a harmful way. MPs are also a site of invasion by biota and a site of invasion by attraction of ARG transfer and hence are an environmental management and public health concern. They are size-, shape-, polymer type-, and biofilm formation-dependent in their actions. The heterogeneity and complexity of such interactions call for an integrated and holistic approach to evaluate and manage MP risks, however.

Conclusion and Future Outlook Microplastics are established vectors of the vast toxic payload of environmental contaminants, including POPs, medications, metals, and biotoxins. Yet, to this day, there is still a great research gap, particularly for freshwater systems. The most pressing research objectives in the near future must include:

Extension to more familiar freshwater ecosystems, particularly riverine systems.

Experiments under environmentally realistic conditions, i.e., MP size, ageing, and concentrations.

Clarification of conflicting reports on MPs' vector role and toxicological relevance.

Development of integrated strategies for quantification and profiling of the contaminants on MPs.

Research support for the use of MPs as vectors of biological molecules, especially in least explored parts of the world such as Africa.

Use of sophisticated molecular and imaging tools to separate adhesion of microbes, gene transfer, and biofilm-based associations.

It is filling such knowledge lacunae that is at the core of designing effective mitigation policies and regulation tools whose aim is to curb the health and environmental effects of microplastic pollution.

7.Global and National Responses

i.Overview

Seven decades after the invention of synthetic plastic, several conventions started to tackle plastic pollution. Although most regulations initially addressed plastic pollution in general, they directly influenced the mid-2000s to 2020 regulations targeting microplastics.

Timeline of policies targeting plastic and microplastic contamination.

Almost 35 years after the first initiatives tackling land- and sea-based pollution, the term microplastics. Due to the groundwork on policymaking carried out to tackle macroplastics, the inclusion of microplastics in policies took merely four years, when they were first addressed in the MSFD (2008). That triggered a cascade effect. In 2012, the United Nations Conference on Sustainable Development, held in Brazil (Rio + 20), emphatically addressed microplastics as an emergent environmental issue. The reasoning of microplastics as harmful substances still resonates in the last updated version of the “Oceans and the Law of the Sea”.

In the following years, microplastics were banned in wash-off cosmetic products in the US, the Netherlands, France, Taiwan, South Korea, Sweden, and the UK. The International Coral Reef Initiative and the Secretariat of the Antarctic Treaty endorsed the reduction of plastic microbeads; the European Chemicals Agency (ECHA) followed the same line of thought to tackle microbeads; and Canada classified microplastics as toxins in personal care products. However, only personal care products were tackled, and microbeads and other microplastics in abrasive materials, such as plastic blasting and automotive molding, were disregarded.

Furthermore, HELCOM proposed a regional action plan to tackle microplastics, including recommendations on legal instruments to act upon it, encouraging microplastic-free formulas and replacing microplastics in personal care products. Additionally, monitoring programs and UN resolutions 1/6 and 2/11 on marine plastic litter and microplastics started to consider microplastic contamination as one of the six key emerging environmental issues. The United Nations Member States committed to supporting the implementation of the Sustainable Development Goal (SDG) 14, including a reduction of microplastic contamination. However, the other SDGs lack indicators related to microplastics.

Further policymaking targeting (micro)plastics is foreseen for the following years, since the United Nations formulated a comprehensive plan to target microplastics worldwide under the 2030 Agenda for Sustainable Development. It highlights the need for setting up action plans, technologies and strategies to prevent and reduce microplastic pollution, promote stakeholder engagement and assess environmental and socioeconomic costs, feasibility and effectiveness of the abovementioned, amongst others. A key question remains: Will there be enough enforcement for top-down and bottom-up policies and initiatives coming up in the following years?

This systematic review cannot ignore the COVID-19 outbreak. This pandemic is considered a plastic renaissance; since the healthcare industry demanded an enormous quantity of single-use plastics (SUP). The amount of takeaway food packaging augmented, and countries have postponed or backtracked on policies to reduce plastic pollution, e.g., the UK delay in the plastic straws ban. The impact of COVID-19 on plastic pollution is yet to be assessed.

Bio-Based Polymers Bio-based plastics are another response discussed by stakeholders to minimize fossil fuel overexploitation and to prevent pollution from oil-based plastics. Even though the former represented only 1% of the current total annual plastic production (2.1 million tons in 2019), the bio-based polymers are recently gaining more attention. Several bio-based polymers with efficient mechanical properties can be produced using direct fermentation of blended starch and other raw materials, such as polyhydroxyalkanoates (PHAs), polylactic acids (PLAs) and polyhydroxy butyrates (PHBs). Some of these polymers, e.g., PCLs, PHAs and PHBs, can be produced from sewage sludge and further incorporated as biopolymer and hard packaging products. That may represent a potential strategy to recycle waste and reduce plastic contamination. Furthermore, chitosan, pectin, starch, lignin and jute fiber are other bio matrices under investigation worldwide with the potential to occupy the plastic market in the coming years.

Bio-based polymers have been used successfully for fishing gear making. However, bio-based polymer production and use are still under debate due to high costs (2–4 times more than oil-based plastics), non-ideal mechanical properties, lack of waste management infrastructures, water footprint and substantial land use. Moreover, the transition towards bio-based plastics may be misleading since not all bio-based plastics are biodegradable, e.g., bio-PE.

Market-Based Instruments (MBIs) Regulatory MBIs impact behavioral changes toward plastic littering and microplastics contamination. These instruments estimate the externalities derived from plastic littering, considering their improper management costs and the urge for revenue-raising policies, rewards and incentives to retrieve these pollution costs. Considering these externalities in products' prices is essential to assuring that the stakeholders are dealing with full costs. Here, MBIs with the potential to prevent microplastics are discussed.

Green procurement: Environmental considerations are integrated into procurement decisions, for instance, a seaside community requiring restaurants to use only reusable plates, cups, and cutlery, or Nordic countries proposing a joint investment in recycling infrastructure.

User/Consumer/Beneficiary pays: A levy is applied to users/consumers using products that are harmful to the environment or citizens receiving a benefit. For example, a user of a clean beach contributes to beach clean-up, or users must pay a 10% fee on the use of plastic bags (in Portugal this measure led to a decrease of about 60% in plastic bag consumption per person per shopping trip). However, these measures tend to fail without well-implemented monitoring systems.

Polluter pays principle (PPP): Polluters are responsible for addressing pollution. That encourages companies to find alternatives within their manufacturing processes, e.g., the Alliance to End Plastic Waste will invest up to USD 1.5 billion over the next five years on projects targeting a plastic-free ocean, and Extended Producer Responsibility (EPR) to achieve zero plastics in landfill by 2025 in Europe. Regarding microplastics, the polluter can pay for mitigation strategies, such as research on eco-design or innovative cleaning-up initiatives and microplastic removal from wastewater treatment plants.

Deposit-refund programs: Strategy already implemented in several countries to encourage citizens to return containers that can help prevent the entry of such objects into the environment, e.g., returnable beverage bottles. The deposit–refund systems in Denmark, the USA, Canada and Australia for bottles are a success and could serve as a benchmark for worldwide implementation.

Incentives/subsidies: Mechanisms that maintain prices below market levels for consumers or higher than market levels for producers. Examples include the fishing gear buyback program (700 tons of waste recovered in South Korea between 2007 and 2011); fiscal subsidies to recycling companies, fishers and other enterprises using recycled material; and the European Maritime and Fisheries Fund promoting the Fishing for Litter activities.

Liability/Fines/Charges/Fees/Taxes/Bans: Constant reinforcements and audits can discourage microplastics use during manufacturing. Although tracing back the microplastic producers is a strenuous task, especially in developing countries, the money acquired from fines, SUP surcharges and other liabilities could be invested in alternative upstream responses.

Banning SUP: Bans on SUP commodities, such as plastic bags and plastic-based microbeads, have the potential to prevent microplastics pollution from both primary and secondary sources and to disrupt consumers' behavior by undermining the possibility of acquiring SUP; however, the unintended impacts of bans should be meticulously reviewed beforehand, e.g., impacts of disposable paper cups with plastic coating.

Ecolabeling: Reduce the adverse environmental impacts of products and raise awareness among consumers when purchasing products. Ecolabels are only given to products respecting strict criteria and are regulated. For instance, rinse-off cosmetic products with microplastics cannot acquire the EU Ecolabel, and only products containing an elevated proportion of recycled plastics obtain the Nordic Swan Ecolabel. Although imposing ecological requirements can represent a solution to cope with this issue, consumers would seldom choose labeled microplastic-free products when the label comes along with an additional "ecological" cost. However, microplastics-free labels convey information about companies' environmental consciousness and enforce the idea of communicating political and ethical preferences through conscious consumption.

Private governance: MBI efficiency tackling microplastics is only feasible with non-fragmented governance involving third-party organizations. Even though challenging certification systems could be used as transnational instruments for environmental standards through the orchestration of several actors and directives, certification labels to prevent microplastic pollution are not as effective as top-down governance methods encouraging consumers to pay more for eco-friendly alternatives through state regulatory frameworks.

Primary Microfibers from Clothing Primary microfibers are constantly released by the clothing industry, from the manufacturing stage to the washing cycles. Microfibers formation depends on the type of polymer used in the textile, the cutting process, washing machine type, washing cycles selected and the clothing age. To cope with this issue, thin coating fabrics made of silicon or bio-based materials could reduce microfiber loss by about 30%. Moreover, three pre-washes, superimposed filter meshes and detergent use could reduce more than 53% of microfiber emissions. LUV-R filter and Cora Ball, technologies already available in the market, could capture 87% and 26% of microfibers by count in the wash, and XFiltra filter and Guppyfriend bag could reduce 78% and 54% of microfibers loss, respectively. However, these strategies demand time and care from users, impacting their comfort. That highlights the need to develop a filter already connected to the washing machine.

Even with such improvements, about 15 thousand tons of microfibers would still be released into the environment. Hence, engaging the textile sector and washing machine manufacturers as well as sharing the technological advances and establishing protocols for monitoring fiber loss is necessary to palliate the microplastics released from clothing garments.

Cleanups and Removal Strategies

Continuous cleanups to avoid plastic accumulation on shorelines are effective, even on a minor scale, for reducing the amount of plastic, microplastics and additives in the environment. Although scarce cleanups are exclusively targeting microplastics, microplastic contamination is mitigated when macro litter is removed. The Ocean Conservancy International Coastal Cleanup and the Zero Plastiko are worth mentioning due to the high social commitment and awareness-raising events.

Specific microplastic removal strategies include the GoJelly prototype made from jellyfish mucus to retain microplastics the Clean Swell application from Fighting for

Trash Free Seas that connects citizen scientists worldwide to cleanups the “Mr. Trash Wheel” in Baltimore and giant drain socks to trap litter in the mouths of Australian stormwater drains. Furthermore, Ocean Cleanup® developed an u-shaped system to trap floating marine litter from garbage patches and an interceptor for polluted rivers in Indonesia, Vietnam, Dominican Republic and Jamaica, and intends to transform the collected marine litter into revenue.

https://www.mdpi.com/journal/microplastics

ii. WHO and UN Initiatives

A comprehensive review of legislations on plastics and microplastics showed a number of legislations developed to address plastics discarded in landfills. These legislations require further strengthening and review to address all forms of plastics. A review of governance strategies of controlling MPs in marine ecosystems found a lack of community involvement in monitoring and conservation, largely attributed to the absence of citizen science and co-management initiatives by key players; in addition, no standardized management strategy has been put in place. The legislations heavily relied on bans, the imposition of levies, and campaigns by volunteers to ensure the reduction and reuse of plastics. In addition to the need to strengthen the legislations, the review proposed a closed loop approach that integrates existing ones to shape consumer behavior, enable plastic redesign and recycling, and evaluate the impact of those reaching the landfill so as to ascertain the effectiveness of existing legislation and guide the development of new laws on single-use plastics and MPs.

Policies on MPs have largely neglected its pollution of agricultural land, which is mediated through sewage and plastics-coated fertilizers. This necessitates the development of policy and governance-based measures that will prevent the contamination of agricultural lands and other potential toxic elements (PTEs) that can be carried by MPs, as well as instituting regulations that will ensure food quality assurance. The measures are expected to prevent human exposure to both MPs and PTEs.

EU countries have recognized sewage sludge (SS) as a major factor contributing to the contamination of agricultural land, and this has led it to formulate high-level strategy for sustainable SS management by its member countries. The strategy involves multiple stakeholders being expected to work harmoniously to achieve the desired goal of appropriate and efficient management. It requires a review of directive 86/278/EEC on SS that will recognize the relationship between sewage and MPs, as well strictly prohibiting SS disposal on land unless necessary. Additionally, it requires plans to actualize a circular economy and provide alternatives to SS handling through high tech processes in waste water sewage plant to be strengthened by research and development.

The United Nations (UN) has provided international communities with statistics detailing how plastic pollution of the oceans adversely affects marine life, and by extension the humans who largely depend on it for their livelihood. In its SDGs report of the year 2021, the UN revealed that over 3 billion people rely on the oceans for their livelihoods, and further showed the sustainability of the oceans to be under serious threat due to plastic and marine pollution, among other factors (ocean warming, eutrophication, acidification, and fishery collapse). This has led to the development of dead zones (water areas lacking sufficient oxygen to support marine life) which have increased at an alarming rate, from 400 in 2008 to 700 in 2019. It has also increased the vulnerability and lack of protection to over half of the marine key biodiversity areas.

The UN has recognized marine plastics and MPs under 13 out of its 17 sustainable development goals (SDGs) due to the pollution of the water body and the resulting adverse effects on ecosystems and livelihoods. Notable among the 13 SDGs that specifically and directly address plastic pollution is SDG 14, which is aimed at the conservation and sustainable use of the oceans, seas, and marine resources for sustainable development. SDG 14 focuses on plastic pollution under target 14.1, which aims to prevent and significantly reduce all types of marine pollution, particularly those caused by land-based activities, by 2025. The target is expected to be measured by indicator 14.1.1b and evaluated by an index of coastal eutrophication and floating plastic debris. Only a single indicator of SDG 14 out of 247 indicators of the SDGs is meant to address the plastics problem, with the rest having no specific targets or indicators to measure their success, thus making implementation, reliable reporting, and monitoring by governments and organizations a huge challenge. Despite this, only about half of the countries in the world have adopted initiatives to support small-scale fishermen, and on average only about 1.2% of national research budgets are allocated to ocean science. Additionally, the indicator of SDG 14 to date has no internationally accepted index of floating plastic debris density.

In response to growing concerns regarding the increasing amount of marine litter—including plastics and MPs, which have become a global issue and pose serious environmental threats to marine biodiversity, ecosystems, animal health, livelihoods, fisheries, maritime transport, recreation, tourism, food safety, and the economy—the United Nations Environmental Assembly of the United Nations Environment Programme (UNEP) adopted resolutions in its fourth session on 15 March 2019, which was held between 11 March and 15 March 2019 in Nairobi, Kenya. These resolutions include the resolution on marine plastic litter and MPs (UNEP/EA.4/Res.6), which aims to control the release of plastics and MPs into the environment, provide alternatives, and halt and reverse its effects. This resolution emphasizes the need to prevent and reduce marine litter, including plastics and MPs, from land- and sea-based sources for the implementation of the 2030 agenda of sustainable development for the SDGs. It reiterates the need for sustainable management of plastics throughout their life cycle, in order to increase sustainable consumption and production patterns, including a circular economy, sustainable economic models, environmentally sound waste management, resource efficiency, the three Rs (reduce, reuse, recycle), sustainable material management, technology innovation, environmentally friendly marine plastic litter clean-up, and international cooperation to enact sustainable consumption and production patterns. It also recognizes the need to urgently strengthen science–policy interfaces at all levels so as to improve on science-based approaches that will look at the fate, distribution, and consequences of marine litter (including plastic litter and MPs) on the environment and also encourage local, national, regional, and global action to prevent and eradicate the discharge of litter, including plastics and MPs, into the marine environment.

The UN resolution on addressing single-use plastic product pollution (UNEP/EA.4/Res.9) was formulated due to poor management and recycling of plastic waste by all member countries in order to ensure efficient waste management and provide environmentally friendly alternatives. It was noted that less than 9% of 9 billion MT ever produced are recycled, and if plastic consumption and waste management remain as it is currently, 12 billion MT of plastics will be released in the environment by the year 2050, most of which will come from plastic packaging. These plastics are projected to heavily impact the environment through waterway blockage, clogging sewers, providing a favorable breeding ground for mosquitoes and other pests, and blocking the stomachs and airways of animals, as well as impacting on human health due to poor solid waste management practices. In an attempt to address these problems, the resolution encourages member countries to develop and implement policies to control single-use plastics at national and regional levels. It also encourages the identification and development of environmentally friendly plastic alternatives and calls for improvement in waste management that will reduce plastic waste spills into the environment. Governments are encouraged to invigorate the private sector to pursue resource-efficient design and production and also engage in educating their communities and stakeholders as to the impact of plastic pollution and the sustainable alternatives so as to promote sustainable consumption patterns. It incorporates collaboration between member states, intergovernmental and non-governmental organizations, the scientific community, the private sector, and other stakeholders to encourage research and development so as to come up with single-use plastic alternatives and also find a solution to plastic pollution at various levels. It requested funding by UNEP and other UN agencies to facilitate technical support and policies in developing countries in relation to collaboration between the government and stakeholders to enhance research into plastic alternatives and provide information as to the measures taken by the member states to address plastic pollution, all of which is to be communicated at the fifth session of the Environment Assembly.

The third UN resolution was formulated to control plastics pollution by integrating and implementing its resolutions with SDG and circular economy laws to ensure strict control of plastic pollution and the use of sustainable materials as alternatives. The resolution (UNEP/EA.4/Res.1) considers sustainable consumption and production as key factors for sustainable development. The resolution was passed to ensure that change in consumption and production patterns is reflected in the goal of the 2030 agenda for sustainable development through sustainable development goal 12. Its goal is to ensure the implementation of policies related to the circular economy and the use and management of sustainable materials. The resolutions 2/11 on marine plastic litter and MPs and 3/7 on marine litter and MPs are expected to address the menace of plastic pollution as part of the 10-Year Framework of the Programme on Sustainable Consumption and Production Patterns and Environment Assembly resolutions.

The United Nations Environment Programme (UNEP), the International Union for Conservation of Nature (IUCN), and the Life Cycle Initiative formulated guidance that provided a harmonized method expected to be used worldwide that will enable the identification of plastic leakages, referred to as “hotspots”, tracing their impacts in the plastic value chain and making provision for priority actions on the identified hotspots. The “National Guidance for Plastic Pollution Hotspotting and Shaping” provided an effective and systematic strategy and framework for countries, regions, and cities to use in their respective environments. It allows countries and regions to set a baseline benchmark to be used for assessing the progress of interventions using comprehensive, consistent, comparable, and credible-based methods that encompass existing data, tools, and resources. The guidelines are expected to significantly contribute to achieving SDG 12 (sustainable production and consumption patterns) and SDG 14 (conservation and sustainable use of the oceans, seas, and marine resources). It is also expected to aid in implementing the resolutions adopted in the fourth session of the United Nations Environment Assembly, which include but are not limited to the resolutions on achieving sustainable production and consumption, marine plastic litter and MPs, and on addressing single-use plastic production.

In 2019 the World Health Organization (WHO) made a call for the assessment of MPs in relation to their presence in the environment and their potential impact on human health so as to reduce pollution and prevent human exposure. It called for the reduction of plastic pollution and reiterated the need for more in-depth research to enable an accurate assessment of exposure to MPs and the implications of this on human health. It further requires the development and standardization of the methods of measuring MPs in water, studying the sources and occurrences of MPs, and testing the efficiency of different treatment processes. The WHO further required drinking water suppliers and regulators to prioritize removing chemicals and pathogens that are known to pose risk to human health, which is expected to have a double advantage, as treatment systems that are capable of removing both fecal content and pathogens will go a long way towards removing MPs effectively. It was noted that effective wastewater treatment can remove 90% of MPs, whereas conventional drinking water treatment can remove MPs of less than a micrometer. However, these will not go a long way towards providing a lasting solution to the problem, as the larger global population does not benefit from enough water and sewage treatment.

On 5 June 2019, the European Parliament and Council adopted a directive (EU 2019/904) in order to reduce the impact of certain plastic products on the environment and human health. It promotes a circular economy through innovative and sustainable business models, products, and materials that will lead to the efficient functioning of the internal market. The scope of the directive revolves around single-use plastic products, oxo-degradable plastic products, and fishing gear containing plastics. The directives were aimed at combatting the menace of single-use plastics in member states through consumption reduction, market placement restrictions, consumer awareness measures, and coordination measures, among others. It also directs member states to impose penalties on the infringements of national provisions adopted pursuant to the directive. An evaluation and review of the directive would be conducted by the commission by 3 July 2027, and submitted to the European Parliament, the Council, and the European Economic and Social Committee. However, the scope of the directive does not cover MPs, even though they contribute to marine litter, and the EU is expected to adopt a comprehensive approach in that respect, as currently, it only encourages producers to strictly limit MPs in their products.

The Association of Southeast Asian Nations (ASEAN), comprising of Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam, had adopted and initiated the ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021–2025) as a regional action which aligned with the countries' agenda of combatting the major environmental challenge of plastics. The regions generate about 30 million tons of plastic yearly. The plan is aim to ensure a harmonious strategy that is scalable and will provide a solution to the problem of marine plastic debris in the region. The policy will align resources that will strengthen the already available actions against plastic debris in the countries and has been supported by the World Bank Group through PROBLUE, which is a trust fund under its multi donor umbrella. The plan is committed to reducing plastic release into the system, increasing mop up, reducing leakage, and enhancing waste reuse by value chain creation. It has a guideline for countries that will ensure the phasing out of single-use plastics, harmonise plastic recycling and a packaging standard in the region, and enhance the capacity for monitoring and measuring marine debris in the region. The measures are expected to be coordinated and improve the capacity of the regional platform for innovation, investment, and training.

It can be seen that, based on the foregoing discussion and as summarized in Table 3, most of the laws at the international level do not provide a framework and the tools to be utilized globally and be able to track the success of the set targets, even though they have good governance strategies as summarized in Figure 3. They depend on individual countries to interpret and devise ways to implement them, which will, in turn, depend on the country's political will and the resources that will be allocated to address the problem. The UN has recognized the problem of plastics through 11 other SDGs in addition to SDG 14. However, allocating a single indicator out of 247 indicators to measure the impact of plastic in the ocean is highly insufficient to address the fast generation rate of plastic pollution on the planet and should be reviewed urgently. The European Parliament and Council have not included MPs in their directive, while the measures expected to address the problem by the WHO are not obtainable in most countries, despite the evidence of human consumption of MPs. This therefore requires a commitment to allocating resources that will fund research and provide realistic and measurable tools that will holistically address this problem.

iii. Scientific Research and International Collaborations

The ongoing international negotiations on a global plastics treaty will have pivotal implications for future efforts to transform the plastic economy. This is essential since the current use of plastic in the economy impacts the environment beyond the planetary carrying capacity. To ensure that the forthcoming Treaty can provide the foundation for this transition, the best available science must be made available in the negotiations, but with no formal scientific mechanism to inform the negotiations process, this is not ensured. The Scientists' Coalition for an Effective Plastic Treaty serves as an example of how the global scientific community has self-organized and come together to address this task, working with five different categories of science-policy communication. The Scientists' Coalition's work is made transparent here with the hope that it can inspire organization of scientific input into other future policy areas.

The triple planetary crisis of climate change, biodiversity loss, and pollution is threatening the health of the planet and all its inhabitants. This unprecedented challenge requires strong partnerships where the relevant stakeholders come together to seek out responses. These responses must be built on a foundation of robust scientific evidence, which implies an understanding of the drivers and potential solutions to this crisis while avoiding misinformation which could lead to regrettable solutions. This will require robust independent science and knowledge systems that are free of conflicts of interest (CoI). Indeed, CoI is a central topic in international policymaking. For example, the United Nation's Working Group on Human Rights discusses the importance of strict CoI policies as a means to ensure balanced access and participation for all stakeholders in policy processes. The group mentions that strict CoI policies can be an important measure to ensure such participation. Disclosure of information that is supportive of the human rights to science and access to information will "ensure that environmental policy is driven by facts and evidence instead of denialism, greed, and profit." In the UN Special Rapporteur's report on the implications for human rights on sound management of hazardous chemicals several examples are provided showing the implications of not having sufficient CoI policies. These include the hazards of asbestos and certain pesticides not being sufficiently addressed. The report also mentions the plastics industries' portrayal of recycling as an allegedly sufficient means to control plastic pollution.

Science plays a pivotal role in guiding policymaking and promoting informed evidence-driven development of different policy landscapes. The science-policy interface can be defined as "social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making." Recent years have sometimes been referred to as a post-truth era where a growing disbelief in facts occurs, making the playing field for science-policy communication more difficult for scientists to engage in. This implies that experiences from successful ways of communicating science to policymakers are increasingly important and that such experiences should be documented to strengthen future efforts to ensure that future policymaking is also based on robust science. It further implies that means to avoid distrust in science should be taken where appropriate. Science funded by associated industries has been known to produce results "that are favorable to the sponsoring industry.” Examples are the tobacco industry and the food and beverage industry. It is important to stress that the majority of industry funded studies are good and robust science, but that organizations such as the UN and OECD recommend strong CoI policies to ensure that the science communicated to policymakers is indeed free of vested interests.

While the communication of science to policymakers is important across a broad range of topics, it is especially relevant for complex and transdisciplinary topics, and where scientific understanding is rapidly evolving, such as the issue of plastics. With an annual plastics production in excess of 400 million tons, distributed across almost all economic sectors, and with prospects to increase production exponentially in the future, the challenge of adequately regulating plastics pollution is of high global concern. Plastic pollution is a wicked problem, requiring inter- and transdisciplinary scientific insight into areas such as atmospheric, terrestrial, and aquatic pollution, material science, waste management, circular economy, health impacts, behavioral psychology, political science, anthropology, and economics, among other disciplines. Understandings within this field are constantly evolving as illustrated by the 1951 peer-reviewed articles published on the issue of plastic pollution in 2022 and 2023 alone (Web Of Science search conducted with “plastic pollution” as the search term on 24.04.24). At the same time, there is a lot of misinformation being spread by stakeholders with special interests, and a need to increase science communication regarding plastic pollution.

The aim of this perspectives article is to present the approach taken by the Scientists’ Coalition for an Effective Plastics Treaty (hereafter the Scientists’ Coalition). As explained below, the Scientists’ Coalition is a unique example of how scientists across different disciplines and regions of the world have come together with the common goal to disseminate science to negotiators of the UN plastics treaty, in order to provide the best possible scientific foundation for the negotiations. Within a relatively short period of time, the Scientists’ Coalition has obtained a significant status among negotiators and other stakeholders. Since its formation in early 2023, the Scientists’ Coalition has been mentioned in more than 50 news articles published by outlets such as The Guardian as well as scientific journals such as Nature, and it has provided expert contributions to several webinars hosted by entities such as United Nation Environmental Programme (UNEP) and an alliance of UN member state countries known as the High Ambition Coalition (HAC). The goal of the current article is to explain how the Scientists’ Coalition operates, by providing an insight into the dissemination strategy across the different forms of science-policy communication, thereby allowing these experiences to hopefully aid future science-policy processes and potentially inspire other scientists who wish to work together to provide the best possible science-policy communication.

The need to strengthen the science-policy interface for the prevention and mitigation of plastics pollution was raised more than a decade ago, and organizations such as UNEP have mandated scientific reports such as those produced by the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), which typically focused on the environmental implications of plastics pollution. The most recent international plastics pollution policy development is the adoption of the United Nations Environmental Assembly (UNEA) Resolution 5/14 “End Plastic Pollution” (UNEA 5/14). Executive Director of UNEP, Inger Anderson, illustrated the level of importance of the Resolution, referring to it as “the most significant environmental multilateral deal since the Paris Agreement.”

The mandate for the global plastics treaty was the culmination of negotiations through the previous four UNEAs, starting with the first in Nairobi 23–27 June 2014.

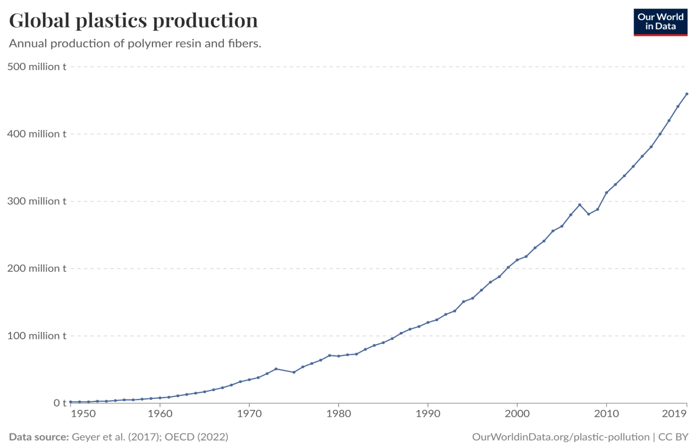
Initially, UNEP’s focus was on marine litter and microplastics as a threat to the marine environment. However, subsequent UNEA sessions (UNEA2 to UNEA5) expanded the scope to include plastic pollution in general, recognizing its presence in all ecosystems. One important outcome of this process was the establishment of a Government and Major Groups and Stakeholder nominated Scientific Advisory Committee on Marine Litter and Microplastics (SAC) to provide input and guidance into the scientific assessment requested by member states in Res. 4/6. SAC produced the scientific report “From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution,” which emphasized the need for urgent action and highlighted the contribution of global market failures. In the most recent resolution, Resolution 5/14, the scope is now “plastic pollution, including in the marine environment, Recognizing that plastic pollution includes microplastics and that plastic pollution can only be tackled through a ‘full-life-cycle approach’” (UNEA 5/14). The adoption of the Resolution has initiated an intense policy process to negotiate a global, legally binding plastics treaty before the end of 2024.

The Scientists’ Coalition is one of several entities providing scientific input to the negotiation process. Organizations such as GRID-Arendal (www.grida.no), the Science Advisory Committee, and the International Science Council (https://www.council.science/) and others all provide equally important input to the process. Similarly, different stakeholders such as the Business Coalition for an Effective Plastic Treaty (www.https://www.businessforplasticstreaty.org/) and NGOs such as Break Free From Plastic (www.https://www.breakfreefromplastic.org/) all provide scientific inputs to the negotiations process. Finally, several member states have scientific experts in their delegations, providing valuable scientific insights to shape and support the positions of the negotiators.

8. Policy Solutions and Risk Management

i. Reducing Plastic Production and Consumption

The amount of plastic produced worldwide every year has exploded in a human lifetime: From 2 million tons in 1950 to over 390 million tons in 2021. These are the plastics industry's own figures, production is expected to quadruple by 2050 (compared to 2019) to 1480 million tons.



This is almost three times the total weight of the current world population. An estimated 9.2 billion tons of plastics were produced from the 1950s to 2017. Just over a quarter of this is still in use and only 600 million tons have been recycled. Around 40% of all plastic products are thrown away within a month. Every year we fill the world with around 300 million tons of plastic waste.

Improving plastic waste management around the world - especially in poorer countries where most ocean plastics come from - is therefore critical to tackling this problem.

Plastic is ubiquitous in everyday social practices and few consumer activities do not involve its direct or indirect use. Single-use plastic (SUP) based on fossil fuels is particularly problematic because it seems almost unavoidable in everyday products, from plastic cucumber wrappers to shampoo bottles. While reducing SUP is crucial, there is little evidence that this is being achieved in everyday social practices. This paper explores the practicality of SUP reduction and consumer frustration. Using diary entries and workshops over two weeks, we examined the social practices of 20 adults. Our findings show that everyday practices shape SUP use and that reduction disrupts daily life, even for environmentally conscious consumers. Package-free stores are a popular approach to reducing SUP use. However, consumers are hindered from using this alternative by limited availability, convenience and product variety. Future research should explore the seamless integration of alternatives to reduce SUP into everyday social practices.

Packaging accounts for more than 40% of plastic waste.

Single-use plastics such as plastic bags, straws, cups, plates and utensils may only be used once, for a few minutes, but since plastics do not biodegrade, they will remain on the planet forever.

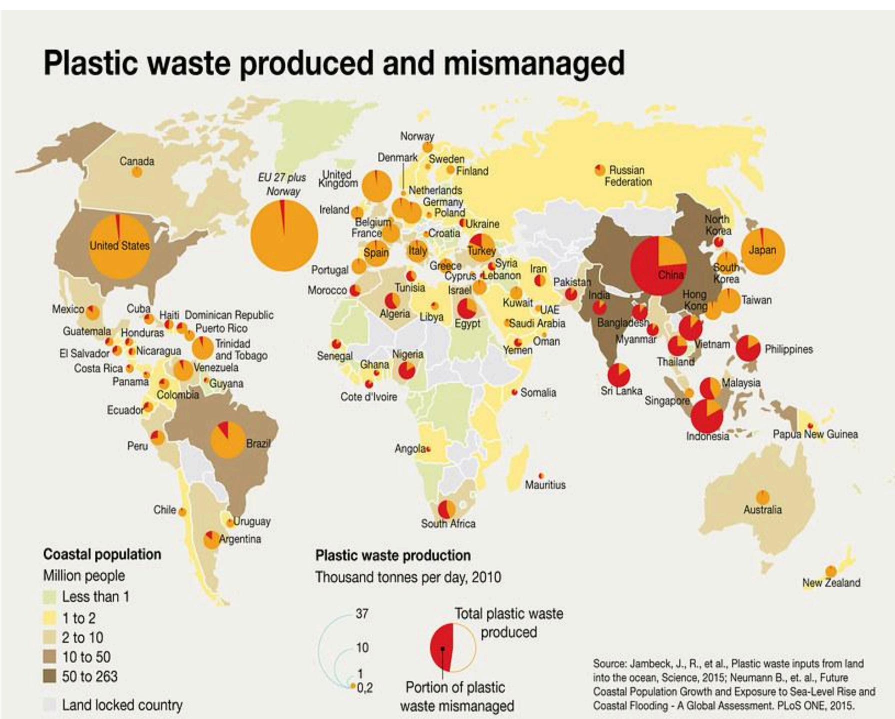
Another problem with plastic consumption that can be addressed through design and technology is the lack of knowledge on how to prevent plastic use. While recycling and reusing plastic waste are great ways to live sustainably, the best way is to reduce or avoid plastic consumption. Some plastics are unnecessarily more toxic, polluting and non-recyclable. Instead of seeking a recycling solution for these materials, they should all be reduced.

simplify and standardize plastic packaging and create innovative approaches to ensure that the plastics we need are reusable, recyclable or compostable.

A recent report by the nonprofit Beyond Plastics found that by 2021, the recycling rate for plastics in the US will have dropped to about 6 percent. While we may not find our way out of the plastics crisis through recycling, recycling is still important to reduce the footprint of our waste stream.

ii. Strengthening Waste Management Systems

While it is generally preferable to avoid generating plastic waste, once it is generated, managing it in an environmentally sound manner is essential for the protection of human health and the environment. Without proper collection and disposal systems,



plastic contaminates air, soil and water, harming ecosystems and people. Since the adoption of the amendments on plastic waste, the Basel Convention provides guidance for better management of plastic waste.

Since the 1950s, an estimated 9% of all plastic produced by humanity has been recycled. While there has been an increased interest in and development of plastic recycling systems and facilities, still only 14% of plastic waste is currently being collected for recycling. As plastic disposal in landfill and burning has damaging consequences on human and environmental health, recycling is increasing seen as having huge potential to tackle the plastic crisis. However, plastic recycling presents many challenges due to the nature of the material itself. Meanwhile, relying on recycling alone is not sufficient to solve the plastic crisis and address the full impacts of plastics across the value chain.

Plastic is primarily landfilled, recycled, or incinerated—each of which produces varying amounts of greenhouse gas emissions. Landfilling emits the least greenhouse gases on an absolute level, although it presents significant other risks. Recycling has a moderate emissions profile but displaces new virgin plastic on the market, making it advantageous from an emissions perspective. Incineration leads to extremely high emissions and is the primary driver of emissions from plastic waste management. Globally, the use of incineration in plastic waste management is poised to grow dramatically in the coming decades.

Besides playing an increasing role in packaging and consumer products plastics also take up a growing percentage of municipal solid waste streams and pose environmental challenges. Plastics have attracted severe criticism from the environmentalists because of its lack of biodegradability credentials. As widely known, plastic materials take about 100 to 1000 years to degrade when used in landfills besides polluting air and water around. Land availability will pose a challenge in many countries if landfill practice is continued and restrictions are now being put in place to curtail this approach. Besides, extremely thin plastic bags made from less than 20 micron thick films are choking the drains of many cities causing uncontrolled floods during rainy season. Plastics in garbage are estimated to be killing a million creatures in the sea every year. Plastic bags littering has lead to banned use of thin plastic bags by the consumer industry during retail sales of products in many countries.

Plastics in the waste stream are dealt with in one of three ways: incineration, burial, or recycling. Incineration, used to dispose about 16% of all municipal wastes in developed countries burn garbage in waste-to-energy facilities that use heat energy to generate steam or electricity. Because plastics are typically derived from petroleum or natural gas, they can generate almost as much energy as fuel oil, although the much higher amount of energy initially required to produce the plastic is lost. Potential hazardous emissions from incinerating plastics include hydrogen chloride, dioxin, cadmium, and fine particulate matter. Even with stricter air pollution standards in place, there is considerable public opposition to incineration.

Land filling plastics is generally a benign practice because plastics are chemically inert. Some additives to plastics do provoke concern as they may migrate from the plastics into the leachate. Plasticizers known as phthalates are hazardous substances and have been found in a number of leachate analyses at various concentrations. A more significant problem for land filling is that plastic wastes now constitute about 10% by weight and about 20% by volume of the municipal waste stream. Since plastics are essentially nondegradable, their volume will not shrink and plastics may eventually consume a disproportionate amount of landfill space.

Recycling is a four-part exercise of collecting a mix of plastics at curbside or drop-off centers, sorting the plastics into the six types, reclaiming the plastic by physically or chemically converting them to flakes or pellets, and then processing the flakes or pellets into a final product. One reason plastics are recycled less often than glass or metal is because the sorting step is very labor-intensive and, hence, expensive. However, the cost and accuracy of sorting are crucial elements in making plastics recycling economically viable because each type of plastic has different performance characteristics that make it best suited for specific applications.

iii. Regulatory Frameworks and Public Health Strategies

Health risks arise at all stages of the plastics life cycle, from production and use to recycling and disposal, as well as from old plastics in the environment. Increasing evidence on the consumption and inhalation of micro- and nano-plastics, concerns about exposure to hazardous chemicals used to impart certain properties to plastics, and the need for better waste management practices are at the center of the public health debate.

Consequently, the Seventy-sixth World Health Assembly called on Member States to support WHO to increase its work on plastics and health. It also encouraged contributions to the Intergovernmental Negotiating Committee (INC) convened by the Executive Director of the UN Environment Programme to develop a legally binding instrument on plastic pollution, including marine pollution.

Research based on plastics proves their injurious nature towards human health in many direct or indirect ways. Phthalates or phthalate esters are esters of phthalic acid mainly used as plasticizers (substances added to plastics to increase their flexibility) in Poly Vinyl Chloride (PVC). PVC is a widely used material, including extensive use in toys and other children's products such as chewy teethers, soft figures and inflatable toys. Di (2-ethylhexyl phthalate (DEHP), dibutyl phthalate (DBP), di-isononylphthalate (DINP), di-isodecyl phthalate (DIDP), benzyl - butyl - phthalate (BBP) and di-n- octyl- phthalate (DNOP) are phthalates mainly used in converting polyvinyl chloride (PVC) from a hard plastic to a flexible plastic. Phthalates migrate into the air, into food and into people including babies in their mother's wombs. Phthalates can be released from soft PVC by surface contact, especially where mechanical pressure is applied e.g. during chewing of a PVC teether). Release of phthalates during manufacture, use and disposal of PVC products, in addition to their use as additives in ink, perfumes etc. has lead to their ubiquitous distribution and abundance in the global environment.

Growing literature links many of the phthalates with a variety of adverse outcomes, including increased adiposity and insulin resistance, decreased anogenital distance in male infants, decreased levels of sex hormones, and other consequences for the human reproductive system, both for females and males, Infants and children may be especially vulnerable to the toxic effects of phthalates given their increased dosage per unit body surface area, immature metabolic system capability and developing endocrine and reproductive system. Legislatures and government agencies in Australia, Canada, the European Union, and the United States have restricted or prohibited the use of phthalates in consumer products Plastics industry generally asserts that Polyethylene terephthalate (PET) bottles are not a source of endocrine disruptors and must be distinguished from phthalate which acts as an additive and is chemically dissimilar. PET is most commonly used to make the clear plastic bottles in which bottled water is sold and as containers for soda beverages, sports drinks, and condiments such as vinegar and salad dressing. PET bottles are also commonly used for the packaging of cosmetic products, such as shampoo, particularly when such products are sold in clear plastic bottles. Indeed, phthalates are not used as substrates or precursors in the manufacture of PET but the available research suggests that the concentration of phthalates in the contents of PET bottles varies as a function of the contents of the bottle, with phthalates leaching into lower pH products such as soda and vinegar more readily than into bottled water. Temperature also appears to influence the leaching both of phthalates and of antimony from PET, with greater leaching at higher temperatures. Lower-pH condiments such as table vinegar and salad dressing may warrant particular attention. The findings suggest that ingesting several servings of salad dressing that had been stored in a warm warehouse for a month might result in a dose of di-(2-ethylhexyl) phthalate (DEHP) on the order of several hundred micrograms, possibly reaching the reference dose limit of 20 kg/day.

9. Promoting Public Awareness and Behavioral Change

Multi-layered governance among general citizens, governments, industries, NGOs, academia, fishers and local communities are fundamental to the prevention of the leakage of microplastics into the environment. Thus, promoting environmental literacy among youths and adults, as well as engaging stakeholders to advocate the reduction of plastic pollution, are essential strategies to tackle littering. Anti-littering campaigns, such as “Basuraleza” in the Basque Country and “Keep Britain Tidy” in the UK, can be underlined as behavior-shifting efforts. More specifically, the tailored ocean literacy tools could help to reduce microplastic contamination. For instance, the ResponSEAble project (https://www.responseable.eu/, accessed on 6 December 2020) tools successfully raised awareness among participants, triggered behavioral changes and minimized microplastic contamination from cosmetics and ballast water.

In light of this urge for behavioral changes, the Dutch government proposed to raise awareness of microplastic pollution in 2016 by fostering research, elaborating public procurements, enhancing media outreach and including microplastics as pollution indicators in abrasive cleaning agents of international certifications. Furthermore, Belgium developed a system to stress where industries could reduce primary microplastics use throughout their production system. Those actions combined with the worldwide concern of microplastic pollution have led to the ECHA proposal of a wide-range restriction on microplastics in Europe. When successful, this proposal will prevent the release of 500,000 tonnes of microplastics in the next 20 years.

Lack of knowledge is a hurdle to any behavioral changes. Citizens are generally unaware of microplastics pollution. However, Henderson and Green (2020) point out that some know about microbeads present in personal care products due to media outreach. However, only a few correlate their use of personal care products with microplastic pollution in the environment, highlighting that environmental awareness is more effective when the content aligns with the values and realities of people.

Media strategies and educational films emphasizing the issues arising from microplastic could increase social engagement. Moreover, mediatic campaigns linked to academic measures, e.g., MOOC on Marine Litter and Ocean Plastic Webinars, could support policymakers to trigger long-term behavioral changes through moral obligation. Although the media strategies are often related to the aquatic environment, these media efforts should target all environments (e.g., aquatic, aerial and terrestrial ecosystems) due to microplastic ubiquity.

One key aspect of raising awareness involves highlighting the contribution of daily consumer habits to microplastic pollution. For instance, single-use plastics, improper waste disposal, and the use of products containing microbeads, such as cosmetics and detergents, are significant contributors to microplastic contamination. Informing consumers about these sources can encourage behavioral changes, such as choosing sustainable alternatives and supporting products with environmentally friendly packaging.

Moreover, consumer awareness initiatives have the potential to drive broader societal and legislative changes. As public understanding of microplastics grows, so does the demand for policies aimed at mitigating their production and spread. For example, bans on microbeads in cosmetics and efforts to regulate plastic waste have often been driven by informed and engaged consumers advocating for change. This demonstrates how individual awareness can cascade into collective action, amplifying its impact on environmental sustainability.

Educational campaigns and awareness programs have proven effective in enhancing understanding of the microplastic problem. For instance, integrating microplastic education into school curricula or community workshops has been shown to significantly improve knowledge and inspire action. Studies reveal that individuals who are better informed about the environmental impacts of microplastics are more likely to adopt sustainable behaviors, such as reducing plastic use and participating in recycling programs.

Raising consumer awareness about the health risks associated with microplastics is critical as these pollutants have become pervasive in daily life, with potential long-term implications for human health. Microplastics have been detected in drinking water, food, and even the air, exposing individuals to risks of ingestion, inhalation, and dermal contact. Despite their ubiquity, public understanding of their health impacts remains limited, emphasizing the need for targeted education efforts.

Microplastics can carry harmful chemicals, such as endocrine-disrupting compounds and carcinogens, which may leach into the human body after ingestion. These chemicals have been linked to various health issues, including hormonal imbalances, developmental disorders, and even cancer. For instance, studies have shown that microplastics can serve as vectors for persistent organic pollutants (POPs), which are known to bioaccumulate and pose significant risks to human health. Increasing consumer awareness about these risks can encourage individuals to reduce their reliance on plastic products and support stricter regulations on plastic usage.

The presence of microplastics in food products, particularly seafood, highlights the need for consumer vigilance. A study found that microplastics were present in commonly consumed fish and shellfish, raising concerns about the cumulative health effects on consumers. Informing the public about such findings can drive behavioral change and increase demand for safer, more sustainable food production practices. Demand for safer production and consumption practices, such as sourcing food from areas with lower plastic contamination and supporting sustainable aquaculture.

Another concerning pathway of exposure is through the inhalation of airborne microplastics, which have been found in indoor and outdoor air. These particles can lodge in the respiratory system, potentially causing inflammation and other respiratory disorders. Public awareness campaigns highlighting these risks can encourage changes in behavior, such as minimizing the use of synthetic textiles that shed microplastics during washing and opting for natural materials instead.

Consumer awareness is a cornerstone of efforts to combat microplastic pollution. By understanding the origins, consequences, and solutions related to microplastics, individuals are empowered to make informed choices and advocate for sustainable practices. This, in turn, contributes to reducing the environmental harm posed by microplastics and fostering a healthier planet for future generations.

By understanding the health risks of microplastics, consumers can make informed decisions that protect not only their well-being but also the broader ecosystem. Education initiatives, supported by scientific evidence, can empower individuals to advocate for sustainable solutions and adopt healthier lifestyles. Enhanced consumer awareness can also contribute to collective efforts aimed at reducing plastic pollution and its associated health hazards.

The results showed a strong trend towards environmentally positive behaviors among participants. A large majority of them attempted to reduce single-use plastic and actively sought eco-friendly alternatives in their daily purchases. Many also participated in recycling programs, reflecting a clear individual commitment to reduce microplastic pollution.

Regarding public awareness, many participants followed news or awareness campaigns related to plastic pollution risks, indicating the importance of expanding these campaigns to increase general knowledge. While most participants understood the importance of changing consumption patterns to address microplastic pollution, more educational initiatives are needed to raise awareness overall.

The study also revealed strong support for government initiatives and community actions. Most participants supported governmental efforts to reduce plastic use in daily life and believed that institutions and companies are responsible for reducing plastic in their products. Many were also interested in participating in community activities to combat pollution.

Respondents demonstrated a strong understanding of the environmental and health risks associated with microplastics, particularly their impact on marine ecosystems and human health. Many showed eco-conscious behaviors such as reducing single-use plastics, recycling, and choosing sustainable alternatives. However, there remains a need to correct common misconceptions and improve public understanding about the sources and long-term effects of microplastics.

There is broad support for institutional responsibility and coordinated governmental action, and media campaigns and community initiatives could further strengthen both awareness and concrete action, especially among less informed segments of the population. Awareness campaigns should focus on correcting misunderstandings and deepening the public's understanding of the health and environmental impacts of microplastic pollution. Sustainable behavior can be encouraged by motivating individuals to take part in recycling programs and to choose alternatives to plastic.

This effort can be supported through educational campaigns that offer detailed information about the risks of microplastics via workshops, social media, and school education. Community engagement should be increased by encouraging participation in environmental programs and building a culture of sustainability. Policy efforts are needed to promote stronger regulations on single-use plastics and to support companies committed to sustainable practices. Effective use of both traditional and digital media will help share this information broadly and strengthen public involvement.

10. Questions to be Addressed

1) How can the Committee reduce the negative impact of microplastics on living creatures?

2) What measures can be taken internationally by the countries to reduce unconscious plastic consumption worldwide?
3) How to Stop the Global Distribution of Microplastics?
4) What can be done to raise public awareness about the dangers of microplastics?
5) What steps can be taken to strengthen waste management systems?

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