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Framing the plastic pollution problem within the water quality–health nexus: Current understandings and policy recommendations

Plastic pollution in the environment has become a serious global concern, as it negatively impacts ecosystem and related services. South Africa is no exception. It is very difficult to imagine a world without plastics. Since plastics were first made, production has increased from 1.5 million tons in the 1950s to approximately 322 million tons today.¹ On the African continent, South Africa tops the list with a production of 8987 kilotons of plastic, followed by Egypt (3977 kilotons) and Nigeria (2308 kilotons).² Plastic consumption, unlike production, reveals a clear link to GDP with countries such as South Africa, Egypt, Algeria and Morocco (13–19 kg/year) having on average twice the per capita consumption of plastic than countries such as Nigeria, Kenya and Ghana (4.4–8 kg/year).² Huge amounts of plastic are also imported into Africa, contributing further to local plastic consumption. In order to maximise the beneficial properties, additives such as plasticisers, flame retardants, thermal stabilisers, light and heat stabilisers, are added to some plastics.^{3,4}

Sources, material flow pathways and fate of plastics in the environment

Within a year of production, most plastic generated for single use (packaging, straws, bottles, bags) has been disposed of as waste, often incorrectly. Rapid urbanisation in many African cities, compounded with failing or a lack of, appropriate waste management infrastructure and policy implementation, has resulted in plastic waste not being properly collected. Plastic often ends up in landfills or is burnt or illegally dumped into the surrounding environment.⁵ Although most of the highest plastic producer and consumer countries in Africa are located on the coastline, it is still not known exactly how much plastic waste in our oceans originates from land. However, it is estimated that globally 4.8–12.7 MT (metric tons) of plastic transported by rivers or wind enters the ocean every year.⁶ Transport models of plastics are still to be better understood. Complexities that exist between particulate movement in different hydrological catchments (atmospheric, terrestrial, and fresh water) hamper that understanding. However, there is consensus that marine environments are plastic sinks with very little flow of plastics out of them.⁷ Freshwater environments such as streams, rivers and lakes, which are in close proximity to plastic waste on land are, to a large extent, the pathways for marine plastics.⁷

As plastics are not biodegradable, they never truly disappear but continue to break down into smaller and smaller pieces. Despite their origin (soil, fresh water, air), macroplastics invariably are found in the marine environment in their manufactured sizes. Through exposure to UV, mechanical action or animal interaction, macroplastics break down into secondary microplastics and eventually nanoplastics.⁸ On average, 8 million tons of secondary microplastics enter the ocean annually.^{9,10} Primary microplastics on the other hand are produced at a small size to enable their functionality. Primary microplastics have various shapes and occur as fragments, fibres, foam, spheres, pellets and film.

Literature on land-based flows on the African continent is available, and so is research related to land-based solid waste management inventories, public health risk associated with mismanaged waste, and action plans for plastics. However, when it comes to plastics in the marine and freshwater environments in Africa, research is only now gaining momentum.¹¹ It is clear that more research is needed on the leakage of land-based plastic into the environment and their movement through freshwater systems, in order to better protect the marine environment.

Potential human and ecosystem health risks due to exposure to plastics

Despite these gaps in knowledge, studies are emerging on the risks posed by the presence and use of plastic to human and environmental health.¹² The negative physical effects of plastics on marine biota is now quite well documented. Less visible, and highly insidious, is the effect that plastics have on nutrient and water flow, surface temperature of sand and sediment, as well as on food webs (zooplankton and crustaceans). Changes in the above-mentioned parameters lead to changes in habitat, breeding conditions and food availability of various marine species which could result in marked population declines.^{13,14}

The presence of plastic particles in freshwater resources used for drinking water is an emerging area of research. So far, available information has clearly demonstrated that microplastics are present in both raw water resources and treated (drinking water) sources that reach the consumer. Concentrations ranging from 0.00015 to 12.6 microplastic particles per litre have been reported from studies conducted on raw water sources in China, Europe and the USA. However, to date, very few studies have quantified levels of microplastic particles in drinking water. In a study commissioned by the Water Research Commission (WRC), plastic particles were detected in surface water, groundwater and drinking water in samples collected from two metropolitan cities in Gauteng Province, South Africa.¹⁵ Concentrations of plastic particles were much lower in comparison to those in freshwater environments in industrialised countries. Total microplastic particle concentrations of up to 0.189/L and microfibre counts up to 1.8/L were reported. Preliminary findings from the study also indicated a higher proportion (88%) of finer microplastic particles (sizes of between 20 μm and 300 μm) than that of larger particles in the final treated water.¹⁵ Similarly, 83% of samples analysed in a global survey of tap (drinking) water were found to contain microplastic particles. Almost all of these (99.7%) were fibres in the concentration range 0–57 particles per litre.¹⁶ Due to the lack of standard protocols for microplastics detection and quantification in drinking water, there is narrow scope to compare findings between different reports.

It is clear that wastes generated from both the industrial use and manufacture of microplastic particles and abrasions from plastic materials, as well as those from domestic use, are the main contributors of microplastics entering the aquatic environment. The discharge of inadequately treated waste-water effluent is one route by which microplastics enter the drinking water value chain and also the marine environment. Consequently, water service institutions are under pressure to retrofit existing treatment trains to optimise the retention and removal of microplastics during water treatment. Conventional treatment processes, such as filtration, are reportedly able to remove up to 97% of microplastic particles larger than 300 μm . Advanced treatment processes, such as membrane filtration, have been reported to remove 85–99.9% of microplastics in water.¹⁷ Other technologies that have been investigated include dissolved air flotation that is capable of removing up to 95%, and disc filter, with a removal efficiency of 40–98.5%.¹⁷ In most studies, higher removal efficiencies have been reported for larger microplastics, whereas lower efficiencies have been observed for particles of 20–300 μm diameter. Thus, depending on the size and composition, microplastics may not be completely removed during waste-water treatment and there is a high chance that they may enter receiving raw waters, potentially even accumulating in the final treated (tap) water. Removed particles from waste-water treatment plants have been detected in sludge. The routine practice of applying biosolids from waste-water treatment plants to agricultural lands as fertiliser results in the accumulation, over time, of microplastics in the soil, indicating that sludge could be a driver for microplastic contamination in soil.¹⁸ Although still to be explored, there is potential for plastic to be remobilised in soil under certain conditions, such as flash flooding, resulting in the contamination of freshwater systems.¹⁸

Attempts to understand the uptake of fine particles, including plastic particles, in mammalian (including human) systems and associated risks have not yielded conclusive findings. The inconsistencies in microplastic detection and quantification protocols, as well as lack of epidemiological data, limit the interpretation of the current concentration data sets into meaningful risk assessment. Therefore, more collaborative research among the science community (both academia and water service institutions) is needed in order to understand the flow of microplastics from source to sea, and their removal during water treatment, both waste water and drinking water, and to assess the potential exposure, and risks, to consumers via drinking water. Since April 2019, the WRC has funded Project K5/2919, a study that aims to develop methods from an ecotoxicology perspective to enable the effective biomonitoring of microplastics in South African water resources. When completed in 2022, there should be greater understanding of novel endpoints in organism growth, development and survival that can be used as accurate predictors of the effect of short-term and long-term exposure to various shapes and sizes of plastic monomers as well as their additives. A greater understanding of the unique eco-threat that microfibres pose will also be elucidated from the WRC project. This will be a key finding as, historically, the unique health effects of microfibres when compared to microbeads have been difficult to assess, even in the marine environment.

There is a definite relationship between the abnormalities visible in humans and other animals versus the timing and type of plastic exposure that has occurred.^{19,20} Exposure to the same plastic as that of an adult, but in utero, results in distinct health outcomes. Phthalate exposure can cause allergies and asthma while BPA (bisphenol A) exposure shows in social and behavioural problems (particularly in childhood).^{21,22} Population groups with the highest risk of developing a plastic exposure related condition include those that work directly in the plastic industry (extraction and transport, refining and manufacture and waste management) as well as communities situated next to plastic production centres or plastic dumpsites, and whose air and water quality are affected by various plastic emissions.¹² Although the body of evidence of the health effects of nano- and microplastics continues to grow, there is still a great deal of experimental and observational research needed before a direct link between exposure to these particles and subsequent illnesses can be confirmed. Preliminary research findings do show that nano- and microplastics may be even more harmful, because not only do they serve as carriers and vectors for other harmful chemicals, metals and pathogens, but due to their size, they

themselves might be able to physically injure the lung and gut at a cellular level through ingestion or inhalation.

Any accurate determination of the health risk of exposure to plastics is largely unknown in Africa or among African populations. Consumption patterns of microplastics and subsequent health implications depend on the concentration of exposure and the type of plastic involved. For this reason, human health risk values calculated for population groups outside Africa are not reliable as a true reflection of exposure, because exposure patterns are different and cannot necessarily be extrapolated. A 3-year WRC-funded study that began in April 2020, seeks to develop appropriate models for determining the ecological and human health effects of microplastic contaminants in the Diep and Plankenburg Rivers in the Western Cape Province. By the conclusion of the study, there should be baseline data on the human health effects and risk that the local population around those two rivers will face. Health and ecological risk models and training information should be available for use by other African countries which have similar plastic and waste management practices or the lack thereof.

Summary and way forward

South Africa is actively involved in the global fight against environmental pollution and is a signatory to numerous global initiatives supporting environmental sustainability, including those specifically addressing plastic pollution. Commitment to the UN Environment's Clean Seas Campaign and Assembly, are among the most recent and notable examples. Over and above our own National Development Plan, South Africa has also committed to the UN's Sustainable Development Goals (SDGs), which are centred around water quality (SDG 6), with SDG 14 aimed at addressing marine pollution of all kinds. All these initiatives complement and strengthen the country's commitment to addressing environmental pollution and thereby curbing the negative effects that environmental pollution has on water quality and human health.

In support of the above campaigns, and based on the 2018 microplastics in freshwater environments scoping study, the WRC will continue to fund and support research that determines the presence and quantity of plastics in freshwater systems and to assess the health risks attributable to exposure to plastic-contaminated water for various uses. Particular focus will be on appropriate and realistic studies that reflect the current nature of chemical/plastic exposure that is in the form of mixtures rather than a single chemical so that data gathered from these mixture studies can be readily applied. It will be important to pursue toxicity studies that consider increased exposure and dosage concentrations to plastics in light of extreme weather events. Cohort studies which, for instance, involve pregnant women and their children until they reach adulthood, are key to understanding the long-term effects of plastic exposure in relation to different illnesses (developmental disorders, cardiovascular diseases, etc.).

As we gain a better understanding of how best to mitigate against the negative effects of plastic on our health, it is clear that reducing the production, use and disposal of plastic in South Africa and throughout Africa will be key to protecting human and environmental health.

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