Microplastics and the impacts of the tobacco production chain

2nd revised edition,
based on the 2nd edition in Portuguese

CENTRO DE ESTUDOS SOBRE TABACO E SAÚDE – CETAB
ENSP • FIOCRUZ

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Ministry of Health

Oswaldo Cruz Foundation - Fiocruz

President
Mario Moreira

Director of the Sergio Arouca National School of Public Health - ENSP
Marco Menezes

Coordinator of the Center for Studies on Tobacco and Health - Cetab/ENSP
Silvana Rubano Turci

Coordinator of the WHO FCTC Knowledge Hub for Articles 17 and 18
Marcelo Moreno dos Reis

Text elaboration and organization
Milena Maciel de Carvalho

Collaboration
Breno Luiz Guilherme Gaspar
Germano Ehlert Pollnow
Marcelo Moreno dos Reis
Raquel Torres Gurgel
Vera Luiza da Costa e Silva

Reference standardization
Amanda dos Santos Callian

Text translation
Raquel Torres Gurgel

Cover image
Freepik and Adobe Stock

Design
Marcelo Moreno dos Reis
Raquel Torres Gurgel

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1. Overview

The theme of environmental impacts in their various forms has been one of the most important global discussions of our time. Topics such as climate change, disasters, food supply and security, ecosystem health, and plastic and microplastic pollution have been gaining increasing attention from researchers worldwide, as they significantly impact life on the planet. This material specifically addresses the issue of microplastics and the environmental impacts caused by the tobacco production chain.

Pollution and health impacts caused by microplastics are rarely attributed to tobacco products and related electronic devices, and in many cases, only discarded cigarette filters are mentioned. This makes this discussion even more urgent, especially because it contributes to the inclusion of more elements that reinforce the deleterious nature of these products.

As part of the tobacco control actions advocated by the WHO Framework Convention on Tobacco Control (WHO FCTC) (1) and as a way to support negotiations and decision-making for the United Nations Treaty to End Plastic Pollution, this document sheds light on important aspects of the tobacco production chain and its relationship with the environmental impacts generated by plastics and microplastics.

This became even more relevant after the Tenth session of the Conference of the Parties to the WHO FCTC (COP10), when decision FCTC/COP10(14) was adopted by consensus (2). The decision recognizes that "plastic cigarette filters are unnecessary, avoidable and problematic, single-use plastics" (2). It considers "the pollution of soil and water resources by waste from tobacco products and related electronic devices, including filters of cigarettes as well as batteries, plastic cartridges and metals" (2). Interventions made by WHO and the WHO FCTC Secretariat during the Intergovernmental Negotiating Committee on Plastic

Pollution (INC) have resulted in plastic cigarette filters to be proposed for inclusion in the initial list of problematic plastics. Furthermore, the decision also mentions that "WHO has recommended an immediate ban on cigarette filters and vaporizers in its submission to the Intergovernmental Negotiating Committee on Plastic Pollution" (2).

Given the relevance and variety of tobacco and related products and their environmental impacts, this report also covers the so-called novel and emerging nicotine and tobacco products, which includes heated tobacco products (HTPs) and products that do not contain tobacco, such as electronic nicotine delivery systems (ENDS) and electronic non-nicotine delivery systems (ENNDS). In this context, it should be noted that only HTPs are recognized as tobacco products by the COP8 (3) and are therefore subject to the provisions of the WHO FCTC. However, both classes of products are being considered in this document for having a harmful impact on the environment.

Another important event during the writing of this report was the fourth Intergovernmental Negotiating Conference (INC-4) of the United Nations Treaty to End Plastic Pollution (4,5). The defense of several countries for the complete ban on plastic filters in cigarettes and the mention of the WHO FCTC in their preambular text stand out. Concern about waste from electronic cigarettes has also been raised, especially due to the toxic composition of their batteries and other components, making waste management difficult.

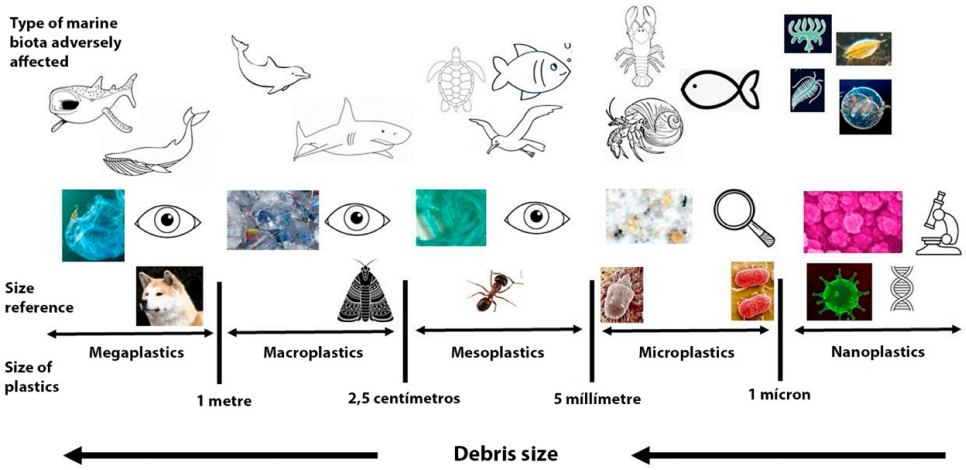
2. What are microplastics?

Plastics are composed of different types of synthetic polymers with a repetitive structure of organic molecules called monomers. This variety of polymers means that each one has a specific usefulness in industrial processes (6,7).

Microplastics are fragments of plastic with sizes ranging from 0.001 to 5 mm in length, composed of synthetic polymers that have low solubility in water and do not easily degrade. When they fragment into particles smaller than 0.001 mm, microplastics are referred to as nanoplastics (6–10). Therefore, they are plastics in smaller dimensions. Figure 1 illustrates the difference between the dimensions of plastics and their respective classifications. According to the authors, although scientifically more rigorous, the definitions presented in Figure 1 have not been formally proposed for adoption by the international research community (11).

Microplastics are derived from various sources and can be divided into two categories: primary and secondary sources. Primary microplastics are those released into the environment already as plastic fragments with sizes of 5 mm or less. They are manufactured in reduced sizes to be added to certain products, such as microbeads for cosmetics, toothpastes, and other personal care items. In addition to these types of products, they are also present in synthetic fabrics, paints, fertilizers, among others (12). Secondary microplastics are particles resulting from the degradation and fragmentation of larger plastics. Due to exposure to sunlight, wind, water, photochemical, and biological processes, larger plastics undergo degradation, reaching micro and millimeter dimensions. Examples of secondary microplastics include plastic waste generated from bottles, cigarette filters, among others (12).

Figure 1: Range of Plastic Sizes



Source: de Granda-Orive JI, Solano-Reina S, Jiménez-Ruiz CA, 2022, p. 396 (11).

They are mainly composed of polymers such as polyethylene, polystyrene, polypropylene, nylon, polyvinyl chloride (PVC), polyamide, and polyethylene terephthalate (13). An important aspect is that in the manufacture of plastics, in addition to the use of the main polymer, various chemical additives are used to increase their durability, mechanical, thermal, electrical and weather resistance, hardness, and ductility. This implies slower degradation in the environment when discarded, resulting in environmental damage due to its chemical composition, and greater spread of these particles in various environments (14).

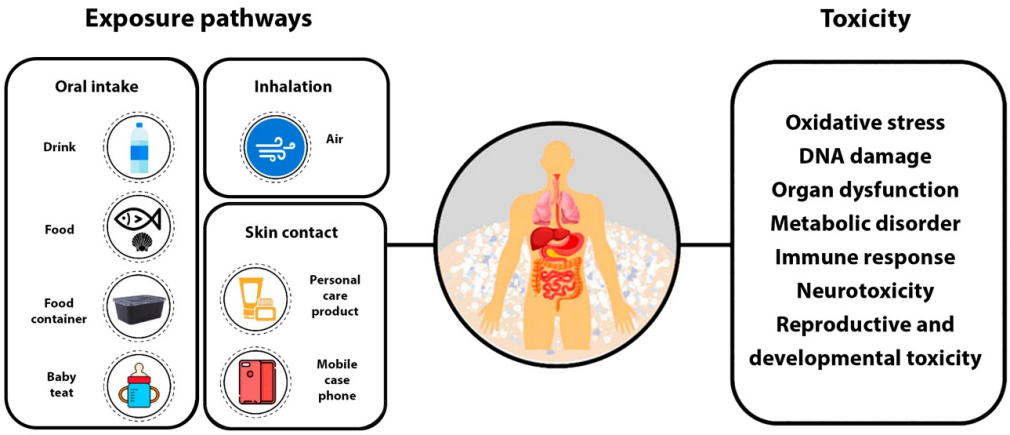
3. How do plastics and microplastics harm the environment and human health?

The presence of microplastics in the environment represents a serious problem for the planet, generating soil and water pollution and interfering with marine life, the food chain, water resources, air quality, food security, and the health of living beings (15–21). Studies from various fields have shown the presence of these microparticles in the air, soil, water, food, and animals (22–24). This discovery reinforces the urgent need to identify ways to reduce these impacts on the environment and human health and to intervene in the processes and behaviors that perpetuate this problem.

In 2019 and 2022, the WHO published two materials on micro and nano plastics, presenting evidence and analyzing the adverse effects of these particles on human health (25,26). Despite the limitations in available data on these effects, there is evidence of health risks due to their ingestion (25). In 2023, the World Health Assembly expressed concern about the presence of microplastics in the environment, which could cause potential impacts not only on human health, but also on plant and animal health (27). Studies have shown that microplastics have been found in the human body (such as in the lungs, blood, feces and placenta), which is worrying considering the composition of these materials (22–25) 19-21,25.

As shown in Figure 2, there are various sources of exposure to microplastics, and they often occur simultaneously, potentially causing harm to human health and environmental health. Microplastic particles can move between different environmental compartments. Human exposure can occur through oral ingestion, inhalation, and skin contact (8,28). Among the toxic effects caused by exposure, the following are highlighted: DNA damage, metabolic disorders, neurotoxic effects, alterations in brain development, intestinal damage, oxidative stress, infertility, among others (28,29).

Figure 2: Sources of exposure and toxicity of microplastics.



Source: Adapted from Li Y, Tao L, Wang Q, Wang F, Li G, Song M, 2023, p. 249 (28).

Chemicals found in microplastics can be of two types: additives and plastic raw materials (polymers) added during plastic manufacturing, and chemicals absorbed from the environment (14). The first type includes lubricants (calcium or magnesium stearates), dyes (many containing heavy metals), flame retardants (containing chlorine, bromine, phosphorus, and aluminum hydroxide), heat stabilizers, fillers, antioxidants, light stabilizers, and plasticizers. The combination of these additives results in a mixture of contaminants that alter the original characteristics of plastic and contaminate water, food, and air (14).

These chemical additives are known as one of the main causes of environmental imbalances, and according to some studies (14), when associated with microplastics, their environmental impacts are greater than when they are in isolated exposure periods. On average, commercial plastics consist of 93% polymer resin and 7% chemical additives (7).

As for chemicals absorbed from the environment into microplastics, these are diverse and exhibit high variability. Studies have been conducted to identify the relationship between microplastics and which substances are most absorbed, as in the study by Wang et al. (30), which analyzed the absorption of zinc and copper from anti-fouling paint into polystyrene and polyvinyl chloride (PVC). The researchers found that heavy metals from the paint were released into the water, and both types of microplastics absorbed the metals, with copper absorption being significantly higher in PVC particles (explained by their larger surface area and polarity). Throughout the experiment, metal concentrations increased in both types of microplastics, except for zinc in polystyrene (14,30,31).

A study conducted by the Institute of Environmental Systems Research at the University of Osnabrück, Germany (32), presented data on the ability of

microplastics to absorb toxic products in the oceans, including heavy metals and persistent organic pollutants (POPs). The latter can cause hormonal, immunological, neurological, and reproductive dysfunctions. Intoxication by these contaminants is propagated when smaller animals and plankton contaminated by plastic ingestion are ingested by larger fish, reaching human consumption and affecting the food chain (32,33).

The impacts of microplastics on the environment are more evident than those on human health, as presented in the First International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris (9), held at the University of Washington in 2008. In addition to reinforcing the highly harmful impacts of microplastics on nature, the proceedings of the workshop cite the risk of imbalance in the food chain as a serious problem. One example mentioned is the blockage of the digestive tract of small animals and the consequent contamination by toxic substances present in plastics (9,33).

According to the United Nations (UN), with more than 51 billion microplastic particles, the seas have 500 times more microplastics than our galaxy has stars (34). The UN draws attention to the fact that the ingestion of these microparticles by marine animals affect the food chain, as humans and other animals are part of it. In this sense, microplastics are associated with serious effects on human health, such as alterations in DNA, brain development, increased risk of certain types of cancer, and infertility (14,29,35–39).

Although information about the neurotoxicity of microplastics is limited, it is known that exposure to these microparticles can lead to inhibition of acetylcholinesterase activity and alterations in neurotransmitter levels (29). Additionally, it can cause oxidative stress - an imbalance caused by the accumulation of oxidizing agents (free radicals) and low levels of antioxidants to counteract them - a condition that can lead to cellular damage and increased susceptibility to the development of neuronal diseases (29).

Impacts on brain development occur when plastic microparticles reach the brain through absorption by the intestine, nasal cavity, or lungs. Once in the brain, these microparticles can induce oxidative stress, leading to cell damage and neuroinflammation. These conditions favor the emergence of neurodevelopmental and/or neurodegenerative disorders (29).

Intestinal damage caused by exposure to micro and nanoplastics occurs due to the absorption of chemical additives from these plastics, resulting in endocrine and inflammatory dysregulation, interference with the intestinal immune response, and intestinal diseases. Ingestion of these microparticles may pose a potential risk of inflammatory bowel disease due to the action of inflammatory cytokines (40).

While polymers have previously been considered inert in relation to metals, and studies on the impact of microplastics on human health are still in their infancy, it is possible to relate the interaction between heavy metals and microplastics and their effects on human health (14,31,41–46). Meanwhile, the effects on the environment are more robust, such as the recognition of microplastics as a persistent pollutant and vector for the proliferation of metals. Studies indicate, for example, the ability of metals present in microplastics to determine the co-selection of antibiotic-resistant human pathogens. In other words, the high concentration of metals such as zinc, mercury, and lead that accumulate in the environment leads to antibiotic resistance in bacteria (14). Table 1, adapted from Campanale (14), shows the potential effects on human health and the environment of heavy metals in plastic products.

Table 1: Main use of heavy metals as additives in plastic products and their impacts on human health and the environment

Heavy metals	Additives	Types of plastics where they are found	Impacts on human health	Impacts on the environment
Antimony (Sb)	Flame retardants and biocides (47–49).	It is found in a variety of polyethylene terephthalate (PET) or polyester-based products, such as food trays, water bottles, clothing, curtains, and backpacks (50). As an additive in colored pigments, it is common in toys and office equipment (50). It is found in non-PVC electrical equipment, such as chargers, heaters, remote controls, circuit boards (50). It is found in PVC products, such as plugs, wire insulation, USB connectors, hoses, pipes (50). It is recycled from electrical equipment: office equipment, toys, tool cables, new electrical products, items that come into contact with food (50).	Metalloestrogen: Associated with the occurrence of breast cancer (47–49). Human exposure, although considered low, can occur through the inhalation of particulate matter in the air, the ingestion of drinking water and food containing antimony, and skin contact with soil, water, and other substances containing it (51,52). Chronic inflammation in the lungs, chronic bronchitis, and emphysema are the main effects of long-term inhalation exposure. Acute exposure through inhalation causes irritation of the respiratory tract and lung damage, and in more severe cases, pulmonary edema. Heart problems, nausea, and vomiting have been linked to occupational exposure to antimony (52). There is potential toxicity and ecotoxicological effects derived from the presence of antimony in old plastics and discarded materials deposited in landfills. The International Agency for Research on Cancer (IARC) classifies antimony trioxide as Group 2B - possibly carcinogenic to humans (53).	It has the potential to primarily impact soil. Additionally, it can travel long distances in groundwater. In Europe and the European Union, waste containing antimony is considered ecotoxic and hazardous above certain concentrations, due to potential carcinogenic properties (50). Products derived from recycling, especially electronic plastic waste, still retain the present antimony, as current technology cannot remove it from plastics during recycling. For this reason, it is considered a widespread contaminant in marine litter and freshwater (50).

(table continued on next page)

Table 1: Main use of heavy metals as additives in plastic products and their impacts on human health and the environment (continued)

Heavy metals	Additives	Types of plastics where they are found	Impacts on human health	Impacts on the environment
Cobalt (Co)	Inorganic pigments (48,54,55).	PET bottles (polyethylene terephthalate) (48,54,55).	Formation of reactive oxygen species (ROS); neurological effects such as auditory and visual impairment; cardiovascular and endocrine deficits (48,54,55).Exposure to high levels of cobalt can cause adverse effects on blood, lungs, and skin (56). Based on studies conducted with humans and animals, the US Department of Health and Human Services (DHHS) classified cobalt and its ion-releasing compounds in the body as potentially carcinogenic (56).	The entry of cobalt into the environment occurs from natural sources and the burning of coal, oil, and cobalt alloy production. When released into water or soil, it adheres to other particles. Cobalt also mixes in the air with particles of other substances, falling to the ground within a few days (56).Cobalt mining also causes significant environmental impacts, such as habitat destruction and pollution of water and air (57).
Lead (Pb)	Thermal stabilizers, UV stabilizers, and inorganic pigments (47–49,54,58,59).	PVC and all types of plastics where red pigments are used (47–49,54,58,59).	Anemia; hypertension; spontaneous abortions; disruption of the nervous system; brain damage; infertility; oxidative stress, and cellular damage (47,48,54,58,59). Depending on the level of exposure, lead can cause harm to the nervous system, kidney function, immune system, reproductive, cardiovascular, and developmental systems, as well as affect the blood's oxygen transport capacity (60).Children and babies are more susceptible to lead exposure, as their nervous systems are more sensitive to its harmful effects. In addition to absorbing more lead than adults, they are more exposed by putting their hands and objects in their mouths. Some of the effects of this exposure in this age group are behavioral problems, learning difficulties, hyperactivity, slow growth, hearing problems, anemia, and decreased IQ (60).Adult exposure can lead to the following health effects: cardiovascular problems, increased blood pressure, hypertension incidence, decreased kidney function, reproductive problems in men and women, and risk of problems in the fetus for pregnant women (60).	High levels of lead in the environment can lead to decreased growth and reproduction of animals and plants, as well as neurological impacts on vertebrate animals (61). Due to the deposition of atmospheric lead pollution sources in soils, it is a persistent metal in the environment. Mining and discharge of waste into water resources are also sources of lead for ecosystems (61).

(table continued on next page)

Table 1: Main use of heavy metals as additives in plastic products and their impacts on human health and the environment (continued)

Heavy metals	Additives	Types of plastics where they are found	Impacts on human health	Impacts on the environment
Mercury (Hg)	Biocides (48,54,62, 63).	Polyurethane (48,54,62,63).	Mutagenic/carcinogenic; can induce molecular DNA structure rupture and brain damage (48,54,62,63).Health effects resulting from mercury exposure are determined by the amount, duration, and route of exposure, age, and presentation form (64,65).Mercury is a neurotoxin, meaning it is a poison that acts on the nervous system. It can affect brain and kidney functions. It can also result in permanent damage to children at birth (66).Health effects associated with mercury exposure include: eye, skin, and stomach irritation; coughing, chest pain, or difficulty breathing; insomnia, irritability, headache, weakness, or exhaustion, and weight loss. It is also associated with problems in the nervous, cardiovascular, gastrointestinal, hepatic, immune, neurological, renal, reproductive, and respiratory systems, as well as effects during organ development stages (67,68).Health effects from long-term exposure: anxiety, excessive shyness, anorexia, sleep problems, loss of appetite, irritability, fatigue, forgetfulness, tremors, changes in vision, changes in hearing (69).Health effects from short-term exposure: cough, sore throat, shortness of breath, chest pain, nausea, vomiting, diarrhea, increased blood pressure or heart rate, metallic taste in the mouth, eye irritation, headache, and vision problems (69).	Mercury exists in the environment in two forms: naturally, as ore and present in the Earth's crust; and through industrial waste discharge, leaching from landfills, and volatilization. Its release into the environment also occurs through industries, either through water or air (57,64).In water, bacteria transform mercury into a bioaccumulative and more toxic form, which accumulates along the aquatic food chain. Thus, mercury is found at high levels in fish, other aquatic organisms, rice, and vegetation (64,66,67).Furthermore, a study shows that microplastics and mercury, whether present alone or in combination, caused oxidative stress in the gills and liver of fish. The study indicates that microplastics influence the bioaccumulation of mercury by the studied fish and cause neurotoxicity, stress, oxidative damage, and alterations in enzyme activities in this species (D. labrax juveniles). Such findings reinforce concerns about the exposure of large aquatic predators and the consumption by humans of fish contaminated with microplastics and heavy metals (70).

Source: Adapted from Campanale C, Massarelli C, Savino I, Locaputo V, Uricchio VF, 2020, p. 11 (14).

It is believed that the primary form of exposure of living organisms to microplastics is the inhalation of these microparticles dispersed in the air. As previously mentioned, these microplastics reach the atmosphere through the washing of synthetic fabrics, industrial processes, the use of fertilizers, tire wear, and other sources (12). Smoking is also a form of inhalation of these particles (71).

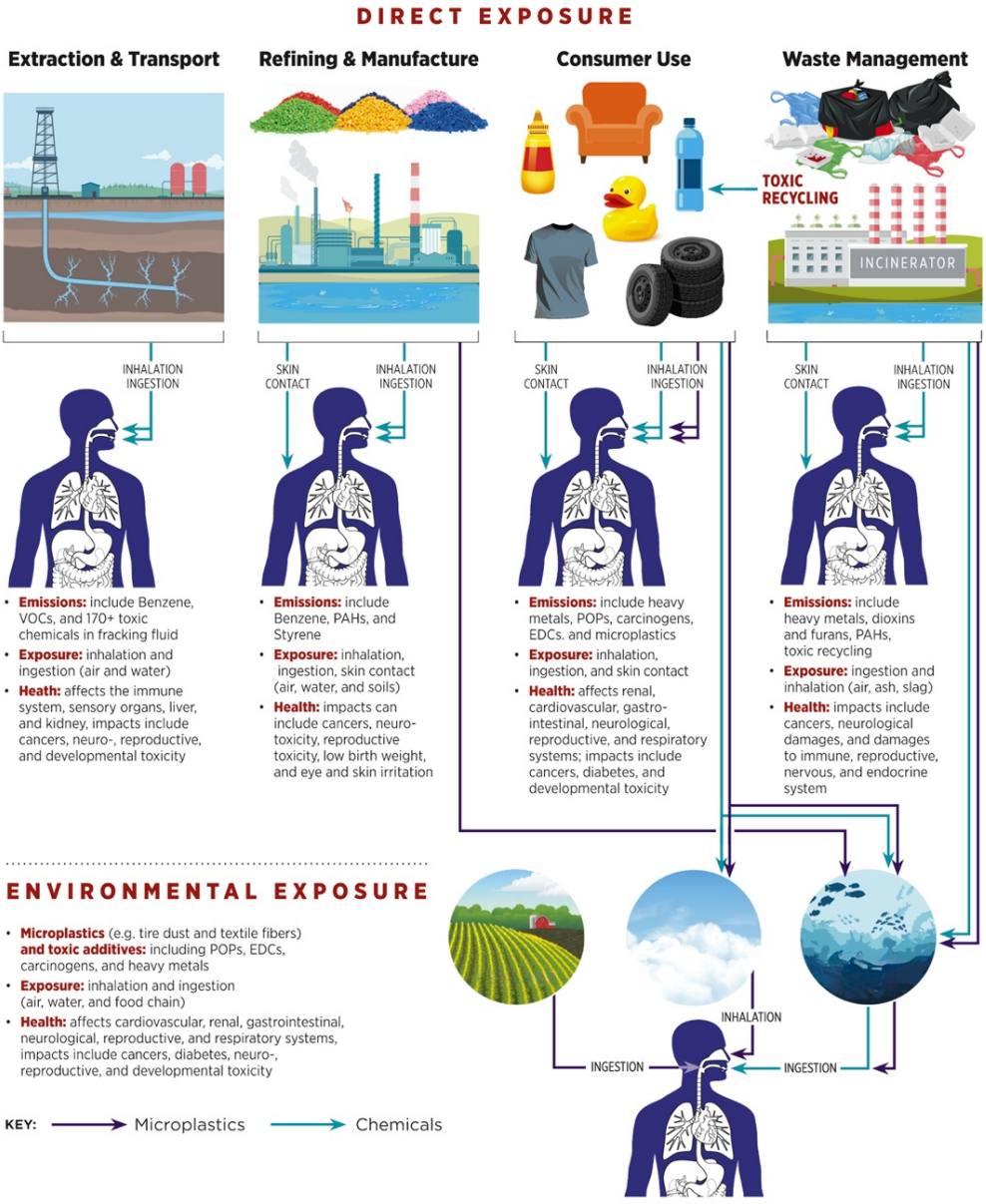
One study worthy of note was conducted at Princeton University and published in 2020 in Science Advances (72). The researchers discovered a process they

consider a new finding: microplastics are transported over long distances and become trapped in soil and other porous surfaces, moving when detached from these surfaces. Until then, it was thought that when microparticles became trapped, they remained in that state (72). The authors explain that there is a cyclical process of deposition and erosion. Microparticles accumulate, create obstructions on the surfaces where they are, and over time are broken down by the erosion process. As a result, they are moved through pore spaces and the obstructions rebuild. In this cyclical process where microparticles become trapped, accumulate deposits, and then are pushed, they end up dispersing over even greater distances and becoming fixed on other surfaces (72). The study's results are important for understanding the impacts of plastic pollution and intervening in the prevention of the spread and accumulation of contaminants in food and water sources (72).

Another relevant aspect is that the smaller the dimension of the plastics, the greater their capacity to absorb highly toxic substances, such as mercury, for example. In other words, the toxicity of plastics is related to the size of the particles and their composition, among other factors, with macroplastics having lower toxicity, microplastics intermediate toxicity, and nanoplastics higher toxicity, according to a study conducted in 2020 (73).

An interesting illustration, which shows the effects of plastics on health and the environment, is presented in the document Sowing a Plastic Planet: How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future, from 2022 (6). It reveals the ways in which humans are exposed to microplastics, through ingestion, inhalation, and direct skin contact, as well as forms of environmental exposure (Figure 3) (6).

Figure 3: Plastic and health: the hidden costs of a plastic planet



Source: Sowing a Plastic Planet: How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future, from CIEL, 2022, p.4 (6).

4. Microplastics and tobacco products: dual prejudicial association

With an estimated 4.5 trillion discarded cigarette butts annually, the most prevalent type of plastic waste in the world is cigarette filters (74). They account for 1.69 billion pounds of toxic trash annually (74). In addition to releasing over seven thousand toxic substances into the environment, they are non-biodegradable (74–77).

Regarding Article 18, in carrying out their obligations under the WHO FCTC, "the Parties agree to have due regard to the protection of the environment and the health of persons in relation to the environment in respect of tobacco cultivation and manufacture within their respective territories" (1). Implementing this Article involves thinking about strategies to reduce the environmental and human health damages resulting from the tobacco production chain. It is essential to understand that this protection against tobacco-related environmental damage is not restricted to producing countries but to all Parties to the treaty. The focus of implementing Article 18 primarily in producing countries needs to be addressed and changed, especially since environmental damages are identified in all stages of the production and consumption of tobacco products, not just in the cultivation and processing of leaves (78).

In 2022, WHO released the document Tobacco: Poisoning our planet (79), which reinforces the impacts of the tobacco lifecycle on the environment and health. In addition to the release of chemicals into the air, soil, and water resources, microplastics also have a harmful effect in this chain. The publication provides recent data on the tobacco production chain and the pollution from packaging and transport of toxic waste, water, air, and soil pollution, impacts on marine life, use of agrochemicals, carbon emissions, electronic waste from novel and emerging tobacco products, among other topics related to the impacts of the production cycle. It addresses, for example, newer electronic smoking devices and nicotine delivery products. They contain "metals, plastics and batteries which are

classified as toxic hazardous waste, whether they are littered into the environment or properly disposed of in a waste bin" (79). Some are made of disposable plastic and/or metal, producing solid waste that impacts landfills due to their toxic components. The disposal of electronic cigarette cartridges and batteries, for example, represents a major environmental concern.

Smokeless tobacco products (such as chewing tobacco and nicotine pouches) also are mentioned in the document as damage to the environment because they are "made of single-use plastic and metal for packaging, which produces solid waste and results in additional pressure on landfill, as well as toxic chemical leakage into the environment from landfill" (79).

Also, according to the document, "additional harm to the environment is caused by improper disposal of electronic waste (e-waste) from electronic nicotine delivery systems such as e-cigarettes, one-time use electronic cigarettes and heated tobacco products, which also generate toxic emissions and waste products. (...) The majority of plastic e-cigarette liquid cartridges are not reusable or recyclable and end up in gutters, streets and waterways. These products contain plastics, metal coils, atomizers, batteries, microcontroller chips and chargers. For example, the blade of an iQOS heated tobacco product is made of platinum and gold, coated in ceramic. Many of these products are single-use disposable products made with non-biodegradable and non-recyclable materials that can cause damage to the environment" (79).

In addition to them, cigarette filters made of cellulose acetate are significant contributors to environmental damage, because they can remain in the environment as microplastics for many years, releasing nicotine, heavy metals, and other chemicals absorbed by them during this period. The impact on the livelihood and health of fishing communities that depend on and consume contaminated products is also discussed (79).

The tobacco production and consumption chain consists of several stages. This document addresses leaf production, cigarette manufacturing, distribution, consumption, and disposal (80). The purpose of presenting these stages is to shed light on the presence of microplastics in this production and consumption system, as well as their direct and indirect impacts. In addition to the harmful nature of tobacco products themselves, this report adds more elements that corroborate the negative impacts of its production, highlighting its doubly detrimental characteristic.

Leaf production: In this initial phase of the production process, tobacco farmers use, in the vast majority of cases, fertilizers and pesticides, which not only cause harmful effects on people's health and the surrounding environment through direct and indirect contact with these products but also pollute water resources and soil,

impact animal and plant life, and release microplastics into the environment due to the composition of the agrochemicals used (79). Additionally, there is also the use of pesticides and fertilizers encapsulated in microplastics (6). Thus, microplastic pollution adds to the risks of the agrochemicals themselves, many of which are derived from petroleum-based raw materials. This coating with semi-permeable polymers allows for the controlled and slow release of the active ingredients present therein.

A report published in 2022 by the Center for International Environmental Law (CIEL), titled Sowing a Plastic Planet: How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future (6), highlights the increasingly deliberate use of microplastics in agrochemicals, their risks to human health and the environment, and the encouragement of various industries to this practice. According to the report, these products should be banned worldwide, as the known risks of fertilizers and pesticides are compounded by the fact that they contain microplastics - a combination of toxic chemicals (6).

It is not surprising that the agrochemical industry is "selling" the mistaken idea that the controlled/slow release of products is positive for the environment. According to the aforementioned report, companies market their products as originating from "sustainable and climate-friendly agriculture" (6). This makes their damages appear smaller than they really are.

Manufacturing: Plastics are used in various stages in the production of cigarettes and in the novel and emerging nicotine and tobacco products. These particles can be found in inks, aluminum, paper, and flavor capsules added to the products. In addition to the decomposition of plastic waste in the sea and runoff through pipes, plastics and microplastics enter lakes, oceans, rivers, and seas through industrial discharges (39,75,77,81). Unfortunately, the harmful effects on the environment caused by the production of these devices are still poorly documented (79). Therefore, studies that investigate further into these impacts are essential for more fruitful discoveries and interventions in the field.

Distribution: It is estimated that approximately 6 trillion cigarettes are marketed in about 300 billion packages each year (79). These packages contain paper, ink, glue, and BOPP (biaxially oriented polypropylene) plastic films, which turn into microplastics when degraded in the environment. These are called secondary microplastics, resulting from the degradation processes of materials that contain larger plastics in their composition. The waste from cigarette boxes and packaging used for the distribution of tobacco products accounted for at least 2 million tonnes of waste in 2021.

To provide an illustration, this amount is equivalent to the weight of more than 9,400 freight trains (75,79).

Consumption: Although little explored when it comes to impacts related to microplastics, some studies have indicated that these particles are inhaled during tobacco consumption, through cigarette smoke (72,82).

One of these studies, published in 2023 (71), confirms and extends the evidence on the presence of microplastics in the lower respiratory tract of smokers. It is one of the first studies – if not the first – to show exposure to microplastics through smoking behavior, combining a population study with an experimental method (71). The researchers analyzed two types of samples: 1) through bronchoalveolar lavage fluid (BALF), a liquid present in the human body responsible for irrigating the lower respiratory tract and which makes it possible to identify the distribution of substances present in the distal airways and 2) simulation of an active smoking model. BALF samples were collected from 17 smokers and 15 non-smokers in the city of Zhuhai, China. In the smoking simulation model, samples were analyzed from a group of 400 people, randomly divided into a smoke-exposed group (200) and a control group (200) (71). For those exposed to smoke, cigarettes were lit and smoked according to ISO 3308:2012 (83), which corresponds to a 35 ml puff lasting 2 seconds for 60 seconds (83,84). The control group followed the same procedure, but with the cigarettes extinguished (71,84).

The study identified high concentrations of total microplastics, polyurethane and silicone in BALF samples among smokers and in the group exposed to cigarette smoke, confirming the evidence on the existence of microplastics in the lower respiratory tract. They also observed relevant differences in the concentrations of total microplastics, polyurethane, silicone, polyethylene terephthalate, and polyethylene between the groups exposed to cigarette smoke and the control group, consistent with the results in the BALF samples (71).

The publication cites other similar studies showing that cigarette smoking can facilitate the inhalation of microplastics and favor concentrations of these particles in the respiratory system (71).

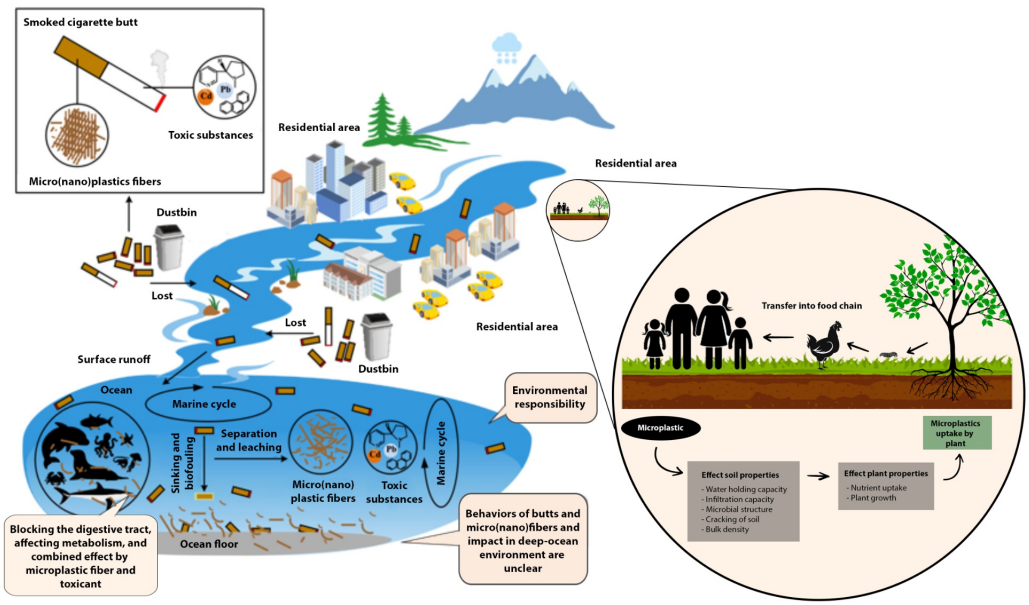
Polyurethane and silicone are materials commonly used in the manufacture of cigarettes, with polyurethane being associated with the manufacture of products related directly or indirectly to cigarette butts. The reason for its use is to alter the surface adhesion of the tipping paper (the outer coating of the cigarette filter that is in direct contact with the user's lip; used to join the tobacco stem to the tip of the filter) and to increase the resistance of the filters to water and heat. Silicone, on the other hand, is known for its flame retardant function, guaranteeing the safe burning of cigarettes. The authors believe that the high concentrations of these two substances in the human respiratory tract can be explained by the microplastics that are released from these cigarette-related products (71). Therefore, the relationship between smoking and inhaling microplastics needs to be considered in this discussion.

Disposal: Numerous studies and international campaigns have been dedicated to better understanding the impacts of cigarette butts on ecosystems (85,86). However, there is a lot to include when it comes to the disposal of cigarette products.

Cellulose acetate fibers are considered the most common type of plastic in cigarette filters. They take years to degrade and turn into plastic microparticles containing various chemical substances. Therefore, they impact ecosystems in different ways, either by contaminating soil and water resources, or by the absorption of plastics and microplastics by plant roots (87), fish, birds, turtles and other animals (39,75,76,79). Ingestion of these particles can cause asphyxiation, genetic and behavioral changes (39). There are estimates that around 300,000 tons of potential microplastic fibers can enter the aquatic environment every year from cigarette butts. Cigarette butts contain both the smoked filter and the rest of the unsmoked tobacco, and can have more than 15,000 strands with the potential to separate and become microfibers - one of the most common types of microplastic identified in the environment (88,89). One important aspect is that, in addition to exposure to these contaminants through the food chain (consumption of seafood), people can inhale microplastics through the air, ingest them through water and food and absorb them through the skin (39).

Figure 4 broadly shows the trajectory of cigarette filters and some of their impacts on the environment.

Figure 4: Potential destinations and effects of cigarette butts in the environment



Source: Adapted from de Granda-Orive JI, Solano-Reina S, Jiménez-Ruiz CA, 2022, p.396 (11), Shen M, Li Y, Song B, Zhou C, Gong J, Zeng G, 2021 (89); Bostan et al., 2023, p.5 (87).

Cigarette filters are a separate discussion, because apart from being made of a type of plastic that when degraded becomes microplastic, they don't make cigarettes any safer than those without a filter. In other words, there is no point in using filters (a reduction in harm, as the tobacco industry claims). One of the explanations for the use of cellulose acetate filters is the cheaper cost of the latter when compared to tobacco leaf, as well as the fact that it reduces the rigidity of the cigarette (90,91). In addition, the perforations in the tips of the filters can cause even more health risks, because they suggest that this is a way to reduce risks (90–93). These perforations in the filters allow the smoke to be diluted by the air that enters through these small openings, making them appear to have less nicotine, tar and carbon monoxide in the readings of the smoking machines to check the levels of these substances. However, when in use by the smoker, these holes are blocked, either by the smoker's lips or fingers, bringing concentrations of chemical substances that are different from the test conditions (92).

Another concern related to filters, more specifically cigarette butts, is the release of nanoparticles from cigarette smoke. These facilitate the movement of toxic metals onto surfaces and into the environment in general. In addition, exposure does not only occur when the cigarette is being smoked, but also through the cigarette butts, i.e. through the cigarette as waste. Carbonyls, hydrocarbons and pyrazines included in cigarette butts make them hazardous waste (94).

An increase in these waste impacts is being observed in relation to novel and emerging tobacco and nicotine products. The increase in disposable electronic devices has concerned scholars, as they are disposed of incorrectly and end up in landfills (94). Discarded electronic cigarettes, for example, affect the environment because of the plastic that is being left in the environment, the lithium batteries and the chemical residues contained in their capsules (such as nicotine and lead) (77,94–97). Both HTPs and ENDS/ENNDS are plastic products that can be disposable or reusable. Disposables (known as single-use plastics) are designed to have a short lifespan, which leads to recurrent disposal and rapid accumulation in the environment (96,97).

Reusable products, on the other hand, despite having a longer useful life, contain items that are disposable, such as plastic cartridges that need to be changed periodically and other materials. In this sense, these products generate even more impact on the environment, with new classes of plastic, cartridges and other polluting items and chemical substances all together (81,97–100). An aggravating factor is that these devices with nicotine and batteries cannot be recycled with other plastic waste, due to contamination from the nicotine itself and also from the lithium contained in the batteries (76,81,95).

As suggested by a publication in The Lancet in 2022 (101), electronic cigarettes are potentially more harmful to the environment because they generate three types of

waste: batteries, e-liquid containers and packaging (101,102). In other words, the impacts of electronic cigarette disposal add to an already worrying context of environmental damage (86). In addition, electronic cigarettes are produced according to the parameters of the countries that manufacture them and do not necessarily comply with the substance exposure legislation of the country in which they are consumed (100).

5. Sustainability? The inherent contradiction of the tobacco industry

Companies that produce goods detrimental to public health and the environment often engage in what is known as "Corporate Social Responsibility" (CSR) initiatives. These initiatives can create a facade of environmental sustainability and social responsibility, despite the fundamental harm caused by their core products.

For instance, the tobacco industry, in its attempt to project an image of environmental stewardship, has adopted measures such as the development of cigarette filters and programs aimed at collecting discarded cigarette butts from beaches. However, these actions are widely criticized for being ineffectual in mitigating the health risks associated with tobacco consumption (103). The introduction of cigarette filters has not been shown to significantly reduce the health risks of smoking (93). Similarly, beach clean-up campaigns for cigarette butts shift the responsibility for waste management onto consumers, circumventing the principle of extended producer responsibility (104).

Such CSR activities are often viewed as attempts to distract from the inherent contradictions in the company's core operations. The apparent commitment to social and environmental issues can serve as a strategic tool to enhance the company's public image while maintaining practices that cause significant harm.

In evaluating measures that ostensibly promote environmental sustainability, it is important to scrutinize their potential to perpetuate harmful cycles rather than do meaningful change. A case in point is the inclusion of cigarette filters within the framework of the circular economy (105). This type of model advocates forms of economy centered on the minimal use of new materials and the reuse of products, without this negatively affecting the well-being of the user. The circular economy aims to change the logic of production and consumption based on the "take-make-waste" model (106). Product innovations, reuse of materials, recycling and repair are also part of this model (95).

Cigarette filters, however, are problematic within this model due to the significant waste they generate annually. The large-scale removal of toxic substances from these filters is impractical and energy-intensive, and its efficacy remains unproven (105). Furthermore, any attempts by the tobacco industry to redesign filters or introduce alternatives to cellulose acetate filters may foster a misleading perception that these products have mitigated their harmful effects (75,76). For instance, biodegradable filters, while potentially reducing visual litter, continue to release toxic substances into the environment. Additionally, altering filter design could contravene regulations that restrict the tobacco industry's ability to produce visually appealing or innovative filter designs (105).

The term “inherent contradiction”, as utilized in the context of this discussion, was originally employed by WHO (107) to refer to the tobacco industry's CSR. Despite any initiatives by the industry aimed at mitigating environmental damage, the fundamental nature of industrial tobacco production ensures that it remains both an environmental pollutant and a persistent public health issue (100).

6. Treaties and global agendas on plastic pollution and tobacco

Given the serious impacts of microplastics on the environment and global health, it is urgent to combat this type of pollution and reduce the impact of the tobacco production and consumption process, including its new forms of commercialization, such as HTPs and ENDS/ENNDS. To this end, it is essential to adopt regulatory measures and joint actions among countries.

A major step in this direction was the adoption by the United Nations Environment Assembly (UNEA), in March 2022, of resolution 5/14, entitled *End plastic pollution: Towards an international legally binding instrument - UNEA Resolution 5/14* (108). This resolution was created with the aim of developing a global treaty on plastics. In it, the UNEA expresses concern about the increase in plastic pollution and its impacts on the social, economic, sustainable development and environmental dimensions. It recognizes the inclusion of microplastics in the context of global plastic pollution; reaffirms General Assembly resolution 70/1 of 2015, which adopted the Agenda 2030 for Sustainable Development (109); recalls the resolutions on marine plastic debris and microplastics (110), marine plastic litter and microplastics (111,112), marine litter and microplastics (113), environmentally sound waste management (114) and pollution by single-use plastic products (114). The document also talks about the urgency of strengthening global coordination, cooperation and governance for actions to eliminate plastic pollution in the marine environment and other environments in the long term, avoiding damage from plastic pollution to ecosystems and human beings (108).

As for the idea of a more sustainable world, the resolution reinforces the importance of products and materials that can be reused, remanufactured or recycled and the reduction of waste generation (108).

It also reaffirms the importance of complementing these discussions with other local and international normative instruments. To this end, the document

concludes by calling for a meeting with an intergovernmental negotiating committee, responsible for developing a legally binding international instrument on plastic pollution, which could include both binding and voluntary obligations (108).

Negotiations on the treaty have progressed rapidly, through meetings of the Intergovernmental Negotiating Committees (INC). The aim is for the treaty to include microplastics and the entire plastic life cycle (108,115). The Global Plastic Pollution Treaty is an international agreement proposed by UNEP to tackle plastic pollution in the world, which is considered a global crisis.

The INCs were convened by UNEP to develop this international instrument, which is expected to be ratified in 2024. At the first session of the Committee (INC-1), which took place at the end of 2022 in Punta del Este, Uruguay, in a hybrid format, the foundations were laid for the construction of the global agreement to combat plastic pollution (105).

The second session of the Committee (INC-2) was held in May and June 2023, in Paris. One of the resolutions was to prepare the zero draft, which would be developed by the INC President in conjunction with the INC Secretariat and then discussed at INC-3 (116,117). One of the highlights of this session was the mention of the WHO FCTC as one of the international treaties that needed to be integrated into the United Nations Treaty to End Plastic Pollution (117). Mention was also made of the disclosure obligations for producers under the WHO FCTC (105,117,118).

At the third session (INC-3), held in November 2023 in Nairobi, Kenya, delegates made proposals for texts to be included in the zero draft. Due to different interpretations of UNEA resolution 5/14 (108) on the complete life cycle of plastics, some delegates raised points in favor of measures on plastic production, others in favor of measures to dispose of plastic waste and another group advocated ways to guarantee lasting design standards for plastic products (108). UNEP's executive board reinforced the importance of this legally binding international instrument being based on a comprehensive approach that includes the entire plastic life cycle, considering the plastic value chain, from polymers to pollution (116).

INC-4 took place in Ottawa, Canada, in April 2024. During the negotiations, the World Health Organization, in partnership with the WHO FCTC Secretariat, issued a joint statement calling for the ban on cigarette filters and other plastic waste generated by disposable tobacco products. This declaration also requested that the INC acknowledge the decision adopted at COP10 relating to Article 18 of the FCTC/WHO (2). In addition to focusing on advancing the revised text of the treaty, discussions on waste management, financing, and problematic and avoidable plastics were highlighted during the session. Despite the participation of various

sectors of society in the session and action-oriented partnerships, concerns were also highlighted due to the resistance from some industry sectors, given the conflict between economic and environmental objectives, such as increased costs (4,5,119). One of the topics discussed was the impact of new smoking products, such as electronic cigarettes (5).

At INC-5, held from November 25 to 29, 2024, in Busan, South Korea, the proposal to ban cigarette filters made of plastic remained in an annex of the draft (120). The second part of the session (INC-5.2) is scheduled to take place from August 5 to 14, 2025, in Geneva, Switzerland, with regional consultations planned for the beginning of that period.

Regarding the decision adopted at COP10 relating to Article 18 of the WHO FCTC (2), mentioned in INC-4, the Parties to the WHO FCTC reaffirm the negative environmental impact of tobacco products and note that there is a need for greater collaboration between the WHO FCTC and the UN environmental agendas, including the negotiations on the UN Treaty to End Plastic Pollution. Some points of relevance to be included in its final text: 1) make reference to the WHO FCTC in its Preamble; 2) ensure that the implementation of measures such as extended producer responsibility (EPR) of tobacco products, circularity/ recycling, safe alternatives, incentives and stakeholder participation (private sector) is not used to undermine objectives of the WHO FCTC and its Article 5.3, thus singularizing the tobacco industry as an industry that cannot be recognized as a responsible producer or stakeholder; and 3) consider the pollution of soil and water resources also by waste from tobacco products and related electronic devices, including cigarette filters, as well as batteries, plastic cartridges and metals.

The historic FCTC/COP10(14) decision, among other measures: 1) urge Parties to take into account the environmental impacts from cultivation, manufacture, consumption and waste disposal of tobacco products and related electronic devices, and to strengthen the implementation of Article 18 of the WHO FCTC, including through national policies related to tobacco and/or protection of the environment; 2) invite Parties, under Article 19 of the WHO FCTC, to hold the tobacco industry accountable for the damage it causes to the environment and the adverse health effects on workers involved in the cultivation and manufacture of tobacco products, and the disposal and treatment of waste resulting from their manufacture and consumption; 3) encourage Parties to consider comprehensive regulatory options regarding filters in cigarettes and in other tobacco and related products, and their related electronic devices, taking into consideration their public health impacts and in accordance with national law.

European Union Directive 2019/904 (121) on reducing the impact of certain plastic products on the environment is an important example of a legislative act to tackle

plastic pollution. Its precepts include the need to reduce the environmental impact generated by post-consumer waste from tobacco products. It refers in particular to tobacco products with filters containing plastic, which are discarded directly into the environment. It reaffirms the problem that tobacco product filters containing plastic are the second most common single-use plastic product found on beaches in the European Union (121). Another aspect mentioned in the Directive concerns the extended producer responsibility regimes applied to tobacco products with filters containing plastic. With regard to post-consumer waste, the Directive establishes that Member States must promote measures to reduce waste from filters containing plastic (39,74,121).

When it comes to policies and regulations, it is also valuable to consider the MPOWER measures (122) and the Sustainable Development Goals (SDGs) (123). Being in line with these important global parameters helps us to guide actions in a more coordinated and effective way.

The MPOWER measures are part of a technical package of demand reduction measures, in line with the WHO FCTC measures, to support countries implement the treaty. It is a set of six strategic measures, which include monitoring the epidemic, epidemiological data and indicators of the effectiveness of the strategies. The six measures are: 1) Monitoring tobacco use and prevention policies; 2) Protecting people from tobacco smoke; 3) Offering help to quit tobacco use; 4) Warning about the dangers of tobacco; 5) Enforcing bans on tobacco advertising, promotion and sponsorship; and 6) Raising taxes on tobacco (122,124).

Its policy package, which serves as the basis for actions to reduce demand for tobacco products, could also be directed towards supporting actions to reduce tobacco-related environmental damage, as suggested in the publication "Using MPOWER policies to address tobacco impact on the environment" (78). Monitoring the environmental impact of tobacco and the residues of its products, in order to subsidize governments with this data; extension to outdoor areas when it comes to smoke-free environments (a way of reducing the contamination of soil and water resources by the residues of these products); inclusion of messages about the environmental damage of tobacco on the labels of nicotine and tobacco products; creation of educational campaigns to raise awareness about the environmental damage of tobacco; reinforcement of the ban on tobacco advertising, promotion and sponsorship in tobacco industry initiatives said to be in favor of environmental protection; application of corporate taxes as a way of minimizing the costs of environmental damage; and implementation of regulations aimed at extended producer responsibility in the tobacco industry (78). All of these examples of actions can be related to plastic pollution and, if implemented, can reduce the impacts caused by these products and processes.

As for holding the tobacco industry responsible for the damage caused to the environment, it is also advocated in the document "Policy options and recommendations on economically sustainable alternatives to tobacco growing (in relation to articles 17 and 18 of the WHO FCTC)" (125). This accountability can also be supported by taking into account the Article 19 of the WHO FCTC, which when addressing the possibility of Parties using the legal system to deal with tobacco industry's liability, would also include responsibilities for environmental damage (1,78). Therefore, it is understood that the accountability of the tobacco industry should also be an aspect included in the negotiations of the United Nations Treaty to End Plastic Pollution.

It is also important to align actions in this context with the SDGs – a global call for sustainable development and human rights. It is essential that actions against plastic pollution and its relationship with tobacco take into account the commitment to the 2030 Agenda, its 17 SDGs and 169 goals (123). In this regard, the mention of the WHO FCTC in SDG 3 -Good Health and Well-being - stands out, particularly Target 3.a: Strengthen the implementation of the Framework Convention on Tobacco Control in all countries, as appropriate (123). Also related to the impacts of microplastics and the production of tobacco products are the SDGs: 2: Zero hunger; 6: Clean water and sanitation; 12: Responsible consumption and production; 13: Climate action; 14: Life below water; and 15: Life on land (123).

Given the effects on human and animal health and the environmental impacts of plastics, the direct relationship with the SDGs mentioned is clear. Taking this relationship into account is in line with the countries' commitment to a more sustainable and healthy planet. In this sense, the Global Treaty under construction must take these important aspects into account.

Recommendations and call to action

The topic of microplastics associated with the tobacco production and consumption cycle is complex, not least because each topic in its essence already raises multidimensional issues. It requires the attention of researchers and legislators and awareness of the connection between tobacco, microplastics and environmental impact;

Society must be aware of the risks and impacts of the process of producing and consuming these products and be attentive to the intricacies of the industry. Waste management is fundamental, but there are processes that are independent of correct disposal or more sustainable manufacturing. Exposure to microplastics occurs invisibly, either through inhaling smoke with its chemical compounds and microparticles or by consuming contaminated food and water;

On a path of positive action, there are ways of dealing with these disturbing issues. Extended producer responsibility mechanisms are important resources, as they place the costs related to waste (collection, cleaning, etc.) under the extended responsibility of the industry and not the consumer or the population. In addition, establishing environmental taxes on the industry and also reducing tobacco consumption are aspects that need to progress every year;

Experts in the field of tobacco control are adamant that a total ban on cigarette filters is essential. Therefore, allowing the industry to develop alternatives to current filters would be a new problem - it would give rise to greenwashing and would lead to users' wrong risk perceptions about filters (37);

Cigarette filters, packaging and electronic devices related to tobacco products should be proposed and included in the United Nations Treaty to End Plastic Pollution. Considering that cigarette butts are one of the biggest plastic pollutants on the planet and that new tobacco products are characterized by having

batteries, refills, capsules and plastic chargers containing toxic chemicals, the impacts presented in this document are clear and need global interventions;

It is essential that not only filters, but also the association between the environmental impact of plastics and tobacco products and related electronic devices (like HTPs) be included in this international legally binding instrument on plastic pollution, since the toxic plastics present in these products pose a threat;

There is a need to recognize the relationship between plastic policies and tobacco control policies, especially the mitigation of the damage caused by the toxicity of the plastics in these products;

Intervening in tobacco control and the consequent reduction in the consumption of cigarettes and related products implies intervening in public health and the impacts on the environment, including plastic pollution;

It is necessary and urgent that the tobacco industry be held responsible for the environmental damage to the planet (and consequently to human and animal health), not only for what is most visible to the population, but also for the impacts caused by the tobacco production chain.

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