Plastics in the Food Chain

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Plastic pollution affects God's creation at multiple scales, from microscopic to landscape and ocean-wide effects, including the agricultural, aquacultural, and fisheries systems we rely on for livelihoods and our daily "bread." The scope of plastics pollution, especially microplastics, in mediums pertinent to agriculture and the human food chain, is staggering. Food safety, security, and human health are at risk. Though research into food web impacts is limited, especially in terrestrial and freshwater ecosystems, this article is organized to show why food web problems exist, the potential modes of interference with food webs, and the implications of plastic contamination of the food supply for human and nonhuman organisms alike. We must contend with plastic when thinking of the future of food systems, and especially when it comes to developing a robust theological framework. We suggest that there are a number of theological challenges, which are pertinent in guiding how the Christian faith might interact with the issues outlined in this article. We discuss creation care, ethical and justice issues, and biblical wisdom literature as examples of how scripture might guide us to ask the right questions as to how we should engage with threats to food systems and plastic pollution.

Food production is tightly linked to air, water, and soil quality, and vice versa. Pure, clean waters yield the healthiest seafood and fresh fish. People flourish in the land where the soil is rich and water is plentiful. Healthy ecosystems support agriculture, in addition to all of God's creation. Where the soil, water, and air is contaminated, people and creation suffer, including agricultural systems. Creation is suffering a crisis of plastic pollution: millions of tons of waste swirl in ocean gyres and fill in the crevasses of the deep; microplastics fly through the air as dust; fish, which are later eaten by birds, eat floating fragments; environmental toxins are attracted to and adsorbed onto the surface of plastics in the oceans; microfibers from the washing of synthetic clothes are applied to agricultural fields along with sewage sludge.

The goal of this article is to highlight the concerns and implications of plastics in the human food chain and in creation more broadly. We do not seek to prescribe particular solutions for reducing plastic pollution, as this is beyond the scope of this article; there are numerous resources online to suggest action. We consider the scale of the problem of plastic pollution and the scope of plastics in the food chain, followed by the damaging consequences already known, and areas of uncertainty. Much of the literature cited in this article presents evidence from the marine environment, where most scientific research has been focused. We then look to the future of food systems in light of the ubiquity of plastic pollution, and, finally, we reflect theologically on the questions raised in order to propel thoughtful conversation on the parts of communities, organizations, and individuals seeking to live in shalom with God's creation.

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The Scale of Plastic Pollution

Plastics have changed our world since their manufacture began in earnest in the 1950s, often for the better. They are a marvel of engineering: inexpensive, lightweight, moldable, and allegedly chemically inert.[1] From sports to medicine to textiles to transport to food safety, plastics play a leading role in defining the new normal, with some researchers proposing that the Anthropocene epoch be defined according to our use of plastics.[2] Unfortunately, the properties that make plastics a marvel also make them a window into the crooked heart of sinful human society, revealing the power of ignorance, idolatry of convenience, cheapness both of price and thrill, and self-centeredness. The consequences of plastic addiction, especially single-use convenience plastics, reach into and beyond the very systems that permit agriculture: they damage terrestrial, freshwater, and marine ecosystems, destroying soil, water, and air.

The scale of global plastic production and the nature of permanent synthetic waste all but ensures that plastic pollution is ubiquitous in the environment.[3] Worldwide, an estimated 8,300 million metric tons (Mt) of virgin plastics have been produced from 1950 to 2017.[4] As of 2015, 9% of total plastic waste was recycled, 12% was incinerated, and 79% ended up in landfills or in the environment.[5] An estimated minimum 5.25 trillion items of plastic float in the oceans, weighing 268,940 tons, which does not count the plastic that sinks to the ocean floor.[6] An estimated 4.8 to 12.7 Mt of plastic waste entered the ocean in 2010.[7] Clearly, the scale of plastic pollution since the 1950s, roughly the equivalent of one billion elephants in mass,[8] will affect God's creation, including the agricultural, aquacultural, and fisheries systems we rely on for livelihoods and our daily "bread."

The large-scale harm of plastic pollution is predicated in part on the size and chemical composition of individual pieces of plastic. Microplastics are typically considered to be 5 mm in size or smaller, and macroplastics generally are larger than 5 mm.[9] Types of microplastics include foam, fibers, fragments, pellets, beads, and films, though no formal categorization exists at this time. In the scientific literature, "microplastics" is often used as a catch-all term for a variety of pieces, particles, or items. In this article, we will use "microplastics" to refer to all types, and will use "items" for specific numbers, following the example of Lisbeth Van Cauwenberghe and Colin Janssen.[10] Plastics in the micro- and nanometer size range are under current research scrutiny due to their recent discovery in marine environments,[11] and their ability to affect aquatic food chains,[12] though we will not specifically focus on them in this article.

Many plastic products are created to be small, such as the microbeads in face wash and toothpaste, and are called primary microplastics. Plastic resin pellets, called nurdles, are also a primary microplastic. Though plastic does not biodegrade, it will succumb to photo degradation due to sunlight and UV exposure and mechanical fragmentation due to wind, water, wave action, and salinity, creating secondary microplastics such as fragments, fibers, and films. Microplastics, in turn, degrade to nanoplastics.[13] Plastics by design are chemically complex and diverse from one type to another,[14] making them difficult to recycle and reuse. Differences in additive chemicals, strengths, thicknesses, and sizes mean that there are thousands of different kinds and configurations.

Research into plastic pollution, its effect on various species, and the potential for harm has skyrocketed,[15] along with global awareness and social action, such as country-wide plastic bag bans and the Microbead-Free Waters Act of 2015 passed by the US Congress.[16] A few authors have raised the question of potential consequenses on food safety and security,[17] as well as on human health.[18] There is a dearth of apparent theological resources to address plastic pollution: A Rocha has created a Microplastics Toolbox for Christians, which includes educational, theological, scientific, and lifestyle resources;[19] the Evangelical Environmental Network has introduced "The Last Straw" campaign to encourage awareness of plastic pollution and action on plastic straws in particular;[20] and Tearfund, a UK-based Christian aid organization, focuses on plastic pollution reduction in poorer countries as one of their main projects.[21]

The Scope of Plastics Pollution

The scope of plastics pollution, especially microplastics, in mediums pertinent to agriculture and the human food chain, is staggering. The vast majority of plastics are generated and used on land, while a smaller percent are used and lost at sea.[22] Global waste trade inefficiencies constitute a major source of plastic pollution in oceans. For decades, higher-income nations such as the United States, Canada,

members of the EU, and Japan have been exporting most of their plastic waste to lower-income countries in East Asia and the Pacific for waste management.[23] The top four countries in the world ranked by mismanaged plastic waste are East Asian and Pacific nations, with China at the top of the list, contributing more than 1.32 Mt of plastic marine debris per year.[24] About 10% of China's mismanaged waste came from imported plastics;[25] it is thus logical that a portion of plastic waste generated on land in the United States and shipped to China was mismanaged and contributed to marine plastic pollution. In 2017 China banned nonindustrial plastic waste imports, displacing an estimated 111 Mt of future plastic waste by 2030 that will need to go somewhere else.[26]

Land-based microplastics end up in freshwater and marine environments by passing through wastewater treatment plants; this plastic waste comes from stormwater runoff, and from industry effluent.[27] A major source of microfiber pollution comes from the washing of plastic-based textiles such as fleece, which sheds 1,900 fibers per garment per wash[28] or more.[29] Billions of microplastics, both microbeads and microfibers, are released every day from US municipal wastewater into the environment.[30] Plastic pollution is a concern in inland lakes such as the Great Lakes, due to industrial activity, wastewater effluent, and littering on beaches.[31] Wastewater treatment plants in the US are releasing, on average, over four million microplastic items per facility per day into rivers, lakes, and the ocean.[32] Cristina Munari and colleagues revealed microplastics in seabed sediment in the Ross Sea, Antarctica, possibly from Antarctic research facilities.[33] Even remote Arctic Sea ice contains concentrations of microplastics much higher than those of the "garbage patch" gyres; as global warming melts the Arctic ice, these microplastics are re-released into the marine environment.[34]

Sea-based plastic pollution sources include commercial and recreational fishing, research, tourism, and shipping. Abandoned, lost, or discarded fishing gear is widely known to "ghost fish," catching and killing not just fish, but marine mammals and reptiles.[35] Derelict nets, ropes, lines, and cages, mostly consisting of plastics, were found to harm or kill coral in a study in the Gulf of Thailand.[36] In the UK, the fishing industry is the main source of marine debris, including plastics such as packaging crates, plastic floats, nets, and rope.[37] Research vessels may also release plastics.[38]

Soil microplastic contamination is not well studied, though it is known to occur through sewage sludge application, often as agricultural fertilizer. Applying sludge to land is common and more economical than incinerating, dumping at sea, or landfilling.[39] Waste water treatment may remove 98% of microplastics by retaining them in the biosolids.[40] These biosolids in the form of sewage sludge from wastewater treatment plants and septic tanks are sometimes applied to agricultural fields or deposited in landfills. Synthetic fibers were found to be a reliable way of detecting past waste sludge application to soil because they do not degrade and are not filtered out completely during treatment.[41] Agricultural materials such as plastic mulches, fertilizer bags, and silage covers can also fragment and contribute to both terrestrial and eventually freshwater and marine plastic contamination.[42]

Microplastics even disperse into the air. A study of indoor and outdoor air in Paris showed a median of 5.4 microplastic fibers/m^3 indoors.[43] The outdoor median value was 0.9 fibers/m^3, significantly lower than indoors; however, researchers note much higher microfiber levels outdoors during rain events, demonstrating atmospheric fallout.[44]

Known Deleterious Consequenses of Plastic Pollution

Animals are known to consume plastic objects either inadvertently or intentionally; internet photos of the stomach contents of albatross, whales, sea turtles, and other marine animals that have ingested plastics are widespread. A wide range of fish and shark species attack floating plastic, potentially viewing it as prey;[45] some of this plastic may be ingested. Cattle and other livestock eat plastics, especially when feeding in urban areas where trash is prevalent and animals are allowed to graze freely, resulting in malnutrition and occasionally death.[46] Plastic object consumption thus poses a challenge to agricultural livelihoods in the Global South.[47] In freshwater, environmentally relevant concentrations of microplastic items negatively affected the survival, growth, and emergence of *Chironomus tepperi*, a sediment-dwelling midge, and this response was strongly particle-size dependent (10–27 μm).[48] In humans, a person may breathe in 26–130 airborne microplastic items per day from indoor sources, exposing vulnerable people to risks of inflammatory diseases, lesions, and plastic chemical additives.[49]

Plastics also release chemicals and adsorb environmental toxins. Microbeads from personal care products attract pollutants such as flame retardants—for example, polybrominated diphenyl ethers (PBDEs). These pollutants have been shown to bioaccumulate in fish when consumed.[50] Plastic pellets (nurdles) adsorb and highly concentrate pollutants such as polychlorinated biphenyls (PCBs), DDE, and nonylphenols (NPs) from seawater, making them a toxic raft of chemicals in the marine environment.[51] Chemicals added to plastics during the molding process, such as PCBs, polycyclic aromatic hydrocarbons (PAHs), NPs, PBDEs, and brominated diphenyl ether congener (BDs) have all been found on marine plastics.[52] Transfers of hazardous chemicals from ingested plastic to fish have been demonstrated.[53] Very few studies have attempted to understand complex, real-world scenarios of microplastic and contaminant trophic level transfer through the food web in the natural environment.[54] One of these few confirmed trophic transfer of microplastics and sorbed chemical benzo(a)pyrene from brine shrimp to zebrafish;[55] another showed nanoplastic trophic transfer from zooplankton to *Daphnia magna* to a predator fish, with a deleterious effect on the top consumer.[56]

Future of Food Systems: We Must Contend with Plastic

The pervasive, demonstrable, damaging consequences of microplastic pollution explored above do not completely address the problem of potential global systems-level disruption to food security and food safety. Scientists are concerned by the possibility of ecosystem or biome contamination through outdoor airborne fallout of microfibers onto soil, water, and crops,[57] and the microplastic-facilitated spread of exotic species and harmful bacteria dubbed the "Plastisphere" across marine environments,[58] which could exert changes on land and ocean-based agricultural productivity.[59]

Plastics must be considered with regard to the health of future food systems. For example, plastic pollution is a barrier to restoring ecosystems; this effect hinders our attempts to conduct creation-friendly agriculture, where both wild and domestic species flourish. We need more and better research. Very few studies focus on terrestrial ecosystem damage caused by microplastics, despite the very high likelihood for some level of interference with ecosystem function.[60] Coral reef restoration may be stymied because corals may ingest microplastics from their environment,[61] leading to further decline of fisheries. In a study of blue mussels in Nova Scotia, farmed mussels had statistically significant higher concentrations of microplastics than did wild mussels.[62] Wild and especially farmed seafood, seaweed, and fish in marine environments may not be safe to consume due to plastic contamination. Even in land and seascapes that appear pristine, microplastic contamination is likely due to air currents.[63] Our knowledge is limited because we can see only the largest of microplastics, and very few studies have focused on nanoplastics.[64]

Plastic is in our food chain, including drinking water, and the long-term human and other creation health effects are unknown. Mortality from plastics consumption in livestock may present a food security threat,[65] particularly in the Global South where livestock graze in urban centers and in garbage. Microplastics have been found in the skin, gills, and guts of six different important fish species in China.[66] Microplastics floating in marine environments may serve as rafts for potentially pathogenic bacteria *Vibrio* species, since synthetic polymers degrade more slowly than natural materials.[67] European seafood consumers will eat 11,000 microplastic items per year according to results extrapolated from a study on blue mussel *M. edulis* and Pacific oyster *C. gigas*.[68] Pelagic microplastics concentrations in Lakes Superior and Erie are higher than concentrations reported in several ocean gyres.[69] The Great Lakes provide 30 million people with drinking water in the US and Canada.[70] Wastewater treatment plants in the US are releasing, on average, over four million microplastic items per facility per day,[71] so there is no easy solution to prevent microplastics from entering the environment—soil, water, and air.

Theological Reflections

Plastic brings ethical problems to the forefront in each of the steps in its production, use, and disposal. These include the use of fossil fuels in production and transport, justice issues related to labor, the placement of industrial plants, the uses of plastic, and, ultimately, the disposal of plastic. We reflect here mainly on plastic use and disposal, or the lack thereof. We do not fully understand the long-term ecological, biological, and human health ramifications of our plastic addiction; however, we believe

that the solutions will require robust theology and long-term commitment by the body of Christ, resulting in transformed people and places. This section offers only a few theological reflections of how the Christian faith might interact with the issues outlined in this article, but it highlights some of the major themes that can be reflected upon and applied.

Our culture prioritizes convenience and the ability to easily dispose of waste products, leading to literal mountains of trash that will exist for hundreds or thousands of years. Plastic waste is thus a symptom of a spiritual illness that causes us to seek comfort and convenience more than God's Kingdom.[72] We must consider where we will put all our trash, given the projected increases in human population and the land required to feed 11 billion of God's children. Plastic waste is outside the biological, biodegradable systems of creation. If we maintain production and management status quo, about 12,000 Mt of plastic waste will exist in landfills or in the environment globally by 2050.[73]

Psalm 104 has often been called the Ecologist's Psalm. The connections between abiotic and biotic creation alongside and interfacing with the built human world echo our ecological knowledge of food webs and the interdependence of all life. Richard Bauckham calls this interconnectedness the "Community of Creation."[74] While we alone among creatures are created in God's image, we are not the Creator; we are theological and ecological members of the community of creation. This has huge implications for our creation of plastic. The Psalmist says, "He makes grass grow for the cattle, and plants for people to cultivate—bringing forth food from the earth" (Ps. 104:14), and "All creatures look to you to give them their food at the proper time. When you give it to them, they gather it up; when you open your hand, they are satisfied with good things" (Ps. 104:27–28). This indicates that food webs ultimately were created by God and flow from his goodness to all creation, including us. Plastic subverts this system that God made by disrupting food chains and breaking the systems of nutrient recycling.

Christians have been given the "ministry of reconciliation" (2 Cor. 5:18): between people and God, among people, within individuals, and the reconciliation of humans and the rest of creation. We have seen previously how our relationship with plastic can be something that distracts from or hinders our relationship with God. We must reflect on these topics in light of how plastic is keeping us from the abundant life Jesus promised. What resources might be necessary to help people understand and reflect on these issues in light of their relationship with God?[75] Our plastic use negatively affects not only our relationship to God but also our relationship to our neighbors, a break that must be healed through appropriate action. We explore this in more detail in the following paragraphs. We also need internal reconciliation—the cross heals our broken mental and emotional health. The science in the first sections indicates that plastic pollution is likely to affect our health. How might Christians take this research into account in their ministry of reconciliation in this area? Much of what we have written in this section is part of the ministry of reconciliation between people and nonhuman creation. What exactly does it look like for image-bearers to be reconciled to nonhuman creation, and how do we know when or if that reconciliation is complete?

We live in the "already—not yet" time between the cross and the second coming of Christ, so while we are already reconciled through Jesus, the fullness of reconciliation has not arrived. Yet we can begin to understand how creation might have looked without the influence of plastic pollution. To a great extent, this is a value-driven exercise—our beliefs about what the world should be, indicate the end goal of our reconciliation. While the timeline of scripture and creation is always forward, in that our vision is toward the new creation and the New Jerusalem, we look to the past to give us indications of what is possible. In the case of habitats damaged by plastic, we can easily quantify plastic effects, but we can also imagine a plastic-free restoration. Science gives us pointers as to how species, habitats, and ecosystems function: science can help us set reasonable goals or reflect on how we might implement restoration with reconciliation as the ultimate goal. Therefore, we need to include plastic pollution in research, in restoration goals, in monitoring, and in educational engagement with the public. Church leaders, especially teachers and preachers, should speak toward reconciliation and restoration in the lives of Christians today, showing how these goals pertain to plastic pollution, guiding listeners to hopeful, place-specific application of these principles.

Food systems should preserve the praise of species, such that when looked upon from the outside, they exhibit some quality, albeit ever so subjectively, of beauty that reflects the God-bestowed value and worth of the animals and plants, and the land and seascapes where they are being produced. Plastic pollution mars the face of creation, which exists for the glory of God and speaks to the presence, divinity, power, and beauty of Yahweh (Rom. 1:20). Many do not realize that we are making the world a less beautiful place by polluting with plastic. We silence creation's praise to the Creator when we permit the loss of biodiversity and beauty, harming the general revelation of God to the world. We see throughout scripture that creation praises its Creator and that this does not stop in the new creation, but finds all creation "in heaven and on earth and under the earth and on the sea, and all that is in them" (Rev. 5:13) before God's throne, singing his praises.

Our misuse of plastic is not only silencing the voice of nonhuman creation today, but it is also influencing us in ways in which we do not realize. Children today are unlikely to visit a beach that is not polluted by plastic debris; when worse-than-before becomes the new normal, baselines are shifted and people never know what they are missing. This baseline shift is a detriment to the gospel, because fostering beauty is a signpost to the coming renewal of creation by the power of Jesus.[76] Even as we are considering plastic's impact on food systems, we must remember that food production, human use, and threats to human health and wellbeing are not the ultimate guide.

Plastic pollution is a gospel issue with justice implications. The Global North, the historical source of most plastic waste, has been pushing this waste onto the Global South, where proper recycling facilities are scarce. East Asian and Pacific nations are beginning to push back on the Global North's sending trash to them. Malaysia recently began sending 150 shipping containers full of plastic waste back to their countries of origin, including the seventeen sent back to the United States.[77] Surface currents and prevailing winds move marine plastics around the globe in and between the northern and southern hemispheres,[78] meaning that the ocean is connecting far-away places. Even the air is a great connector, making microplastics a global problem.[79] As the world attempts to curb climate change, it is possible that microplastics in soils are inflating soil carbon storage calculations,[80] because plastics are mostly carbon. Yet microplastics in soils provide none of the ecosystem services of true carbon storage, but instead pose as a long-term environmental pollutant.[81]

Plastic pollution also disproportionately affects the poor who often do not have the resources to remove plastic and other waste from their communities, leading to health problems.[82] This includes the lack of purchasing power to buy plastic-free food products and the need to purchase smaller quantities of heavily packaged products marketed by richer multinational companies.[83] Pope Francis, in his eloquent encyclical *Laudato Si'*, stresses that scripture consistently reveals God's heart for the marginalized, and that we must change structures and systems which unfairly affect the poor.[84] We must reflect on how we produce, distribute, and consume food, making sure that we exercise special concern for the most vulnerable.

We should follow the precautionary principle by halting plastic pollution before we know for sure how bad the problem could be. This is a scientific manifestation of the biblical wisdom literature, calling us to seek counsel, be patient, and not rush ahead lest we fall into a pit that we have dug. Let us fear the Lord as it relates to cleaning up our plastic mess, even as we continue using plastics in key sectors such as medicine. It will not be easy nor inexpensive to change our single-use plastic habits. Going a step beyond the precautionary principle, we must be humble, recognizing how many mistakes we have made in the name of solving a problem without properly testing or thinking through the consequences (i.e., DDT and the drug thalidomide).[85]

Finally, we think plastic pollution prevents us from properly loving God and our neighbors. In Colossians 1:15–20, Paul makes it clear that the life, death, and resurrection of Jesus is for the reconciliation of all things, whether in heaven or on Earth. By omitting creation care from the gospel, we tell an incomplete story at best, and a twisted narrative that pridefully elevates humankind beyond our position at worst. Do we love God if we dump our trash onto our neighbor's garden every week? We do this on a global scale with little thought, and we do even worse when we consider all the other ways we neglect to care for creation (climate change, deforestation, overharvesting, coastal development, etc.). Our neighbors both locally and globally depend on the fruitfulness of creation to survive and thrive. The

world's oceans and air currents not only connect us together, but they also transport our waste to others. If we are to love God and love our neighbors, we need to thoughtfully permit our Christian faith to permeate every corner of our lives, including how we use plastic.

Call to Reflective Action

We now live in a world where plastic impinges on every area of our lives. Microplastics are ubiquitous in our environment and both the known and suspected effects on food systems are significant and usually damaging. The Christian faith provides reason for hope in what is likely to be an increasingly costly experiment in the effects of plastic on our food systems. We must act, as Christ would act if he were here; in fact, he is here, working in and through us. Our intention of raising these issues is to generate thoughtful, probing scientific and theological questions. This article highlights many of the problems and reflects on the implications of our Christian faith. How will you be a part of the solution, and what will you do next? ◙

Notes

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Call for Papers

PANDEMIC: FROM CHRISTIAN PERSPECTIVES

Pandemics are part of human life. We lived and died through the Spanish Flu, Ebola, and SARS, only to face Covid-19. What have we learned about how to deal with these assaults, and ourselves in the midst of them? What do we need yet to figure out? What insights might Christian perspectives bring to the table?

On the ASA and CSCA websites Luke Janssen, PhD, has written an essay that informs us about what we encounter in these outbreaks, how such pandemics have shaped our societies before, and some of the unique challenges of Covid-19.

He is well prepared to lead us on this topic as an accomplished member of the Department of Medicine (Division of Respirology) at McMaster University. He has pursued as well an MTS degree at the McMaster Divinity College to reflect on better integrating Christian faith with science. Those studies and his spiritual journey have already yielded an article for *PSCF* and three monographs.

Readers are encouraged to take up one of the insights or questions, or maybe a related one that was not mentioned, and draft an article (typically about 5,000–8,000 words) that contributes to the conversation. These can be sent to Luke Janssen at janssenl@mcmaster.ca. He will send the best essays on to peer review and then we will select from those for publication in a theme issue of *Perspectives on Science and Christian Faith.*

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Looking forward to your contributions,

James C. Peterson
Editor-in-Chief