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POLLUTION BY SYNTHETIC NANO AND MICROPOLYMERS AND THE AGGRAVATION OF PROBLEMS OF THE HUMAN RESPIRATORY SYSTEM

POLUIÇÃO POR NANO E MICROPOLIMEROS SINTÉTICOS E O AGRAVAMENTO DE PROBLEMAS DO APARELHO RESPIRATÓRIO HUMANO

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ABSTRACT

Justification: The human respiratory system is very sensitive to any type of pollution from nanopolymers and micropolymers; their small suspended particles can cause inflammatory reactions or more complex pathologies, and in extreme cases, even death. Other organs are not immune to the effects of air pollution from nano and microplastics. **Objective:** Through a multidisciplinary approach provide healthcare professionals with knowledge, intervention, and guidance on the prevention and precautions related to air pollution from nano and micropolymers, including how the pollution process by nano and microplastics occurs and the risks of absorption by humans. **Methodology:** exploratory and explanatory, with part of the research carried out in the Medscape, SciELO and Virtual Health Library databases, using the descriptors: polymers/and/environmental impacts, micropolymers/and/human health, micropolymers/and/respiratory diseases, in English, Portuguese, Spanish and Italian, at any time, in addition to the authors' professional knowledge on the subject. **Conclusion:** The plastic era began in the mid-20th century, and although its use across all sectors of the economy may be irreversible, recycling programs are necessary to ensure a lower environmental impact and protect human health. Participatory public policies should be implemented, involving users, manufacturers, retailers, and governments to establish commitments to responsible use, collection, and recycling.

Keywords: Environmental chemistry; Medical chemistry; Respiratory system; Synthetic nanopolymers; Synthetic micropolymers; Anthropogenic environmental impacts.

RESUMO

Justificativa: O aparelho respiratório humano é muito sensível a

quaisquer tipos de poluição por nanopolímeros e micropolímeros, suas pequenas partículas em suspenção, já provocam reações inflamatórias ou alguma patologia mais complexas e, em risco extremo, até o óbito. Outros órgãos não estão imunes aos efeitos da poluição aérea por nano e microplásticos. **Objetivo:** Através de uma abordagem multidisciplinar fornecer aos profissionais de saúde conhecimento, intervenção e orientação sobre a prevenção e as precauções relacionadas à poluição do ar por nano e micropolímeros, incluindo como ocorre o processo de poluição por nano e microplásticos e os riscos de absorção pelos seres humanos. **Metodologia:** exploratória e explicativa, com parte da pesquisa realizada nas bases de dados Medscape, SciELO e Biblioteca Virtual em Saúde, utilizando os descritores: polímeros/e/impactos ambientais, micropolímeros/e/saúde humana, micropolímeros/e/doenças respiratórias, em inglês, português, espanhol e italiano, em período aberto, além do conhecimento profissionais dos autores sobre o tema. **Conclusão:** A era do plástico começou em meados do século XX e, embora seu uso em todos os setores da economia possa ser irreversível, programas de reciclagem são necessários para garantir menor impacto ambiental e proteger a saúde humana. Políticas públicas participativas devem ser implementadas, envolvendo usuários, fabricantes, varejistas e governos para estabelecer compromissos com o uso consciente, coleta e reciclagem responsáveis.
Palavras-chave: Química ambiental; Química médica; Aparelho respiratório; Nanopolímeros sintéticos; Micropolímeros sintéticos; Impactos ambientais antrópicos.

1. INTRODUCTION

The human respiratory system is highly sensitive to all types of air pollution; even small particles of suspended polymers can cause inflammatory reactions, contact dermatitis, rhinitis, asthma, sinusitis, anaphylaxis, etc., and, in persistent cases, chronic obstructive pulmonary disease, bronchitis, emphysema, lung cancer, among others. It is worth noting that death is an extreme risk. It should also be emphasised that other organs are not immune to the effects of air pollution from polymers, such as the heart, immune system, and brain. Nanopolymers (< 1 µm) and micropolymers (< 5 mm) contribute significantly to this due to their lightweight airborne suspension.

Given this, the objective of this paper is through a multidisciplinary approach provide healthcare professionals with knowledge to provide healthcare professionals with knowledge, intervention, and guidance on the prevention and precautions regarding air pollution from nano and micropolymers, as well as how the pollution process by nano and microplastics occurs and the risks of absorption by humans.

The methodology used was exploratory and explanatory, with part was researched in Medscape, SciELO and Virtual Health Library with the descriptors: polymers/and/Environmental impacts, Micropolymers/and/Human health, Micropolymers/and/Respiratory system, Polymers/and/Environmental impacts, Micropolymers/and/Human health, Micropolymers/and/Respiratory diseases, in English, Portuguese, Spanish and Italian, at any time, in addition to the authors' professional knowledge on the subject.

2. CHARACTERISATION OF POLYMERS

Synthetic polymers are alloplastics that have impacted nature since their development in 1862 by Alexander Parker to replace rubber. Considered as an emerging pollutant, begin to be produced on an industrial scale the beginning of the 20th century, which ended up being a synthetic or partially synthetic, economical and accessible option to replace glass, ceramics, metals, among others, in addition to being present in the packaging, textile, automotive, computer, medical equipment, robotics, colorants, furniture, toys, cosmetics, food industries, musical instruments, civil construction and various other industries, being part of humanity as a good and a necessary evil[1].

Richard Thompson, a marine scientist at the University of Plymouth in the US, coined the term microplastics in 2004 after finding piles of rice-sized pieces of plastic above the tide line on an English beach[2].

The presence of plastic, from various sources and in different sizes, including micro and nanoplastics, has been detected in various environments (aquatic, aerial, and soil). Several studies have linked plastic to several human diseases, having found it in the bloodstream, brain, kidneys, lungs, heart, gonads, placenta, among others, thus endangering human health.

Synthetic polymers are made from a complex combination of chemicals, including additives that give them strength and flexibility. Both the plastics and the chemical additives can be toxic. The most recent analysis identified more than 10,000 unique chemicals used in plastics, of which more than 2,400 are potentially concerning, according to Scott Coffin, a researcher at the California State Water Resources Control Board[2].

The synthetic polymers are hydrocarbons, can be vinyl ethylene acetate - EVA ($C_4H_6O_2$), polyamide - PA ($C_6H_{11}ON$), polyvinyl chloride - PVC ($(C_2H_3Cl)x$), polyethylene terephthalate or polyethylene terephthalate - PET ($(C_{10}H_8O_4)_n$), polystyrene - PS ($(C_6H_5C2H_3)x$), polytetrafluoroethylene - PTFE (CnF2n + 2), polyethylene or polyethylene - PE ($(CH_2\text{-}CH_2)n$), polymethyl methacrylate - PMMA ($(C_5O_2H_8)n$), polypropylene ($C_3H_6)n$) and others that, due to their biophysiomechanical properties, such as: low degradation, flexibility, non-electrical conduction, in many cases mouldable even during surgical procedures, are widely used in medicine and dentistry[1,3].

The increased production of plastics and the poor management of their waste have drastically increased the amount found in the environment[4]. Plastics are everywhere. More than 460 million metric tons of the material are produced annually, and almost all of it eventually degrades through external processes, such as friction and exposure to ultraviolet light, into microplastics (< 5 mm) and nanoplastics (< 1 µm). These tiny particles, along with chemicals derived from plastic, are almost omnipresent[5].

Plastic polymer pollution has been a global problem since 2016, when its production reached 322 million tons, excluding fibers. Daily discharges of microplastics are estimated to be in the range of 50,000 to 15 million particles, while there is still no information on the release of nanoplastics. Different processes degraded these materials even further, producing more microplastics and nanoplastics[6].

Plastic materials discarded into the environment have a certain relationship with global warming due to their chemical alteration and decomposition process, which releases substances into the environment. According to the United Nations Regional Information Centre for Western Europe, "...in addition to contributing negatively to the climate crisis (due to greenhouse gas emissions from its entire production process), plastic can seriously harm ecosystems"[7].

Current policies are fragmented, reactive rather than proactive, and fail to address the full spectrum of plastic pollution. For example, only 19 countries, including the Netherlands, Canada, United States, New Zealand, and United Kingdom, have banned microbeads. The very definition of microplastics is constantly evolving, with no universally accepted standard, leading to inconsistencies in regulation and compliance[5].

Microplastic concentrations in the environment vary between locations, from <100 to $>1 \times 10^6$ particles per cubic metre [4]. Microplastics have been detected all over the planet, from the peak of Mount Everest to the Mariana Trench. They can accumulate in the human body, posing a potential health risk. Microplastics enter the human body mainly through ingestion of food pollution (accumulation in shellfish or leaching through takeout containers and other plastic utensils that come into contact with food, such as baby bottles or silicone rubber spatulas), inhalation of small airborne particles, and skin exposure through cosmetic products or frequently touched plastic objects, such as cell phone cases[8].

Plastics enter the atmosphere through weathering or abrasion, dispersing microplastics globally[9]. Airborne particles can circle the globe in a matter of days and fall from the sky as rain[2]. Microplastics and nanoplastics can act as cloud condensation nuclei (CCNs) or ice nucleating particles (INPs), affecting cloud formation processes. In sufficient quantities, they could alter cloud albedo, precipitation, and lifespan, collectively impacting radiation equilibrium and Earth's climate[10]. Maritime expeditions to count microplastics in the ocean produce incomprehensible numbers, which have multiplied over time as more tons of plastic waste enter and disintegrate in the oceans every year[2].

While most of the atmospheric mass of microplastic pollution from marine sources remains within the planetary boundary layer (2–3 km) with an average concentration of about 10^{-3} to 10^{-2} $ng \cdot m^{-3}$, vertical transport of PM can extend into the free troposphere and, in some cases, penetrate the stratosphere. Vertical transport patterns show the average mass distribution, mainly linked to the transport of larger microplastic pollution (Dp = 25 μm and 50 μm). These particles can reach altitudes above the tropopause level (derived from the reanalysis of ERA5 data used to conduct the model), up to 20 km in some cases[11].

Risk assessment of microplastic pollution requires an understanding of biodegradation processes and related changes in polymer properties. In the environment, there are bidirectional interactions between microplastic properties and biofilm communities: microorganisms may prefer certain surfaces, and the surface properties of microplastics change during colonisation and weathering. Physical changes include aggregation and sorption of macromolecules, as well as mechanical abrasion of polymer surfaces, while chemical transformations of microplastics include, for example, photo-oxidation and hydrolysis, which can cause the rupture of the chain scission and alterations in the physical integrity of the polymer. Biological transformations occur in conjunction with physical and chemical changes and include the degradation and oxidation of the polymer by microorganisms living in association with the polymer surface in a complex multilayered community. The nature of microplastic transformations needs to be studied to understand the environmental risks posed by these contaminants[12].

The main mechanisms by which microplastics adsorb organic pollutants include hydrophobic interactions, partitioning, electrostatic interactions, and other non-covalent actions, and several mechanisms are frequently involved. Particle size, specific surface area, aging, crystallinity, functional groups, and polarity of microplastics affect their ability to adsorb organic pollutants. Furthermore, hydrophobicity, chlorine substitution number, and charge of organic pollutants, as well as environmental factors such as pH, temperature, and ionic strength, are important factors affecting the ability of microplastics to adsorb organic pollutants[13].

Environmental chemists have an important commitment in this area, as analytical protocols are constantly evolving and are mostly based on the application of techniques commonly used in materials analysis, but now adapted to the environmental context. Complementary techniques are necessary to answer the questions, making the choice of analytical methods strictly related to the research hypothesis, sampling logistics, and the complexity of the collected samples. Visual inspection has been more common for characterising microplastic in environmental samples; however, there is a significant trend and demand for chemical characterisation, driving the development of different analytical methods. Advances in characterisation are a consequence of the need to reduce the subjectivity of the analysis, made possible by advances in analytical instrumentation. Characterisation has become more precise in avoiding false positives, as well as increasing productivity through the possibility of analysing increasingly smaller microplastics with faster and more modern techniques, such as μ-FPA-FTIR and TED-GC-MS[14].

3. MICRO AND NANOPOLYMERS IN HUMAN LUNG HEALTH

In the human health, nano/microplastics are emerging contaminants of human origin with worldwide occurrence. Their small size (below one micrometre), different chemical nature, and persistence make nano/microplastics potential hazards with a probability of penetration and inflammation in tissues or as toxin accumulators[15].

In the United Kingdom, at the University of Hull, a study on lungs showed how intrusive airborne particles are. Scientists expected to find plastic fibres in the lungs of surgical patients – previous research had documented them in cadavers – but were surprised to find the largest number, of various shapes and sizes, embedded deep in the lower lung lobe. One of the fibres was two millimetres long [2].

Microplastic fibres present in the ambient air can be inhaled into the lungs and promote a range of complications including oxidative stress, local injury, and cytotoxicity, but data on the effects of microplastic fibres on individuals with obstructive lung diseases are limited, wrote Magdalena Poplinska-Goryca, MD, of the Medical University of Warsaw, Warsaw, Poland, and colleagues[16].

Zhu and team studied microplastic exposure through the respiratory and digestive systems, using laser direct infrared spectroscopy to identify microplastics with size > 20 μm in different human tissues. And they identified that microplastics of 20–100 μm were concentrated in all tissues, with polyvinyl chloride (PVC) being the dominant polymer. The highest quantity of microplastics was detected in lung tissue with an average of 14.19 ± 14.57 particles/g, followed by those in the small intestine, large intestine and tonsil (9.45 ± 13.13, 7.91 ± 7.00 and 6.03 ± 7.37 particles/g, respectively). The amount of microplastics was significantly higher in women than in men ($p < 0.05$). Despite the significant diversity, the estimate showed that the lungs accumulated greater amounts of microplastic. Additionally, PVC particles can pose potential health risks due to their high polymer hazard index and maximum hazard level[17].

Some fibrous microplastics and nanoplastics can be inhaled. Most of them will likely undergo mucociliary clearance; however, some may persist in the lungs, causing localised biological responses, including inflammation, especially in individuals with compromised clearance mechanisms. Associated contaminants, such as polycyclic aromatic hydrocarbons (PAHs), can be dissolved and lead to genotoxicity, while the plastic itself and its additives (dyes, plasticisers) can lead to health effects, including reproductive toxicity, carcinogenicity, and mutagenicity[18].

Due to their small size, they can be inhaled and induce respiratory system injuries depending on individual susceptibility and particle properties. Although airborne microplastics are a new topic, several observational studies have reported the inhalation of plastic fibres and particles, especially in exposed workers, frequently presenting with dyspnea caused by inflammatory responses of the airways and interstitial spaces. Even if environmental concentrations are low, susceptible individuals may be at risk of developing similar lesions[19].

Although microplastics and human health is an emerging field, existing complementary fields indicate potential risks from particulate matter, chemicals, and microbials. If inhaled or ingested, microplastics can accumulate and exert localised particulate toxicity, inducing or enhancing an immune response. Chemical toxicity can occur due to localised leaching of component monomers, endogenous additives, and adsorbed environmental pollutants. Chronic exposure is anticipated to be of greater concern due to the cumulative effect that can occur[20].

In the report by Moulun it is evident that microplastics also accumulate in organs. Thus, the amount of plastic in the lungs increases with age, suggesting that the particles may be bioaccumulative. The consequences for health are still poorly understood, but exposure to plastics appears to cause changes in the composition of the intestinal microbiota. Furthermore, a decrease in butyrate, a short-chain fatty acid beneficial to health, was observed in children's intestines. Inhaled nanoplastics can disrupt mucociliary clearance mechanisms of the respiratory system. The toxicity of inhaled plastic particles was demonstrated as early as the 1970s among workers in the flocking industry. Some developed impaired lung function, shortness of breath, inflammation, fibrosis and even lung cancer. Similar symptoms have been observed in workers in the textile and polyvinyl chloride industries [21].

4. SOME SOLUTIONS

Until now, no method has been reported for removing microplastics and nanoplastics from the human body. But, for the first time, they demonstrate that extracorporeal therapeutic apheresis may have this capability. However, larger patient groups and quantitative analyses, such as gas chromatography-pyrolysis coupled with mass spectrometry, are needed to confirm the effective removal of microplastics and nanoplastics through therapeutic apheresis. This should include measuring microplastic and nanoplastic levels in plasma samples before and after apheresis, as well as in eluates, across multiple cycles. These analyses will help determine the removal of particles from blood and tissues and assess correlations with symptom improvement in conditions such as ME/CFS[22].

If there is no control over the use of polymers, micropolymers, and nanopolymers, and no establishment of methods for removing and recycling those found in compartmental media such as air, soil, and water, then any methods that may emerge to remove this product from the human body will be ineffective, as a vicious cycle of removal and recontamination will occur, causing constant damage to health and costly treatments.

One particularly important aspect that can be attributed to the low recycling rate is the fact that many of these materials have been used in the production of so-called "single-use" plastics, such as disposable plastics, which are mostly difficult to recycle and represent a significant portion of global plastic pollution. [14].

The US Food and Drug Administration (FDA) announced the removal of the endocrine-disrupting chemicals (EDCs) per- and polyfluoroalkyl substances (PFAS) from food packaging. Issued on 28 February 2024, "this means the major source of dietary exposure to PFAS from food packaging like fast-food wrappers, microwave popcorn bags, take-out paperboard containers, and pet food bags is being eliminated," the FDA said in a statement[23].

Policies aimed at reducing human health risks from EDCs have included the 2022 Plastics Treaty, a resolution adopted by 175 countries at the United Nations Environmental Assembly that "may be a significant step toward global control of plastics and elimination of threats from exposures to EDCs in plastics," the report said[23].

The food industry can reduce microplastic emissions with simple, yet effective, and efficient actions. The MedScape report from 11 July 2025 suggests that: "Manufacturers can significantly reduce microplastic levels by implementing simple measures like washing caps before sealing bottles"[24].

It's worth remembering that many polymers can be reused, giving them a different purpose than environmental pollution. Recycling these materials result in a variety of products, such as: non-ceramic bricks, pipes, doors and Windows for use in civil construction, vehicle parts, furniture for homes and offices, broom bristles made from recycled polyethylene terephthalate from soft drink bottles, among many others. However, there are still polymers that are not recyclable or are difficult to recycle, in addition to excessive consumerism, which has a strong impact on the environment.

5. CONCLUSION

The plastics era began in the mid-20th century, and while its use in all sectors of the economy may be irreversible, recycling programs are necessary, encompassing everything from plastic bags, widely used in South America, to blister packs for pharmaceutical products, among others, to ensure less environmental impact and protect human health. Participatory public policies must be implemented, involving users, manufacturers, retailers, and governments to establish commitments to conscious use and responsible collection and recycling.

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