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Microplastics and Nanoplastics in Antarctica. Considerations on Their Impact on Ecosystems and Human and Fauna Health

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Abstract **-** In recent years, microplastics and nanoplastics have been identified in a range of remote environments, including Antarctica. However, data throughout the Southern Hemisphere, particularly Antarctica, are largely absent. Microplastics and nanoplastics have negative effects on marine organisms and act as vectors for persistent organic pollutants and other toxic substances, which are harmful to aquatic environments and organisms. Microplastics and nanoplastics also pose serious problems for human health, especially due to its nanotoxic capacity, of which the mechanisms are not yet fully established. Microplastics and nanoplastics have been recognized as widespread pollutants in the marine environment and are known to be damaging to terrestrial and aquatic ecosystems, while their small size and relatively low density also allow them to become airborne and transported over large distances. This work summarizes the results of different research carried out by the various Antarctic programs in marine and terrestrial ecosystems of Antarctica. In addition, we analyze the knowlege about potencial nanotoxicity of nanoplastics and underscore the need for further research and development in this field.

Keywords**:** nanoplastics, microplastics, Antarctic enviroment, nanotoxicity.

1. Introduction

The environment and ecosystems of the Antarctic Continent and its surrounding seas are influenced by phenomena such as atmospheric and oceanic circulation acting on a global scale, as well as by human activities or processes that cause physical or ecological changes at specific locations. These influences, or drivers of ecosystem change, can act in different ways in different regions, operate at different spatial scales and rates of change, and often interact with each other.

Antarctica is currently affected by the impacts of global forcing, understood as processes or variables that are larger in geographic scope than the Antarctic continent but significantly affect its conditions. Since 1970, changes in the ozone layer, changes in air circulation, in the Southern Annular Mode (SAM), and the effects of the El Niño phenomenon had notorious impacts on Antarctic ecosystems [1]. Among the expected impacts of these global forcing effects are the loss of ice shelves and sea ice, glacier retreat, and ocean acidification and warming, among others [1].

Local forcings, defined as those influencing ecosystems in a given location or series of locations, that currently significantly impact their Antarctic ecosystems are pollution (marine and terrestrial), non-native species (NNS), tourism and other human visitation, recovery of previously exploited marine mammals, fisheries, and coastal changes due to ice loss and erosion caused by icebergs [2].

Pollution, both marine and terrestrial, is one of the local impacts that has grown in importance and concern in recent years. Within this, microplastic pollution has become a critical area of research based on the results that have been found in recent years. According to recent works this type of contaminants which have been detected in microplastics have been found in pelagic waters [3,4], shallow marine sediments [5], benthic invertebrates [6], pelagic invertebrates [7], seals [8] and penguins [9].

Recent atmospheric transport models indicate that Antarctica is a net importer of microplastics, and that the flux of microplastics from poorly managed plastic waste in the ocean that are transferred to the atmosphere at the Antarctic coast probably exceeds the anthropogenic sources of microplastics on the continent [10]. For all these reasons, there is growing concern about this environmental pressure in the Committee on Environmental Protection of the Antarctic

Treaty and therefore the topic has been established among its priority lines of work and research. The objective of this paper is to survey the state of the problem of plastic pollution (macro, micro or nanoplastics) in Antarctic ecosystems through a literature review of the studies carried out to establish potential risk scenarios for human health and possible future lines of research.

2. Methods

To study the status of plastic pollution in Antarctica we conducted an exhaustive search in journals, bibliographic databases and databases generated by Antarctic scientific entities (SCAR, COMNAP). The response variable of interest in any study was the detection of the presence of some type of plastic in Antarctica. It were classified into macroplastics (>1 cm), mesoplastics (5-10 mm), microplastics (if 1-5000 μm) and nanoplastics (if <1 μm). Once the work was obtained, the type of contaminated environment (marine, coastal, terrestrial), the proximity to scientific stations, the impact on fauna and flora (direct and indirect) and the impact on humans (direct or indirect) were analysed.

3. Results

At the end of the 20th century, floating plastic debris was not yet a problem in Antarctica, but currently plastic waste in Antarctica can originate from multiple sources, both direct and indirect. Direct sources encompass the disposal of waste from research stations and ships [5], while indirect sources involve the transport of microplastics by ocean currents, which can carry them from low latitudes to the high latitudes of Antarctica [11]. Plastics have been found to negatively impact marine ecosystems, including causing direct health problems for marine species through ingestion or entanglement with trash and fishing gear. Additionally, there may be indirect effects such as the spread of invasive species and pathogens that attach to microplastics and nanoplastics and enter the food chain as well as nanotoxic effects impacting various ecosystems. The Antarctic continent and the Southern Ocean, despite being remote and having low levels of human activity, are not immune to plastic pollution. Most plastics found in these areas are packaging bands, synthetic threads, and fishing nets. The analysis yielded different results depending on the size of the plastic particles found, with micro and nanoplastics having the greatest potential toxicity for the fauna, flora, and humans inhabiting Antarctica

3.1 Macroplastic

Macroplastics are the largest size spectrum of plastic pollution and correspond to objects larger than 1 cm. These contaminants have been found both in terrestrial ecosystems, especially near scientific stations, and in the waters of the Southern Ocean. One aspect that should be taken into account is that studies indicate that the plastic pollution found in Antarctic waters comes from outside the polar front [3]. In the case of pollution of terrestrial environments, the pollution has its main origin in the management of current and historical waste and the increase of tourist activities.

Macroplastics in Antarctica present at least three fundamental problems: contamination of the sea surface, ingestion by birds and mammals, and contamination of protected areas. Macroplastic surveys conducted in the Southern Ocean found that most of the debris encountered was plastic, predominantly plastic bottles and plastic pieces, expanded polystyrene, fishing floats (buoys), bottles, and rigid plastic fragments. Flexible packaging (bags and food wrappers) were more scarce [4].

One of the most important problems with plastic is the potential ingestion for the fauna. Macroplastic consumption by Antarctic birds has been recorded since the 1980s [12]. More than 3 decades ago, in some areas of Antarctica, plastic consumption had not been observed however, plastic had already then been detected in birds in the sub-Antarctic islands and directly off the coast of Antarctica where evidence of plastic ingestion by seabirds was detected. Currently threats to marine wildlife are mainly posed by two types of biological interactions with macroplastic: (1) ingestion, i.e., intentional or accidental ingestion of debris that enters the digestive tract of organisms, and digestive tract of organisms, and (2) entanglement, predominantly in packaging tapes, synthetic ropes or drift nets, where loops and holes from various types of debris entangle parts of the animal's body or capture the animal entirely or capture the animal entirely [12].

One of the important aspects of macroplastic pollution in Antarctica is the impact it has on Antarctic Specially Protected Areas (ASPA). The main objective of these areas is to preserve ecosystems and sites with significant fauna and flora of the continent. However, in recent years, the presence of macroplastics has been observed and alerted in numerous ASPAs [13]. The coastal of ASPAs are not immune to plastic pollution. While some plastics may accidentally be lost during scientific activities in the field, the major threat comes from plastics that are carried by the ocean currents. Despite the relatively low concentration of floating plastics found in the Southern Ocean, some Antarctic beaches act as accumulation areas, particularly those located on the west and north sides of the islands. Given their protected and isolated status, it is imperative to monitor the reach of drifting plastics to the land in Antarctica by focusing on coastal ASPAs [14].

3.2 Microplastic

Microplastics are small plastic particles that measure less than 5 millimeters in size and are a significant environmental concern worldwide. While the Antarctic region is one of the most remote and pristine areas on Earth, even here, microplastic pollution has been detected [5]. Several studies have confirmed the presence of microplastics in the Antarctic region, including in its waters, ice, and even in the bodies of marine organisms. Some of the primary sources of microplastics in the Antarctic region include:

1. Ocean currents: Ocean currents can transport microplastics from other parts of the world to the Antarctic region. These currents can carry microplastics from distant sources, including plastic waste from other continents.
2. Research activities: Scientific research stations and research vessels in the Antarctic region can contribute to microplastic pollution. Activities such as waste disposal, construction, and general operations can release microplastics into the environment.
3. Long-range transport: Microplastics can also be transported to the Antarctic region through long-range atmospheric transport. These particles can be carried by winds and eventually deposited in the region.
4. Local sources: While human activity is limited in the Antarctic region, there are still local sources of microplastics, such as fishing gear, that can contribute to pollution.

The presence of microplastics in the Antarctic region is a matter of concern due to its potential negative impact on the delicate and unique ecosystems that exist in the area. These minute particles can be ingested by marine organisms and may consequently enter the food chain, adversely affecting the entire ecological system. Furthermore, the cold temperatures and slow degradation rates in this polar region mean that microplastics can persist in the environment for an extended period. As such, concerted efforts are underway to better comprehend the magnitude of microplastic pollution within the Antarctic region and mitigate associated impacts. Researchers and environmental organizations are actively studying the sources, distribution, and effects of microplastics in this remote area, to develop strategies aimed at reducing their presence and protecting the pristine environment. Once deposited in Antarctica, these particles can accumulate and have an impact on local ecosystems. [2, 15]

3.4 Nanoplastics

Nanoplastics are a major environmental concern due to their incredibly small size, which makes them difficult to detect with the naked eye. These tiny plastic particles can come from the breakdown of larger plastic materials or the direct release of nanoplastic-containing products such as cosmetics and textiles. They have been found in ecosystems all around the world, including oceans, rivers, and even remote areas like Antarctica. It's important to be mindful of the impact our plastic consumption has on the environment and take steps to reduce it. Nanoplastics can potentially affect the Antarctic region in different ways:

1. Atmospheric Transport: Nanoplastics can be transported over long distances through the atmosphere. They may become airborne in more populated areas and be transported to remote regions like Antarctica through global wind patterns.
2. Oceanic Transport: Antarctica is surrounded by some of the world's most pristine oceans, but even these remote waters are not immune to plastic pollution. Nanoplastics, like larger plastic particles, can enter the oceans and eventually find their way to the Antarctic region through oceanic currents. [8].

3. Impact on Wildlife: Nanoplastics can pose a threat to marine life in the Antarctic ecosystem. As small organisms ingest them at the base of the food chain, they can bioaccumulate and potentially harm larger animals, including fish, seabirds, and marine mammals. [16].

The long-term consequences of nanoplastic contamination in Antarctica in regard to its ecological and environmental influence remain predominantly undisclosed. Current research endeavors aim to assess the scale of the matter and its potential consequences on this distinctive and susceptible ecosystem. To achieve this objective, efforts are being made to enhance comprehension of the dispersion of nanoplastics in Antarctica and their possible repercussions on the environment. Researchers are conducting investigations to thoroughly examine the levels of nanoplastics in the sediments, waters, and wildlife of Antarctica to ascertain the scope of the issue and its ecological implications. Additionally, there exists a more comprehensive global campaign to address plastic pollution at its origin and foster sustainable measures to mitigate its impact on ecosystems, including those present in Antarctica.

4. Micro/nanotoxicity

How to assess the overall risk that the presence of plastics in Antarctica may have? One possibility is to hypothesize that the toxicity of microplastics and nanoplastics could have a behavior similar to that of industrialized microparticles and nanoparticles (carbon nanotubes, buckyballs, graphene, etc.). Nanotoxicity refers to the potential harmful effects of nanomaterials on living organisms, including humans and the environment. Nanomaterials are extremely small particles or structures, typically with dimensions in the nanometer scale (1 to 100 nanometers). Due to their small size and unique properties, nanomaterials have attracted great interest in various fields, such as medicine, electronics and materials science. However, their small size can also lead to unique biological and environmental interactions that may pose risks. The main points to consider concerning nanotoxicity include:

- Size and surface area: Nanoparticles have a high surface area compared to their volume, which can increase their reactivity and potential toxicity. This increased surface area allows them to interact more easily with biological systems.
- Different types of nanomaterials: Nanomaterials can be composed of various substances, such as metals, metal oxides, carbon-based materials (such as nanotubes and graphene) and organic nanoparticles. The toxicity of different nanomaterials can vary significantly.
- Biological interactions: Nanoparticles can interact with cells, tissues and organs in the body, which can lead to adverse effects. These interactions can include oxidative stress, inflammation, cell damage and even alteration of DNA or protein structures.
- Exposure route: The route of exposure to nanomaterials can influence their toxicity. Inhalation, ingestion, dermal contact and injection are common routes of exposure, and the effects may differ depending on how the nanomaterials enter the body.
- Accumulation and distribution: Some nanomaterials can accumulate in specific organs or tissues, which can lead to long-term toxicity problems.
- Environmental impact: Nanomaterials released into the environment can affect ecosystems and wildlife. They can bioaccumulate in organisms and cause ecological alterations.

The known nanotoxic mechanisms can interact with various cellular components, including the cell nucleus, which generates primary genotoxicity [17] due to this direct interaction with the cell nucleus, and secondary genotoxicity [18] due to its high capacity to generate free radicals and chronic inflammation, which maintained over time would produce genetic alterations. For this reason, it is essential to measure the effects on living organisms and also on people in Antarctica and not only the presence or absence of these pollutants.

5. Conclusion

The Antarctic continent and the Antarctic Ocean, despite being remote and having low levels of human activity, are not immune to plastic pollution. Most of the plastics found in these areas are packaging bands, synthetic threads, and fishing nets. Micro and nanoplastics have also been found in waters near the effluents of various scientific bases. Different analyses yielded varied results depending on the size of the plastic particles found, with micro and nanoplastics having the highest potential for toxicity to the fauna, flora, and humans inhabiting Antarctica. The presence of micro and nanoplastics in Antarctica raises additional concerns due to their nanotoxic capacity, the mechanisms and effects of which are not yet fully understood. The Argentine Antarctic Program, in cooperation with the International Atomic Energy Agency (IAEA), has entered into a cooperation agreement between the Argentine Republic and the IAEA in the field of nuclear technology for plastic pollution control (NUTECs plastics). It includes projects called "Microplastics in the Antarctic Environment" and "Implementation of NUTECs plastics." This new line of research complements the hypothesis presented in this work regarding the potential toxicity of micro and nanoplastics and their high impact in the short and medium term.

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