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Discussion

The plastic pandemic: COVID-19 has accelerated plastic pollution, but there is a cure

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HIGHLIGHTS

1. In just over 100 years humanity has polluted the whole planet with plastic.
2. Plastic pollution has made it to the Earth’s last wilderness: Antarctica.
3. The COVID-19 pandemic has exacerbated single-use plastic pollution.
4. There is a cure to the global plastic crisis.
5. Concerted efforts from all facets of our global community are required.

ABSTRACT

Plastic pollution is now present in all areas of our planet, including its last wilderness, Antarctica, and the plastic crisis has further escalated because of COVID-19. The pandemic has caused a significant increase in the global consumption of single-use protective items such as masks and gloves. These and other plastic items add to the suite of plastic pollution issues, from entanglement of wildlife to microplastic bioaccumulation. Given plastics are a major threat facing humans and wildlife, swift action to reduce plastic pollution is urgently needed. Solutions to plastic pollution are within reach. With collective, impactful action we will ensure a better future for our planet and ourselves. Here, we propose several measures for decision-makers to implement to achieve a solution and tackle plastic pollution as a united, global community.
1. Introduction

Imagine standing in the crisp air of a serene landscape - no pollution, no debris, just ice, sea, sky and wildlife. In 2019 this is where we found ourselves, standing among one hundred multidisciplinary women across all areas of STEMM (Science, Technology, Engineering, Mathematics and Medicine) on the bow of a ship within the Antarctic Circle.

Together, we marveled at the surreal scenery, free from the plastic pollution we were accustomed to in our own countries around the world. However, we discovered that even this remote and seemingly pristine environment was not unharmed. We learned of accounts of microplastics in the wildlife around us, and the sobering experience of seeing a shampoo bottle wash ashore before our eyes. It was clear that this remote environment was not exempt from the plastic crisis escalating throughout the rest of the world.

We had gathered in Antarctica thanks to a shared purpose and the Homeward Bound Leadership Program. Our ability to unite in such a remarkable setting was made possible, in part, by the Antarctic Treaty which was signed exactly 60 years prior to our visit. The Treaty, a testament to global peace and cooperation, arose from a shared appreciation of Antarctica between nations. Setting aside political differences, leaders agreed that an alliance was imperative to protect this unique and important continent. The Treaty ensured that conservation and scientific enquiry would be prioritized rather than exploitation, recognizing that the Antarctic region is priceless.

Plastic pollution has propagated across the planet as though a faucet for plastic has been steadily opened over the past century. During the COVID-19 pandemic, humans have created a new stream of plastic pollution; one that is exacerbated not just for convenience, but from fear. This plastic pandemic poses an intensified threat that affects the well-being of our people and our planet. A new path forward for managing this plastic crisis is essential.

It is imperative that we take the lessons learnt from the Antarctic Treaty and apply them to this evolving global plastic crisis. Antarctica exists as it does because countries cooperated to protect it. We must once again work together towards a common solution that protects our whole planet from plastic pollution as a united global community.

2. Humble beginnings

Created from synthetic polymers in the 1850s, plastic began as a replacement to natural materials such as wood and glass (Lintsen et al., 2017). Incredibly versatile, plastic revolutionized daily life worldwide, but its negative consequences are now apparent. Since the 1950s, plastic pollution has accelerated alarmingly. Despite increasing rates of recycling since the 1990s, an estimated 60% of all plastic ever produced remains in the natural environment (Geyer et al., 2017). On a planet that is 4.5 billion years old, in just over 100 years humanity has managed to pollute every continent and ocean with plastic (Ritchie and Roser, 2018).

We find ourselves today in a global plastic pollution crisis, with plastics threatening our livelihood, health and ecosystems (Ritchie and Roser, 2018). Plastics ubiquity extends as remotely as the Arctic and the Antarctic, predominantly in the form of microplastics (Peeken et al., 2018; Munari et al., 2017). These plastic fragments, smaller than 5 mm in diameter, often manifest as microbeads, microfibers, or microparticles and are ingested by most marine biota (Lopez-Martinez et al., 2021). In Terra Nova Bay, Antarctica, where organisms such as Antarctic krill and Adélie penguins are found, microplastics accounted for 78.4% of debris in collected sediments (Munari et al., 2017). In the Arctic, high plastic concentrations are also present in sea ice. This presents clear environmental implications amidst rising global temperatures, as melting ice releases microplastics (Peeken et al., 2018).

3. The COVID-19 pandemic - a new era for plastic pollution

Prior to 2020, global progress had been forged in the reduction of single-use plastics, and reusables had taken force in many ways as a global movement (Heiges and O’Neill, 2020). However, the COVID-19 pandemic has exacerbated plastic pollution as people turn to single-use items to protect themselves from infection (Fig. 1). In response to the pandemic, guidelines previously prohibiting single-use plastics have been relaxed, evolving into its excessive use (Woelert et al., 2020). As a result, communities are choosing disposable options in place of reusables. Food safety concerns have promoted the use of food packaging and containers to avoid contact transmission and, in medical care applications, single-use plastics continue to be integral. As we treat infected people and roll out vaccines worldwide, we have only added to the rising magnitude of plastic waste (Peng et al., 2021) (Fig. 1). The combined impact of plastics is rapidly approaching a critical turning point. Beyond the unspeakable hardships that COVID-19 has presented, a possible silver lining is the unique opportunity to tackle plastic pollution as a united global community.

4. Impacts on human health

Plastic poses a threat to all forms of life and the ingredients essential to its manufacture cause further adverse effects. Chemical additives are hazardous to human health through ingestion or direct contact, and the growth of plastics use has made such additives nearly unavoidable (Alabi et al., 2019).

COVID-19 face masks are now a significant source of microfibers in the environment (Kutralam-Muniasamy et al., 2022; Pizarro-Ortega et al., 2022). These consist mainly of polypropylene (PP) and, to a certain extent, polyethylene (PE) polymers (Fadare and Okoffo, 2020), Polylamide/Nylon (PA) and polyethylene terephthalate (PET) (De-La-Torre et al., 2022). Surgical face masks, in particular, also include polyurethane (PU), polyacrylonitrile (PAN) and polystyrene (PS) (Chellamani et al., 2013). Considering that when face masks are exposed to water they can release heavy metals such as lead, cadmium, and antimony (Sullivan et al., 2021), and that the ingestion of PP-containing microplastics by marine copepods results in endocrine disruption (Sun et al., 2021), this increasingly common source of polymers may have both direct (De-La-Torre et al., 2021) and indirect consequences for human health.

Bisphenol A (BPA) is a common component of polycarbonate plastic that has been used to make reusable bottles and other containers (Monneret, 2017). A well-known endocrine disruptor, BPA causes reproductive and developmental disorders, diabetes, and even breast, vaginal, and cervical cancers (Rubin, 2011). Although BPA has been banned from baby bottles and food containers in some countries, many polycarbonate alternatives also leach estrogenic chemicals, failing to alleviate the hormonal threat (Bittner et al., 2014) and making widely used PP and PE alternatives problematic.

Phthalates, or chemical plasticizers, are also a common type of synthetic compound that give plastic its malleability and may be used in items as diverse as raincoats, hoses, and lunch boxes (Monneret, 2017). Like BPA, phthalates inhibit development in children whose mothers were exposed during pregnancy, and it can also cause reproductive disorders such as abnormal sperm quality, reduced testosterone, and altered testicular function (Monneret, 2017). A recent study shows that phthalates enter in single-use face masks may constitute a risk of exposure through inhalation, although daily intakes were estimated 80 times lower than human tolerance thresholds for this chemical (Wang et al., 2022).

Many investigations have linked synthetic ingredients and their properties to common health hazards. Polybrominated diphenyl ethers (PBDEs) and antimony trioxide, used as flame retardants in various plastics, can be bioaccumulative and toxic to both humans and the environment (Monneret, 2017; Schildroth et al., 2021). Lead and cadmium are heavy metals often used to stabilize Polyvinyl Chloride (PVC) plastics and can damage the nervous system and kidneys, and cause various cancers (Kumar and Pastore, 2007). Antibacterial chemicals added to household
plastic surfaces such as chopping boards and sponges to prevent bacterial growth are not only toxic to human health (Kim et al., 2022), but can create antibiotic-resistant strains of bacteria (Laganà et al., 2019). These are only a few examples of a long list of health hazards of plastics.

Over time, plastics leach these harmful chemicals into soils and waterways. This continuous and excessive pollution poses significant repercussions to human health and forever changes ecosystems. Marine life also acts as a vessel for these chemicals, as they bioaccumulate at different trophic levels of the food chain, ultimately reaching human consumers (Mcglade and Landrigan, 2021). As the boundaries of plastic pollution continue to expand into the most southern waters, there will soon be no part of the food chain left untouched. With increased usage of single-use plastic following the onset of “pandemic panic”, the threat of these dangers has escalated as people choose seemingly more hygienic options, unaware of the impacts of these choices.

Recent research has highlighted additional means by which microplastics may impact human health. The surfaces of microplastics in our waterways and coastal environments harbor viruses and bacteria which infect humans (Lear et al., 2022; Moresco et al., 2022). Viruses survive and remain infectious for up to three days by residing on plastic pollution in fresh water (Moresco et al., 2022). The abundance of microplastics in our environment therefore increases the risk that harmful pathogens will persist and be disseminated. Ironically, the rise in the use of single-use plastics as a means of protecting ourselves from COVID-19 results in greater amounts of plastic pollution that could facilitate the growth and diversification of viruses and bacteria, as shown on discarded face masks (Ma et al., 2022; Crisafi et al., 2022).

5. Impacts on wildlife

Plastic pollution impacts all wildlife taxa across land, sea and sky, but the effects of plastic on our marine wildlife is often the most visible. An estimated 4.8 to 12.7 million metric tons of plastic waste entered the oceans in 2010 alone (Jambeck et al., 2015). This exceptional amount of plastic comes with increasing impacts on marine life.

Alarmingly, more than 900 marine species are documented as being impacted by entanglement or plastic ingestion (Kühn and van Franeker, 2020). Flexible plastics, like balloons, are particularly deadly. Seabirds that ingested balloon pieces are 32-fold more likely to die than those ingesting hard plastic (Roman et al., 2019). Plastic has been found in the stomachs of numerous marine species, gravely impeding their welfare and survival (Lopez-Martinez et al., 2021). Over 90 % of harbor porpoises analyzed in Germany had microplastic in their stomachs (Philipp et al., 2021). Across Europe, 75 % of tested dolphin species had toxic levels of PCBs, likely causing population decline and hampering species recovery (Jepson et al., 2016). A recent review of plastic ingestion by marine fish showed that 386 marine fish species had ingested plastic, with consequences on both fish populations and ultimately human health (Savoca et al., 2021). Marine turtles are particularly threatened by plastic pollution as they may mistake plastic bags as a key food source, i.e. jellyfish. Research suggests that 22 % of turtles will die after swallowing just one piece of plastic, with mortality increasing to over 50 % when 14 pieces are ingested (Wilcox et al., 2018). Plastic pollution impacts marine turtles at every stage of their lifecycle, including as hatchlings (Wilcox et al., 2018).

While plastic may enter our waterways through a variety of methods, in the ocean the plastic pollution is also made up of fishing industry by-products, such as nets and ropes. Over 350 marine species have been documented as falling victim to plastic entanglement (Kühn and van Franeker, 2020), resulting in an estimated 300,000 whales, dolphins, and porpoises fatally entangled annually (Johnson, 2021). These fishing industry by-products are not the only culprits — masks and gloves have also entangled a variety of ocean wildlife. With the use of these personal protective items (PPE) on the rise, we can expect the impact of such plastic pollution to worsen. The unrestrained use of single-use plastics due to COVID-19 undeniably adds additional stress to our planet’s marine ecosystems (Hiemstra et al., 2021).
6. Towards a cure

Following the 26th Conference of the Parties (COP26), where the United Nations gathered to determine how to reverse the “clock” on climate change, it is clear that solving the plastic crisis is of paramount importance. Emissions from plastics are predicted to constitute 15% of the global carbon budget before 2050 (World Economic Forum, 2016). There is no “one-size-fits-all” approach to solving the plastic crisis. It will require a concerted effort by all facets of the global community from governments to individuals, but the possibilities for finding a sustainable solution are encouraging (Fig. 2:1–12).

Above all else, leaders must make a commitment to limit plastic use within the communities they govern (Fig. 2:1–3, 7–8, 12). This is achievable and has been demonstrated around the world as countries increasingly address plastic pollution at a national level. Eritrea, for example, was the first country to ban the use of plastic bags and single-use packaging in 2005 (Greenpeace, 2020). Africa is a leader in this area, with 34 of the 54 African countries having passed laws banning plastics (Greenpeace, 2020), though difficulties with implementation and regulation often require further work (Fig. 2:2–3, 8).

Educational campaigns have proven vital in teaching tangible actions that reinforce sustainability and address plastic issues (Fig. 2:9, 11–12). This is particularly important when people may not recognize the behaviors that lead to pollution. An encouraging example of this is Zoos Victoria’s ‘When balloons fly, seabirds die’ social behavior change program (Zoos Victoria, 2021) in Victoria, Australia, which successfully promoted the use of bubbles instead of balloons at outdoor events to reduce balloon litter (Mellish et al., 2019). This campaign has led to balloon bans by major Australian companies and state governments (Fig. 2:3, 6–7, 9, 11) (The Age, 2021), and there was an associated decrease in balloon litter found on beaches and in the stomachs of seabirds. For example, Phillip Island Nature Parks recorded 63% fewer balloons and balloon by-products on the island’s beaches in 2018–2019, compared with the previous year, and all it took was simple yet consistent messaging (Fig. 2:6–7, 9–10) (Zoos Victoria, 2021).

The augmented effect of individual actions is substantial and there are many strategies that reduce the impact of plastic on our environment. Cutting mask ear-loops and soda-pack rings will limit wildlife entanglements, and enabling people with the knowledge to make a difference has a massive and powerful impact.

1. Treat plastic pollution as a climate threat and implement a net plastic reduction strategy.
2. Accountability from companies for waste from the sale of single-use plastics, e.g. through taxes.
3. Phase out and ultimately ban single-use plastics worldwide.
4. Fund the clean up of existing plastic pollution.
5. Fund enhancements to recycling programs, including correct disposal of masks and other COVID-19 related plastic items.
6. Research and innovation targeting plastic pollution - clean up, recycling, and alternatives, and investment in more sustainable alternatives for COVID-19 related plastic items.
7. Specify, commit, and monitor measurable targets for plastic pollution.
8. Develop, sign and adhere to global agreements on plastic reduction measures.
9. Raise awareness across all sectors through media campaigns and education.
10. Transparency in origin of government support and ethical interactions with stakeholders/lobby-groups.
11. Recognition for companies cutting plastic waste, and economic incentives for using non-plastic alternatives.
12. Incentives for organizations and the public to recycle effectively.

7. Crisis, courage, change

Society has achieved, withstood, and succeeded in extensive change throughout the past century. Imagine what can be achieved over the next 100 years with a concerted focus on advancements that support the long-term interests of our global community. The challenges we have faced recently have, at times, felt insurmountable, but in a global crisis we have proven that change is possible. Like COVID-19, the plastic pandemic has, and will continue to have a formidable impact on our lives, yet the effect is ameliorable with collective action.

In the same way that world leaders were able to set aside differences 60 years ago to prioritize the Antarctic for peace, cooperation, and science, today we have everything we need to prioritize a global solution to the plastic crisis (Fig. 2:1, 8). Such actions begin with passionate individuals wielding knowledge and concern towards research, innovation and sustainability (Fig. 2:4–7, 12).

Despite being an example of global harmony, the spectacle of Antarctica is not exempt from the permeating threat of plastic. As plastic pollution has pushed past previously hard boundaries, a proverbial ultimatum has been issued. A victory in this effort to curb global plastic pollution will require people of all backgrounds, each with something unique to offer, to unite for a renewed, common cause. The time for serious and courageous effort is now (Fig. 2).

8. Conclusions

There are solutions to the global plastic pollution crisis, despite its exacerbation by the COVID-19 pandemic. We must recognize plastic pollution as an ever-increasing global threat. Companies and governments must be held accountable for the sale of single-use plastics and move towards a net plastic reduction, and then a single-use plastic elimination strategy. Simultaneously, appropriate and reliable funding is crucial for the removal of existing plastics from the environment, and to further recycling, research, and innovation programs to create sustainable solutions. We require measurable and time-bound reduction and elimination targets for plastic pollution, and for those targets to be mandated at a global level. A key example of such a global agreement is the Antarctic Treaty, proving that diverse nations can unite for a common and important cause, and that such long-term measures can be instigated and successful.

Education and awareness raising must be increased, with transparency in government actions and spending. Finally, economic incentives and recognition for companies cutting plastic waste will further drive business and personal behavior change.
towards a sustainable future. To solve the plastic pandemic, which stretches across our planet even to the most remote environment of Antarctica, a collaborative approach involving all sectors of our society is the only way forward. Thus, we advocate for an injection of impactful actions to cure the plastic pandemic.

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**Data availability**

Data will be made available on request.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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