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Microplastics, physical-chemical and biological principles of this environmental liability

Abstract

The advent of plastic to the social situation has suppressed a series of demands from both the industry and the population, due to cost, durability and disposal. Because they can be rigid, malleable, opaque, translucent, easy or difficult to melt by the action of fire, some make them capable of serving as raw material for various products on the market, including those widely used in the food industry. In view of the above, the present study aims at a bibliographical review on the topic of microplastics, where the search will be to verify the primary and secondary steps necessary for the formation of the compound, its direct and indirect influence on food production, the physical-chemical processes through which compounds are obtained and the presence or absence of regulation regarding this environmental liability. The present study aims to analyze as a basis the search for knowledge of the primary and secondary formation of microplastics. Subsequently, together with its main objective, this study aims to search for the physico-chemical and thermodynamic phenomena involved in the process of formation and obtaining of microplastics, the polluting potential and, like all waste, its implications for human health. A study horizon was established covering the years 2015 to 2023, where 3,750 articles were found and after applying open access filters, duplication of publication, words present only in the abstract and not in the text, 49 articles remained that are the object of this study. The direct implications of microplastic pollution are already a relevant reason for discussion and subsequent regulation by managers, researchers, international organizations and society in general. Public health problems that can transform into microplastics, containment and adsorption mechanisms of these compounds in living organisms, are points to be pursued by academia as a whole. Contamination by these compounds was found in bottled mineral water, human milk, processed foods, seafood, showing the extent of contamination of this material.

Keywords: microplastics, contamination, regulation, environmental liability

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Introduction

With each social evolutionary circle, with the demands of each era, socio-cultural and economic problems common to all also arise. It was like this with the nomadic population that felt the need to settle in a fixed place, it was also the case with the observation that hunting, as population growth was latent, the resource faded, the need for labor to carry out the work, the accumulation of garbage that was not so felt before, but with the fixation of the people, it started to be noticed. Expansion of masses, commercial relations, work, consumption, waste generation, seems an infinite equation from the social point of view, although not from the environmental point of view, the solid waste generated today, bring with it a significant environmental liability. The growing consumption of domestic utensils that feed the energy matrix industry leveraged by fossil fuels in their by-products, namely plastics, may become the new environmental threshold.

Since they can be both rigid, malleable, opaque, translucent, easy and difficult to melt by the action of fire, some characteristics make them capable of serving as raw material for many products on the market, including those widely used in the food industry.[1] Thus, the industrial preference for the use of plastic packaging for most foodstuffs carries such a responsibility for contamination. The advent of plastic for the social situation came to suppress a series of demands from both the industry and the population, due to cost, durability and disposal. If in the not so distant past, plastics triggered several environmental problems due to their degradation time, today microplastics, physical and chemical derivations of this liability, are a more relevant problem to be solved. In view of the above, the present study aims at a bibliographic review on the subject of microplastics, where the search will be to verify the primary and secondary stages necessary for the formation of the compound, its direct and indirect influence on food production, the physical- chemicals by which the compounds are arrived at, and the presence or absence of regulation regarding this environmental liability.

Study objectives

The present study aims to analyze as a basis the search for knowledge of primary and secondary formation of microplastics. Successively, together with its main objective, this study aims at the search for the physical-chemical and thermodynamic phenomena involved in the process of forming and obtaining microplastics, the polluting potential and how all waste has its health implications for human beings (not excluding its daily environment or food consumption), the need for studies that support regulation of the productive sector that seeks protective mechanisms and inhibitors of this environmental liability.

Methodology

The objective of this study is to seek the answer to the question "What is the real importance of microplastics as environmental and human contaminants?" Bibliographic and documentary research was the main vehicle for obtaining and interpreting data. Review and research articles were selected and determined to be relevant to the present study.

To this end, a search for journals was carried out in available databases, such as Scopus Elsevier, Capes journal base, Springer, PubMed, PubChem and Google Scholar, with the keywords: oxidative degradation, crystallization of microplastics, polymers in food, pellets of microplastics, potential for microplastic contamination. The search range was limited to the period from 2015 to 2023, as this is the largest concentration of study publications and reviews on the subject. Initially, 3750 articles were found, which had open access as the initial criteria for elimination, as the Coordination for the Improvement of Higher Education Personnel (Capes), a body linked to the Brazilian Ministry of Education, does not have an agreement with all databases, which makes more comprehensive research unfeasible. At this initial point, 2250 articles were discarded, a second filter applied was the fact that only keywords were shown but the scope of the articles did not address the subject, 850 articles were discarded, and a further 350 were discarded for being duplicates. After applying all filters, the authors separated 49 articles of extreme relevance in addressing the topic mentioned. In addition, information from national and international documents (ABRE, Plastic Europe, etc.) was used, as well as reports from institutions and agencies (Ex.: Ministry of the Environment), publications in magazines and books.

Literature review

Microplastics

Initially suggested by Thompson[2] plastic particles, also called micro plastics, do not have an established universal definition, however in the literature they are referred to as particles of up to 5 mm in diameter, composed of polymers of different compositions, densities and shapes.[3] The world literature has received a large number of studies on microplastics[4] but this concern is not current, as Gregory[5] already showed the environmental and socioeconomic risk generated by this liability. As they also do Nawaz et al.[6] showing its direct effects on the marine ecosystem. In their study by Sabarish et al.[7] they deepen the discussion by showing the marine proliferation of textile fibers in the marine environment, their dimension between 5 and 7.8 mm, an understanding that was also previously discussed by Olivatto et al.[8] The authors also draw attention to another relevant point about the impact generated by non-recycled plastic, which are microplastics, particles smaller than 5 mm that have been found in water from lakes, rivers and oceans, thus assuming a greater polluting potential and well more comprehensive. They draw our attention about the ease of contamination in polyethylene biofilms through biofouling by microorganisms, which further highlights the concern with this environmental liability, as biofilms are in all primary packaging for food preservation.[9,10]

Oxidative degradation

The oxidative degradation of plastics in the formation of microplastics presented by Martin et al.[11,12] an autocatalysis process imposed by hydrogen atoms and which form hydroperoxides, showing the ease of breaking the stability of the plastic, as it is shown according to the authors, inversely proportional to the number of existing carbons in the molecule. When talking about degradation in the formation of microplastics, it is necessary to understand what is the final limit of this process, the cracking that occurs in plastic, vinyl, rubberized parts, has drawn the attention of research, mechanical stimuli, exposure to weather, photooxidation reactions are extremely relevant points for the formation of these compounds that favor the formation of the autocatalytic cycle, massifying the environmental liability through broken and dispersed particles, as shown in Figure 1. The question raised earlier about the limit of oxidative degradation is a key point in understanding the formation of microplastics, observing this premise Cholewinski et al.[13, 14] show in their studies relevant aspects of the contaminant level, its influence on the entire soil macrobiotic system, the methanogenic action for the enzymatic degradation of particles, and the possibility of generating a circular economy with this passive. The authors are very straightforward when they raise in their studies the potential for contamination generated by free radicals formed in the process described above and their chemical affinity to non-polar solvents.

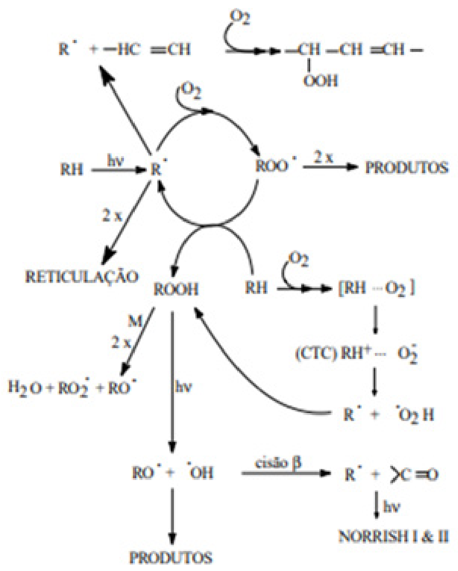

Figure 1 Photooxidation reaction of the polymer.

Chemically, catalysis or the catalytic cycle, a branch of materials chemistry, which emphasizes a surface or a catalytic species is regenerated in a reaction where a delicate balance of reactions is required for the reaction to be successful, and there are no significant changes in the reaction enthalpy energy or the total Gibbs free energy, since the new path proposed by the catalyst is activated with smaller Gibbs energies. The study by Oliveira et al.[15] pages 4,5 describes oxidative depolymerization catalyzed by metallic oxides of iron, titanium and cobalt at low temperatures and with or without incidence of UV light in rice husk biomass, in order to seek competitiveness in production. Already Padermshoke et al.[16] demonstrate in their study the possibility of inserting metallic compounds to accelerate oxidative degradation, although, the results obtained according to the authors for biodegradability are low. In a comparative study, Hernández et al.[17] present, using public domain software, arbitrary calculations of the properties of nanoplatelets, their scattering in light by their diffusion coefficient, which contributes significantly to the study of nanoparticles such as microplastics and their mathematical behavior of compound formation.

As plastic is a compound made up of long-chain polymers, they are subject to failures between monomers, these failures mainly in polyethylene terephthalate (PET) packages are predisposed to the phenomenon of ablation in their tapes, in the meantime Zhou et al.[18] contribute to the discussion raised here, showing that the thermo-oxygen degradation process can significantly help in solving these 'Failures' that occur in (PET) tapes, improving the resistance of the material, reducing capital costs, whether economic or environmental. What can be seen from these studies is that the process of oxidative degradation is similar to plastics, it forms secondary compounds due to the chemical structure of the plastic, it is a low-cost process that can occur with or without the incidence of UV light, but always related directly the partial pressures suffered by the object, in the presence or not of low-cost metallic catalysts, but always with low biodegradability. The role of oxidative degradation in different studies and scientific Kotha et al.[19–23] showing its capacity for electronic suppression of carbon molecules, the orbitals formed close to the spinel of the metallic catalyst, and its methodological advances in the treatment of groundwater through advanced oxidative processes (AOPs), in pharmacology, in metallurgy, showing its relevance through the aforementioned studies.

Crystallization

When dealing with inorganic chemical compounds, defects or imperfections of the compound cannot be ruled out, and their influence on its properties, such as: (i) mechanical resistance, (ii) electrical conductivity and chemical reactivity. This must be considered even in pure substances, as they have intrinsic and extrinsic defects. For organic compounds such as plastic resins, fragmentation is shown to be one of the ways that facilitate subsequent reactions forming stable carbocations to the detriment of the ionization potential of the compounds.[24] These findings show us that the free energy is in inorganic compounds or high spin, somatized to their formation energetic defects, the electronic proximity and consequently attraction and repulsion of electrons, as well as in organic compounds the stability of the carbocation formed in the synthesis reaction of the compound facilitates the increase of energy in the free volume of plastic resins.

Risks to human health

In recent studies they point out its presence in the atmosphere as particulate matter, demonstrate in a randomized study changes in the gastrointestinal epithelium in their study they typify, classify and point out the gateways of this environmental liability in living beings, its direct action on the soil microbiota and consequently its entry into the human body with several problems to human health. Thus, it appears that the negative range of action of microplastics on living beings is present and also consistent. Its risks are real and found everywhere so we have to agree that this is no longer just a warning, but a real problem. During the pandemic of the new corona virus studies show samples found in the cardiovascular epithelium, also point out its hematotoxicity induction and its interference in cellular homeostasis.

The food industry and its polymeric use

Plastic containers are widely used in the food industry mainly due to a lower risk of contamination, better production costs (cheaper) as well as protection and preservation of the food they contain. In the mid-1980s, such materials were almost 100% present in production lines Pires[25] thus making plastic a dominant material in our era. Therefore, materials such as Polypropylene (PP), Polyethylene (PE) or Polyethylene Terephthalate (PET) are commonly present in the foods that make up our daily lives. According to data from ABRE[26] the year 2017 reached the mark of R$71.5 billion for the physical production of packaging, with expectations of quadrupling the results in the following years (with the projection of such values reaching 7, 8 million tons by 2023) where the plastic packaging sector had a 38.85% share in said data.

It is a fact that the use of plastic containers has brought with it social improvements, such as the reduction of energy consumption, since materials such as glass and aluminum generate an energy expenditure of 57%, being responsible for GHG emissions of up to 61%.[27] A growing range of plastic packaging is microwaveable food containers (also encompassing *fast-food packaging*, etc.). These generally used for rapid heating, cooking and transport have intentionally added substances (AI's) which aim to improve the properties of polymeric materials.[28] AI's are usually bonded to the polymeric matrix with non-covalent bonds present in the packaging. However, a migratory effect reported by Fasano et al.[29] points to the release of chemicals present in polymers to food. According to data pointed out by the Ministry of the Environment (MMA), about 33.3% (1/3) of Brazilian domestic waste consists of packaging, where 80% of them are discarded after the first use without the correct destination (recycling). . Along with this, it is estimated that Brazil is the fourth largest consumer country in the *fast-food market*.[30] Since part of consumers have the habit of keeping food purchased in the original packaging, to consume it later, the act of a new exposure to adverse conditions in chemical or physical means tends to be responsible for a greater release of plastic particles in food.

Pollution in food by plastic particles

As the consumer's desire for different types of food grows, the industry tends to make new products available on the market to meet the created demand. Therefore, this demand generates a new concern in production lines: contamination by polymeric particles, that is, micro plastics. The presence of such microparticles may not be a reason for concern in the short term, however, bringing the perspective on a large scale, doubts arise about the free circulation of microplastics and their damage point to the release of plastic particles present in tea bags after infusion under high temperatures, thus indicating the polymeric release due to external influences (heat and mechanical forces). Wang et al.[31] analyzed algae consumption by thick-shell mussels and its physiological effects after exposure and consumption of the animals. The results obtained indicate that the consumed microplastics present in algae directly influence their metabolism (the energy balance is reduced and there is an increase in catalase activity and malondialdehyde levels - an oxidation action is expected in the long term and formation of free radicals). Previous research points to the transporting influence of particles, where the initial consumption of aquatic flora for nutrition will result in products carrying plastic particles, ready for consumption, that is, producers and final consumers are not able to identify the presence of such harm in their foods, since most of the polymers present represent toxicity to the human organism. Phuong et al.[32] estimate that almost 90% of plastics contain synthetic polymers whose excessive use carries with it the responsibility of serious environmental problems.

In studies such as Mason[33] an average of 10.4 plastic particles was reported in 1 L bottles of bottled water. The identified polymers constituted between 6.5 and 100 µm, which were generated during the mechanical packaging process. Since bottled water is considered totally hygienic, the same authors analyzed 11 different brands, where 93% of all the material analyzed showed signs of contamination by particles, breaking a possible question about microplastics being present only after the incidence of heat. Some reports presented by Chamas et al.[34] indicate photo oxidation of packaging and production of smaller particles and by-products when exposed to light in an oxygen-carrying environment. Such steps are likely to occur, especially when the polymer is accidentally modified or stored in inappropriate ways, resulting in deformity, even if minimal, of its structure.[35,36] Thus, when the polymer is irradiated (this step is very common in food industries) and the CH bonds are broken, free radicals are formed.[37]

Regulation for microplastics

In the 1990s, the main global concern with supplying water for industrial production, watering animals and humans, meeting basic needs, was conditioned by pathogenic microorganisms, as shown in Table 1. In 2011, as shown, Dieter[38] concern narrows to toxic substances such as cyanobacteria, lead, manganese, nitrates, nitrites, organochlorines, organophosphates. Following a timeline Brandt et al.[39] they present the regulation of the American Environmental Agency (EPA) dealing with the regulation, protection, organization and financing of the water supply in that country, stipulating rigorous levels of potability standards for consumption, establishing types of treatment. Closing briefly and non-discontinuously, Directive 2020/2184, which revises the quality of potable and marketable water, is to come into force from January 2024, the authors show points of relevance in the directive, as it establishes a standard for bisphenol of 2.5µg/l which was not specified in directive 98/83, and 0.5µg/l of perfluoroalkylated substances (PFAS). Over the course of three decades, there has been an intense movement in the bodies that protect health and the environment in the protection of biodiversity and human beings, moving away from pathogenic organisms, through chemical substances that are persistent organic pollutants (POPs), as well as Bisphenol is involved in the formation of microplastics.[40]

Table 1 Pathogenic microorganisms that can be found in water

Pathogenic	Importance for health	Persistence in water supply	Chlorine resistance	Relative infectious dose	Important animal reservoir
Bacterium					
Camplyobacter jejuni, C. coli	High	Moderate	Low	Moderate	Yes
Pathogenic *E. coli*	High	Moderate	Low	High	Yes
salmonella typhi	High	Moderate	Low	High	No
Other salmonella	High	long	Low	High	Yes
Shigella spp.	High	Short	Low	Moderate	No
Vibrio cholerae	High	Short	Low	Moderate	No
Yersina enterocolitica	High	long	Low	High (?)	No
Pseudomonas aeruginosa	Moderate	can multiply	Moderate	High (?)	No
		can multiply			
Aeromonas spp.	Moderate		Low	High (?)	No
Virus					
adenovirus	High		Moderate	Low	No
Enterovirus	High	long	Moderate	Low	No
Hepatitis A	High	?	Moderate	Low	No
Enterically transmitted non-A, non-B hepatitis viruses, hepatitis E	High	?	?	Low	No
norwalk virus					
Rotavirus	High	?	?	Low	No
small round virus	High	?	?	Moderate	No (?)
	Moderate	?	?	Low (?)	No
Protozoa					
Entamoeba histolytica	High	Moderate	High	Low	No
Giardia intestinalis	High	Moderate	High	Low	Yes
Cryptosporidium parvum	High	long	High	Low	Yes
Helminths					
Dracunculus medinensis	High	Moderate	Moderate	Low	Yes

Discussion

The direct implications of pollution with microplastics are already a relevant reason for discussion and subsequent regulation by managers, researchers, international organizations and society in general. The public health problems that microplastics can become have far greater consequences than one might imagine, since their accumulation in the bloodstream as a function of size due to the oxidative degradation of radicals formed by plastic compounds are true technological impasses due to the lack of calibration of clinical devices for this purpose. The research and development of image detectors, containment and adsorption mechanisms for these compounds in living organisms, are points to be pursued by the academy as a whole. The limitations of the research are shown in function, although the microplastics theme has been quite sought after, researched, and with an interesting range of works published and cited in databases available to researchers at the Graduate level, by thematic area and with the words mechanisms and degradation and microplastics in the period between 2019 and 2023 only 11 results were found, with the environmental thematic area having the largest volume with 6 published works. Thus, the results for food, oxidative degradation, chemical processes were repeated, few studies reflect the Brazilian reality in its dimensions, regions, social and economic problems and direction to effective public policies.

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Conflicts of interest

The authors declare that there is no conflicts of interest.

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