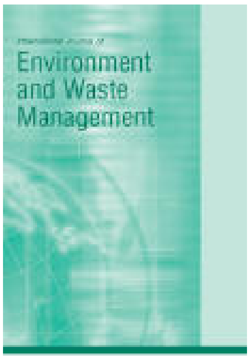


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# Distribution, human and ecological risks of microplastics in the African environment

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# Distribution, human and ecological risks of microplastics in the African environment

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**Abstract:** The presence of microplastics in the environment is progressively increasing and becoming an environmental concern in Africa. Despite the production and use of plastics, there is dearth of information and knowledge about negative impacts of these new emerging pollutants. Rapid industrialisation and urbanisation activities increase the rate of various pollutants in the environment. The main objective of this review was to summarise and discuss the current status of microplastics pollution in African environment. In addition, this review highlights the knowledge gaps that exist on microplastics pollution in African countries. To assess and discuss some information about microplastics in the environment, the published articles, reviews and other online materials were revised. Different papers were critically reviewed and provide an overview of the current, distribution, knowledge gap and abundance of microplastics in African environment. The obtained data indicated that microplastics are highly found in African environment. Few studies were carried out in aquatic environment and there is a lack of research on the presence of microplastics in the African terrestrial environment. Therefore, this review recommends to have more studies on the presence of microplastics in the African environment.

**Keywords:** microplastics; risks; emerging pollutants; human health; Africa.

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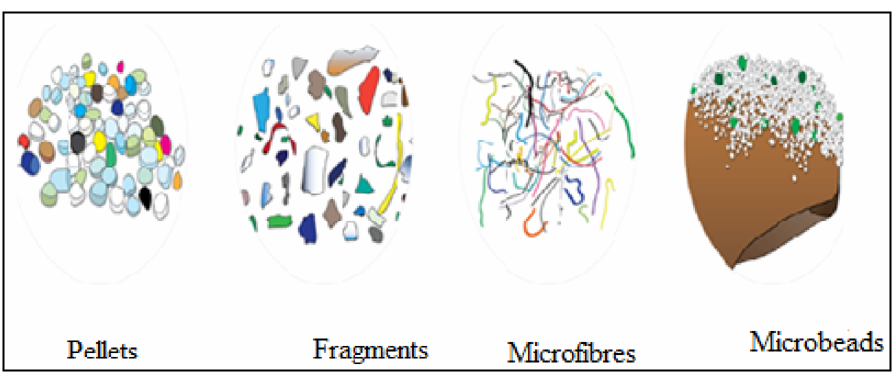
## 1 Introduction

Environmental pollution is becoming the most serious issue that gets worldwide attention (Kelishadi, 2012). Rapid industrialisation and urbanisation activities increase the rate of various pollutants in the environment (Hashmi et al., 2013; Espinosa et al., 2016). Pollution can originate from both natural and anthropogenic sources. However, anthropogenic sources significantly accelerate pollutants into the environments (Chen et al., 2006). The increased rate of different pollutants is connected with human population growth (Jiang et al., 2009; Zhou et al., 2013). The population growth of the world increased from 3.1 billion in 1961 to 7.3 billion in 2015 and expected to exceed 9 billion by 2050. The needs of this population growth drive different pollutants into the environment (Lusher et al., 2017). In addition to different agricultural inputs, other manmade chemicals such as personal care products, flame retardants, pharmaceuticals products and microplastics are becoming dangerous to soil and understanding of their impact on soil and other environmental compartments are still limited (Barh et al., 2015; Dhiraj and Chaudhary, 2016).

There are new emerging pollutants in the environment which are not yet covered, of which plastics pollution with related nanoparticles are among the best example (Verster et al., 2017). Plastics are the group of synthetic polymer material that become a typical sign of artificial waste and environmental pollution (Yang et al., 2021). The ubiquitous presence of microplastics raises great concern (Uri and Lohmann, 2017). The widespread use of microplastics has led to a higher environmental contamination which has raised worldwide public attention over the last few decades (Rodríguez-Seijo and Pereira, 2017; Zhou et al., 2021). Plastics were first introduced in the early 20th century, while the production of polyvinyl chloride and polyethylene started in the 1920 and 1930s. Then after, the mass plastic production started in 1940 and 1950s (EPA, 2016). The production and release of microplastics into the environments are continuing significantly and the global production of microplastics reached 322 million tons in 2015 and expected to reach around 1,800 million tons by 2050 (Gallo et al., 2018).

**Figure 1** Types of microplastics in the environment (see online version for colours)




*Source:* https://africanwastenetwork.org.za/projects/research/microplastics

Microplastics are classified as primary and secondary in the environment (Friot, 2017). Primary microplastics are plastics directly released into the environment in the form of small particulates while, secondary microplastics originates from the degradation of larger plastic items into smaller plastic fragments, once exposed to the environment (Friot, 2017). Microplastics are varied in colour, shape, size, density and chemical composition (Espinosa et al., 2016). The most commonly used plastics are polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polystyrene (PS) (Espinosa et al., 2016). Microplastics are produced and used in terrestrial environment (Leonard et al., 2021) and distributed into the environment by wind and surface runoff (Leonard et al., 2021). Microplastics items such as pellets, microfibres, microbeads and fragments are found everywhere (Figure 1).

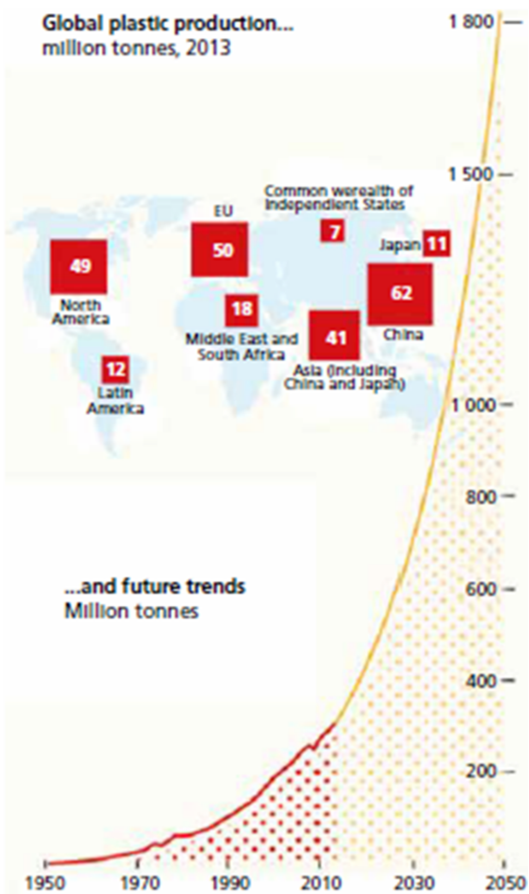
Due to their ability to resist corrosion, cheap price, low weight, durability, easily molded and stability, plastics are highly used for packing, health care and transport in numerous countries of the world (Yang et al., 2021). Global production of polyethylene and polypropylene is increasing at annual rate of about 7% (1950–2012) (Yang et al., 2021). From the total global production of plastics (322 million tons), about 51% was from Asia of which China has been the world largest producer (30%), followed by North American Free Trade Agreement (NAFTA) 18%, Europe 17%, Middle East Africa 7%, North America 4% and Commonwealth of Independent States (CIS) 3% (Plastics the Facts, 2019). Among the total global production of microplastics, 2% is used for agricultural and horticultural activities (Rodríguez-Seijo and Pereira, 2017). The study that has been done by Babayemi et al. (2019), indicated that 33 African countries imported approximately 86.14 million ton (Mt) of polymer form and 31.5 Mt of plastic products between 1990–2017. As a continental level (with 54 countries) about 172 Mt of polymers and plastics imported between 1990–2017. In addition, products estimated to 230 Mt of plastics entered into Africa during that time with the leading share going to Egypt (43 Mt, 18.7%), Nigeria (39 Mt, 17.0%), South Africa (27 Mt, 11.7%), Algeria (26 Mt, 11.3%), Morocco (22 Mt, 9.6%), and Tunisia (16 Mt, 7.0%) (Babayemi et al., 2019). In most African countries, microplastics pollution is not recognised as emergent issues yet. Despite the production and use of plastics, there is lack of information about the negative impacts of microplastics in the countries (Khan et al., 2018). As compared other continents the number of published paper on plastic pollution from Africa is still less (Aragaw, 2021). Even though some African countries have introduced measures to reduce plastic bags, e.g., Kenya in August 2017, Cameroon in 2014, Eretria in 2005, Rwanda in 2008, Tanzania in 2006, South Africa in 2004, Uganda in 2007, Mauritania in 2013, Morocco in 2016 and Botswana in 2010, the ban was still not implemented well (Scientific Advice Mechanism, 2018). Determining the fate microplastics is very important to realistic assessment of toxicity effect of microplastics (Zhou et al., 2021). Therefore, the main objective of this review was to fill the gap in the current literature with updated comprehensive literature regarding the status, human and ecological impacts of microplastics in African environments.

## 2 Literature review

### *2.1 Background and global distribution of microplastics*

The term microplastics was first coined by Thompson et al. (2004) to describe the accumulation of microscopic pieces of plastic in marine sediments and water column of European water. In addition, Arthur et al. (2009) proposed the upper size limit to the initial term and microplastics where called plastics particles smaller than 5 mm. This definition was further redefined in 2011, when microplastics were distinguished according to their origin into primary and secondary by Cole et al. (2011). Primary microplastics are plastics intentionally produced in small size (microscopic dimensions) while, secondary microplastics result from fragmentation and degradation of big plastics in the environment (Di and Wang, 2018; Frias and Nash, 2019). There are different types of microplastics in the environment namely; polyethylene terephthalate (PET), polyester (PES), polyethylene (PE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polypropylene (PP), polyamide (PA) and polystyrene (PS) (Waite et al., 2018). The presence of plastics in the environment has been recognised as the most global issue. It is one of the anthropogenic phenomena that highly threatens biodiversity due to potential entanglement and ingested (Gionfra, 2018). It has been reported that the global production of microplastics in the environment reaches about 322 million tons in 2015 and expected to reach around 1,800 million tons by 2050 (Gallo et al., 2018). The following figure indicates the current and future global plastic productions. From the figure it is possible to conclude that the production rate of microplastic across the world is increasing so fast (Figure 2).

**Figure 2** Global plastic production (see online version for colours)




*Source:* Gallo et al. (2018)

Numerous studies have been done on microplastics pollution in marine and aquatic environments (Di and Wang, 2018; Gallo et al., 2018; Friot, 2017; Verster et al., 2017). The report indicated that microplastics contamination on the land is estimated to be between 4 to 32 higher than in the ocean (Gionfra, 2018). However, there is still lack of research on microplastics in the soil (Rodríguez-Seijo and Pereira, 2017).

### *2.2 Distribution of microplastics in Africa*

Africa is one of the unique places in human history (Khan et al., 2018). Upon entering new era, Anthropocene defined by human factor influences the earth systems, in which plastic pollution is among the new emerging pollutant in Africa with limited information about the occurrence, sources and risks of plastics within African environments (Khan et al., 2018). Africa has been developing rapidly and consumed large amount of plastic products and there is lack of plastic waste management practices (Aragaw, 2021). As compared to other continents, research on microplastics pollution in Africa started lately. The studies that are reported form African countries are still concentrated on microplastics pollution in African great lakes, particularly on Lake Victoria (Aragaw, 2021), South Africa (Nel and Froneman, 2015; Verster et al., 2017), Tanzania Lake Victoria (John et al., 2020; Taylor et al., 2014) and Kenya (Kosore et al., 2018). The report from South Africa indicated that about 1,490,000 metric tons of new plastic and 310,600 metric tons of recycled were used across a broad spectrum of industries in 2015 (Verster et al., 2017). From those packing uses 55%, building construction materials use 15% and other sectors like electronics and electrics, automotive and transport, engineering, agriculture and domestic products use 6% (Verster et al., 2017). Table 1 indicates some of the research that have been reported from African countries and in addition this table indicates as the research that has been reported are still concentrated on microplastic in water, sediments and fish. This implies, till today there is deficiency of report on agricultural soil in Africa. In addition, most of the papers that have been reported are from South Africa. This shows as there is dearth of report on the presence of microplastics on the other African countries.

### *2.3 Sources and distribution pathways of microplastics in the environment*

Microplastics can be entered into the environment through different ways; sewage sludge from municipal wastewater treatment plants as fertilisers for agricultural land, controlled release of fertilisers, plastics mulching, plastics green house, plastics in compost, industrial drainage system, waste water irrigation and personal care products (Cole et al., 2011). Runoff is the main pathway for plastics in the environment (66%), followed by waste water treatment system (25%) and wind (7%) (Gallo et al., 2018). In addition, wild life can also contribute to the overall burden of microplastics pathway when they ingest larger plastics which are then broken into smaller pieces in their guts and they release them back to the environment (e.g., *Fulmarus glacialis* is a type of sea bird that estimated to reshape and redistribute annually about 6 tonnes of microplastics into the environment (Gallo et al., 2018). In developing countries like Ethiopia, where poor awareness of societies on plastic materials, poor waste management practice, high run off and floods are the main sources of plastics to agricultural farmland and water bodies which alter the quality of soil, water and threatens human and other organisms life (Adugna and Tikubet, 2017).

**Table 1** Abundance of microplastics in African environment

| *Country* | *Locations* | *Concentrations* | *Sample type* | *Compositions* | *Reference* |
|---|---|---|---|---|---|
| Kenya | Lake Naivasha | $0.407 \pm 0.135$ particles/m$^{-2}$ | Water | PE, PP, PES, PET | Migwi et al. (2020) |
| South Africa | South-eastern coastline | $688.9 \pm 348.2$ and $3{,}308 \pm 1{,}449$ particles/m$^{-2}$ | Sediment | PS, fibres, fragments | Nel and Froneman (2015) |
| South Africa | South-eastern coastline | $257.9 \pm 53.36$ and $1{,}215 \pm 276.7$ particles/m$^{-3}$ | Water | PS, fibres, fragments | Nel and Froneman (2015) |
| Uganda | Lake Victoria | 0.02–2.19 particles/m$^{-3}$ | Water | PE,PP, PS, PES | Egessa et al. (2020) |
| Nigeria | Nwangele | 440–1,556 particles/L | Water | PP,PE,PS,PVC,PET | Ebere et al. (2019) |
| South Africa | South African coastline | 1.13–1.58 particles/individuals | Fish | PP,PE,PET,PA | Bakir et al. (2020) |
| Kenya | Lake Naivasha | $0.183 \pm 0.017$ to $0.633 \pm 0.067$ particles/m$^{-2}$ | Water | PE, PES, PP, PET | Migwi et al. (2020) |
| Kenya | Kenyan coastline | 33.3–275 particles m$^{-3}$ | Water | PP, PE | Kosore et al. (2018) |
| Ethiopia | Lake Zeway | 6.3–115.9 particle/kg | Sediment | PET,EPR, PUAR | Merga et al. (2020) |
| Egypt | Eastern Harbour | 33–174 particle/g/dw | Marine sediment | PP, PS, PE, PTFE, PET, ABS, nylon, PVA | Hamdy et al. (2019) |
| Tunisia | Lagoon Bizerte | $2340 \pm 227.15$ to $6920 \pm 395.97$ items kg$^{-1}$ dw | Sediment | PP, PE | Toumi et al. (2019) |
| Kenya | Kenyan coastline | 110 particles m$^{-3}$ | Surface water | PP, LDPE | Kosore et al. (2018) |
| Gana | Coastal Gana | 1.85 particle/g | Marine sediment | PS, PP, PE, PTFE | Gbogbo et al. (2020) |
| Ethiopia | Lake Zeway | 1.1–56.3 (mg/kg_ww) | Fish | PE,PP | Merga et al. (2020) |
| Algeria | Annaba Gulf | $182.66 \pm 27.32$ to $649.33 \pm 184.02$ kg$^{-1}$ dw | Sediment | PET, PE, PP, PSE, Butyl Branham, EPR and CTA | Bellucci (2020) |
| Nigeria | Lake Eleyele | 84–337.5 ±1.5 Kg$^{-1}$ dw | Fish | | Adeogun et al. (2020) |
| South Africa | Vaal River | 430–722 mg/m3 | Water | Fibre, pieces | Weideman et al. (2020) |

Note: Polyethylene terephthalate (PET), polyester (PES), polyethylene (PE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polypropylene (PP), polyamide (PA), polystyrene (PS), acrylonitrile butadiene styrene (ABS), low-density polyethylene (LDPE), polyethylene vinyl acetate (PEVA), polytetrafluoroethylene (PTFE), cellulose tri acetate (CTA) and ethylene propylene (EPR).

**Figure 3** Accumulation of plastics in water bodies (see online version for colours)

*Source:* Worm et al. (2017)

**Figure 4** Accumulation of plastics on the surface of land (see online version for colours)

*Source:* Verster et al. (2017)

## 2.4 Impacts of microplastics on human health

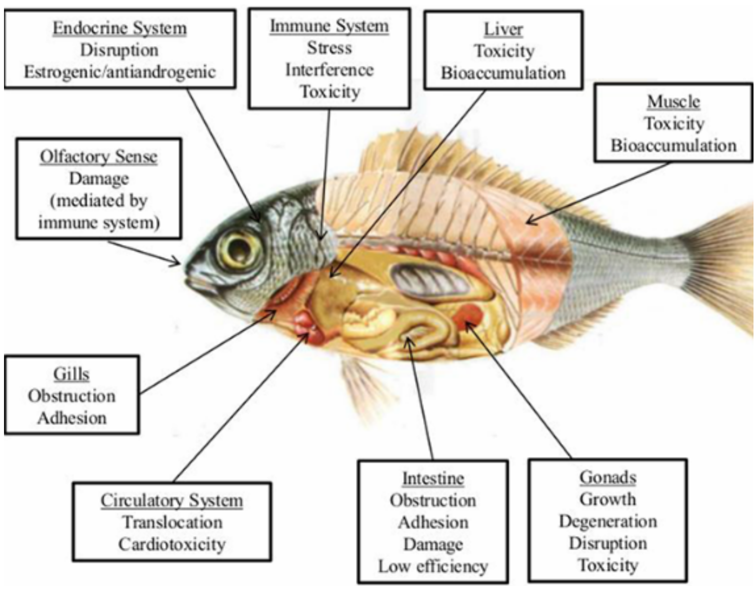
Due to low cost, rapid production as well as wide range benefit, plastics are largely used in different countries of the world (Rubio et al., 2019). It has been reported that microplastics can cause different human and ecological effects (Nel and Froneman, 2015; Rodríguez-Seijo and Pereira, 2017; Leonard et al., 2021). According to Rubio et al. (2019), human being can be exposed to plastics through ingestion and inhalations. He has reported that pulmonary and gastrointestinal tracts are the two main portals of plastic entries into human beings. The research reported by Cox et al. (2019), indicated that microplastics concentration of sea food was about 1.48 MPs/g, sugar (0.44 MPs/g), honey (0.10 MPs/g), salt (0.11 MPs/g), alcohol (32.27 MPs/L), tap water (4.23 MPs/L), bottled water (94.37 MPs/L) and air (9.80 MPs/$m^3$). In addition, he has also reported that daily consumption of microplastics by human being were 113, 142, 106 and 126 for male children, male adult, female children and female adults respectively. The annual consumption via food and beverages of MPs for these groups are roughly 41,000, 52,000, 39,000, and 46,000, respectively. Another report by Campanale et al. (2020) indicated that human could also take an estimated intake of 80 g of microplastics per day. Another reported indicated that during the polymerisation process of microplastics, reactive oxygen species are generated and cause common factor that initiate cellular damage (Rubio et al., 2019). According to Gabriel et al. (2018) report, the interaction of the immune system with the microplastics can lead to the immunotoxicity and therefore, trigger adverse effects such as immunosuppression, immune activation and abnormal inflammatory responses. Another study by Schirinzi et al. (2017) indicated that the vitro studies with cerebral and epithelial human cells from the microplastics, cause cytotoxic effect at cell level in terms of oxidative stress.

## 2.5 Impacts of microplastics on aquatic organism

Due to global distribution and potential risks of microplastics, the contamination of both fresh and marine water from microplastics is growing concern (Bing et al., 2020). According to Ziccardi et al. (2016), between 4.8 and 12.7 million metric tons of mismanaged plastic waste entered the ocean in 2010. It has been estimated that, about 5–13 million tons/year of microplastics entered into the world oceans. From this, about 0.3 million tons are floating on the sea surface and the rest of them are sinking into the water. This implies that, significantly large number of microplastics is sinking in the marine environment (Matsuguma et al., 2017). It has been reported that, microplastics are ingested by marine animals like fish, sea birds such as puffins and trapped into their stomach for long time, which lead to weight loss, malnutrition, reduce feeding rates, less energy for growth and lower reproduction. Over 280 marine species have been found to ingest microplastics (Verster et al., 2017). Thompson et al. (2004) reported that from 504 fishes, one-third of them had plastics in their digestive tract. He has also reported that some species of sea birds had ingested larger quantities of microplastics. Another study from Landon by Van Sebille et al. (2015) indicated that 80% of sea birds ingest plastics into their stomach and his report also indicated that about 10% of their weight is microplastics in their bodies. In addition, microplastics can reduce the reproductive capacity and change larval health (Welden and Lusher, 2020). Another research done by Giacomo et al. (2015) indicated that fish that fed on the contaminated plastic showed the reduction of vitellogenin precursor to egg protein. Likewise, other finding indicated that

Pacific oysters exposed to MPs reduced oocyte size and number, plus the reduction in the larval development and yield (Sussarellu et al., 2016). Cole et al. (2014) also indicated that effect of plastics on egg diameter, and hatching success in *Calanus heligolandicus* after 6 days. Similarly, Lei et al. (2018) reported that plastic contamination result in decreased embryo number and brood size in *Caenorhabditis elegans*. The research that has been done on larvae of Pacific oysters, *C. gigas* revealed the presence of microplastics in the larva. Larva of 3, 10 and 24 days were exposed to microplastics between 0.07 and 20.3 mm, this implies that all ages of larva ingest plastics up to 7.3 (Welden and Lusher, 2020).

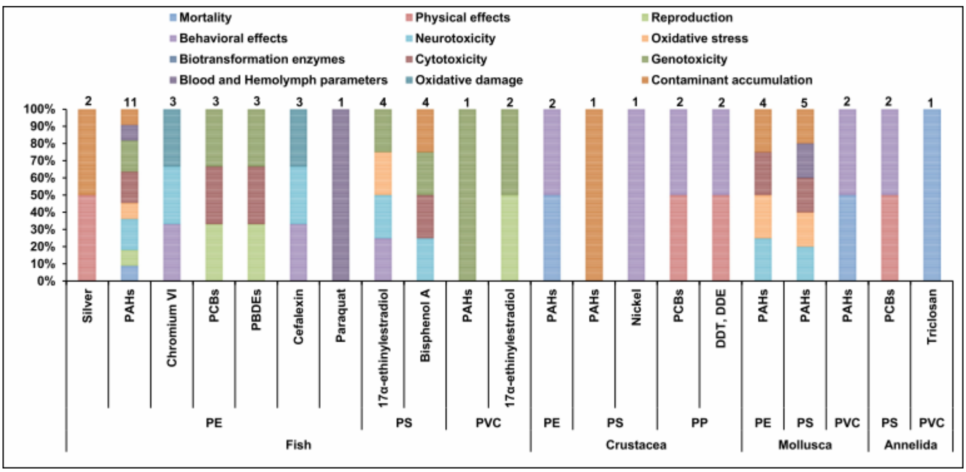
**Figure 5** Health impacts of microplastics on aquatic organism (see online version for colours)




*Source:* Espinosa et al. (2016)

Besides, research has revealed that microplastics can help as vector for hydrophobic organic contaminants such as persistence organic pollutants (POPs) which includes organochlorine pesticides (OCPs), polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs). In addition, they are also carrier for heavy metals such Pb, Ni, Cd, Zn, As and Cu and antibiotic (Ziccardi et al., 2016). They play a great role in transporting chemicals that are associated with plastics within the aquatic environment into the food chain (EPA, 2016). Due to the long persistence of plastic debris in the aquatic environment, plastics can be a source of chemicals to the aquatic environment. The ability of hydrophobic compounds to partition has well been documented because of sorptive capacity. Plastics can be used as passive sampling devices to assess the concentration of persistent organic compounds in the environmental compartments such as soil, water and sediments (EPA, 2016). The concentration of hydrophobic compounds that are sorbed to microplastics can be varied even within individual particles in single environment (Ziccardi et al., 2016). It has been indicated that plastic sample taken from North Pacific Gyre revealed that about 27 to 980 ng/g of PCBs, 7,100 ng/g of DDTs and 1,200 ng/g of PAHs were detected (EPA, 2016). Similarly, Hirai et al. (2011) reported that several alkyl phenols, PCBs, DDTs, PAHs and PBDEs were detected in the concentration between 1 and 10,000 ng/g in sample collected from the open ocean and urban beaches. In addition, the study on the toxicity of microplastics and nanoplastics in the mammalian system (mouse model), indicated that reduction in mucus secretion, gut barrier dysfunction, intestinal inflammation, gut microbiota dysbiosis, liver inflammation and lipid accumulation or lipid profile changes and also changes in the markers of lipid metabolism (Lim et al., 2019; Qian et al., 2020). Figure 6 indicated the combined effect of microplastics with the other contaminants.

**Figure 6** Joined effect of microplastics with the other contaminants on different organisms in which every bar shows the total number of studies according to the types of microplastics groups of organisms and effects (see online version for colours)




*Source:* Carlos et al. (2018)

## 2.6 *Ecological effects of microplastics*

### 2.6.1 *Impact of microplastics on soil quality*

It has been reported that microplastics have impact on soil physical and chemical properties. Yang et al. (2020) reported that microplastics can significantly decrease macropores, bulk density and gravimetric soil water content. In addition, Zhang et al. (2020) also stated that soil saturated hydraulic conductivity, filed capacity and water repellency of soil contaminated with microplastics can be changed from the soil that is not affected by microplastics contaminations. Furthermore, he has also mentioned that microplastics in the soil can create channels for aqueous movement and enhance water evaporation rate of soil, which result in desiccation cracking of soil.

### 2.6.2 *Impact of microplastics on soil biota*

In addition to changes in soil properties, microplastics in soil can alter the behaviour of soil organisms (Zhang et al., 2020). According to Zhang et al. (2020) report, microplastics in the soil change the behaviour of pringtail. The microplastics in the soil disrupted the movement of sprintail as a result of MPs filled these bio-pores. Meanwhile, the occurrence of microplastics in the soil cannot only change the physicochemical properties of the soil but also it can affect the soil fertilities as well (Yang et al., 2020; Zhang et al., 2020). Zhu et al. (2019) reported the effect of plastic nematodes sizes, survival, rate and body length. Moreover, he has also reported the significant downregulated expiration of 17 and unc-47 reflecting damage to cholinergic and GABA neurons. Besides, Zhu et al. (2018) reported exposer of soil oligochaete Enchytraeus crypticuston to nanoplastics indicated that 10% of them showed negative effect on their weight. Moreover, clear shift in the gut of microbiotas was observed. Similarly, study by Ju et al. (2019), indicated negative effect of PE microplastics exposure (0.1–1%) on *Folsomia* reproduction. The above report indicated that, further work is needed to investigate the potential longer-term effects of microplastics, on the other soil organisms.

## 3 Conclusions

This review has summarised the current distribution status, human and ecological risks of microplastics in the environment. The presence of microplastics in the environment is considered as the emerging issue of the world. Human are vulnerable to microplastics through the consumption of seafood, air and water. It is also undeniable that a large number of organisms are exposed to plastic particles. However, the information and knowledge regarding the occurrences, sources and human and ecological fate of microplastics is still scars in different countries of the world especially in Africa. In addition, real environmental risks of microplastics remain uncertain. Therefore, it's crucial if more consideration should be given to microplastics pollution.

## 4 Perspectives for future studies

Based on this review, it is possible to say that knowledge about microplastics is still limited in African countries, where there is still lack of information about these new emerging pollutants. So to bridge this gap, all African countries should encourage awareness raising activities to increase people's knowledge about this new emerging contaminant. Research related to the occurrence, sources and effects of microplastics on the environment should be encouraged. More attention should be given on the policies that help to develop better plastic waste management in all African countries. In addition, for the future study this review should also point out the following recommendations.

a occurrences of microplastics in all environmental compartments (soil, water, sediments, etc.) should be considered

b more consideration should be given to determine the potential human and ecological impact of plastics

c encouraging more research on other environmental pollutants that can be transported by plastics in the environment or considering environmental contaminants that associated with micro-plastics that have a profound toxicity effect on the environment, should be included and more information on the concentration of these compounds should also be investigated.

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