



Environmental Pollutants and Contaminants of Emerging Concern: An African Perspective

Chinaza Godswill Awuchi¹, Ikechukwu Otuosorochi Amagwula²

¹School of Natural and Applied Sciences, Kampala International University, Kampala, Uganda

²Department of Food Science and Technology, Federal University of Technology Owerri, Owerri, Nigeria

*Corresponding Author: Chinaza Godswill Awuchi

Email: awuchichinaza@gmail.com



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Abstract

This review focuses on the environmental pollutants and contaminants of emerging concern in Africa. There is increasing reports and identification of ecotoxicological impact of contaminants of emerging concern (CECs), such as plastic, pharmaceutical products, modern pesticides, and personal care products, in terrestrial and aquatic environment within Africa. Identification of CECs, including pharmaceuticals, plastic wastes, pesticide residues, fungal toxins, and personal care products, have been documented in African region including in sediments, sludge, treated drinking water, surface water, wastewater, groundwater, land, solid deposits, etc. Some of the emerging pollutants of concern to environment and humans include lindane, heptachlor, endrin, endosulfan, dieldrin, dichlorodiphenyltrichloroethane (DDT), benzaldehyde, aldrin, bisphenol A, phthalates, bisphenol S, etc. There is need for more studies to identify and quantify the existing and more emerging pollutants.

Introduction

Contaminants of emerging concerns (CECs) have been among the major challenges in Africa. The increasing identification and reports on ecotoxicological impact of CECs, e.g. plastic, pharmaceutical products, modern pesticides, and personal care products, in environment within Africa are growing. The reports of contaminants of emerging concern in terrestrial and aquatic environment in Africa are increasing, though there is still limited data available (Sorensen et al., 2015). In general, CECs occur in Africa at same magnitude as in most regions, including the Western regions of the world (Abafe et al., 2018). Although, for some compounds and certain locations, higher concentrations have been detected in Africa. While antimalarial and antiretroviral drugs occurrence in Africa have concentrations greater than 100 µg/L, they are not commonly detected in Western regions. Mycotoxins are also becoming serious concern in many countries in Africa (Chinaza et al., 2021; Chinaza et al., 2020a,b). Table 1 shows the common emerging pollutants from Africa as reported by Sorensen et al., 2015. This review shows the pollutants emerging in Africa, with the aim of providing information to create awareness and guide actions on measures required to prevent or control specific CECs.

Table 1. Common emerging pollutants from groundwater in Africa (Sorensen et al., 2015)

Compound	Max. concentration (ng/L)		Common use
	Dry	Wet	
Butylated hydroxytoluene	0.4	0.3	Anti-oxidant
Triclosan	0.02	0.03	Bactericide
Bromodichloromethane	50	–	By-product chlorination

Bromoform	0.8	–	By-product chlorination
Chlorodibromomethane	12	–	By-product chlorination
Caffeine	–	0.17	Drug
Tri-(2-chloroethyl) phosphate (TCEP)	–	0.1	Flame retardant
Benzaldehyde	1.2	–	Food additive
Triacetin	–	0.04	Food additive
Atrazine	0.13	0.07	Herbicide
Bromacil	–	0.09	Herbicide
Terbutryne	0.03	0.02	Herbicide
2,6-Dichlorobenzamide (BAM)	0.01	–	Herbicide metabolite
N,N-Diethyl-m-toluamide (DEET)	0.4	1.8	Insect repellent
4,4 ⁰ -DDT	–	0.07	Insecticide
beta-BHC (beta-HCH)	–	0.05	Insecticide
Dicofol	–	0.06	Insecticide
Dieldrin	–	0.31	Insecticide
o,p ⁰ -DDT	–	0.02	Insecticide
Benzophenone	0.04	0.06	Photo initiator
1,6-Dioxacyclododecane-7,12-dione (DOCDD)	48	34	Plasticiser
bis(2-ethylhexyl)phthalate (DEHP)	21	5	Plasticiser
Bis (4-chlorophenyl) sulfone (BCPS)	–	0.03	Plasticiser
Bisphenol A	1.1	0.09	Plasticiser
Cyclohexanone	–	0.1	Plasticiser
Diisobutyl phthalate (DIBP)	1	–	Plasticiser
Diethyl phthalate (DEP)	22	–	Plasticiser
Dimethyl phthalate	1	0.1	Plasticiser
N-butyl Benzenesulfonamide (NBBS)	168	1	Plasticiser
Triphenyl phosphate	1.1	–	Plasticiser
1,1,1,2-Tetrachloroethane	0.14	–	Solvent
1,2,3-Trichloropropane	1.3	–	Solvent
1,3-Dichlorobenzene	–	0.13	Solvent
2-Chloromethyl-1,3-dichloro-2-methylpropane	7	–	Solvent
Chlorobenzene	1.4	0.07	Solvent
Tetrachloroethylene (PCE)	–	0.4	Solvent
Trichloroethylene (TCE)	0.6	0.5	Solvent
2,4,7,9-Tetramethyl-5-decyne-4,7-diol (TMDD)	–	0.6	Surfactant
Homosalate	–	0.05	UV inhibitor
Octocrylene	0.12	0.04	UV inhibitor

CECs Occurrence in Water Resources Within Africa

Despite the fact that there are few research on the CEC's real status and incidence in Africa, there has been a considerable rise in focus recently. Only 17 percent of African nations are represented in the research, with 59 percent coming from South African studies (Abafe et al.,

2018), Tunisia and Nigeria contributing 9 percent each, and Kenya contributing 7% (Olaitan et al., 2017; K'oreje et al., 2018; Belhaj et al., 2016). Despite the few research, CECs, such as pharmaceuticals and personal care products (PPCPs), have been found in sediments, sludge, treated drinking water, surface water, wastewater, groundwater, solid deposits, and other places in Africa (K'oreje et al., 2019). Plastic wastes have been identified as emerging contaminants in both terrestrial and marine ecosystems in Africa and throughout the globe (Awuchi and Awuchi, 2019a,b).

Pollutants from sediments

CECs partitioning occurs between the aqueous phase and sediments during wastewater treatment, as well as in the river, with the degree of partitioning depending on the chemical, physical, and biological characteristics of the substances, the sediment compositions, and environmental circumstances (e.g., temperature, pH). Adsorbed chemicals may be detectable in the environment for a lengthy period of time. The presence of PPCPs in river sediments and sludge has been investigated throughout Africa (Agunbiade and Moodley, 2016; Lehutso et al., 2017; Rimayi et al., 2018a). A substantial supply of pesticide residues may be found in urban and rural wastewater owing to the agricultural operations carried out in these areas of Africa, as well as the widespread usage of wastewater treatment systems (Vermeiren et al., 2013; Branchet et al., 2018). Plant growth hormones and polycyclic aromatic hydrocarbons (PPCPs) are among the increasing contaminants in Africa, particularly in river sediments and sludge. According to K'oreje and colleagues (2019), significant differences have been observed between dieldrin, sediment (0.03 mg/kg) and efavirenz, sludge (43 mg/kg). Apart from a few outliers (such as aldrin, sulfamethoxazole, and caffeine), a number of drugs have ranges smaller than 1000 g/kg, with the exception of caffeine. In general, organochlorine pesticides are found at greater concentrations as compared to polychlorinated chlorinated pesticides (PPCPs), which is partially owing to their hydrophobic character (Shen and Wania, 2005; Awuchi and Awuchi, 2019a, b). When compared to PPCPs, some organochlorine compounds have a fourfold greater range of concentration than the latter. Behind the most part, there are two main causes for this. As a consequence, the use of many organochlorine pesticides is either limited or prohibited in several African nations, including South Africa, Nigeria, Kenya, and Ghana, and their prevalence in the environment has decreased substantially as a result of this restriction or prohibition (Fosu-Mensah et al., 2016; Pest Control Products Board, 2017). It is possible that there will be a considerable difference in their detection depending on the scope and duration of the ban's enforcement regime. Second, most research concentrate on organochlorines rather than other chemicals, resulting in a greater number of findings accessible.

Pollutants associated with surface water in Africa

Natural dilution and attenuation play a significant role in the degradation of CECs after they have been released into surface water (Sabater, 2015). Pollutant dilution occurs in aquatic environments as a result of their large water capacity as compared to the amount of wastewater entering them (Rimayi et al., 2018a). However, in certain instances, greater runoff as a result of a flash flood may result in higher concentrations of CECs in rivers (Schulz, 2001; Rabiet et al., 2010; Hanamoto et al., 2013). The effects of natural attenuation and dilution, in addition to consumption patterns, are important variables that lead to variations in the distribution of CECs in surface water. A similar trend to that seen in influents has been observed in surface water in Africa, with analgesics, antibiotics, and anti-inflammatory medicines exhibiting the highest amounts (K'oreje et al., 2019). In addition, significant fluctuations in PPCP concentrations have been found across Africa. Generally speaking, the most prevalent antiretrovirals (zidovudine, nevirapine, and lamivudine), antiinflammatory/analgesics (such as paracetamol, ibuprofen, and

aspirin), and antibiotics (such as trimethoprim, sulfamethoxazole, and ciprofloxacin) have been reported recently, with some occurring in concentrations comparable to those found in wastewater. With the exception of methylparaben (6880 ng/L), ethylparaben (2300 ng/L), benzophenone (1580 ng/L), sulfadoxin (1460 ng/L), and valsartan (1770 ng/L), all hormones, PCPs, cardiovascular medications, and 'other' medicines have been recorded at quantities below 1000 ng/L (K'oreje et al., 2019). The majority of studies on the prevalence of PPCPs in Africa's surface water concentrate on streams and rivers that pass through heavily industrialized and urbanized regions (Ngumba et al., 2016; Madikizela and Chimuka, 2017). As a result of their research, it was discovered that, in addition to point discharge from wastewater treatment plants, other sources such as informal settlements and urban areas contribute to continuous and significant PPCPs input into the marine environment (Mandarić and colleagues, 2018; K'oreje and colleagues, 2018).

In contrast to pesticides, which have only recently come to the attention of the environmental community, pesticides have been the subject of environmental concern for more than seven decades, since the application of dichlorodiphenyltrichloroethane (DDT) was reported to cause a decline in the bird population in the United States (Robbins and Stewart, 1949). The use of DDT, as well as the use of organochlorine pesticides, has been prohibited in many countries for a long time owing to its toxicity and persistence in the environment. A number of studies have been conducted as a result of this, with particular emphasis on the presence of organochlorine pesticides in the environment in the African area (Nesser et al., 2016; Elibariki and Maguta, 2017; Unyimadu et al., 2018).

In Africa and other areas of the globe, neonicotinoid pesticides are now among the most widely used and most widely sold insecticides. Neonicotinoid insecticides are extremely soluble in water, making them an excellent choice for aquatic applications. In addition to having poor soil adsorption (log KOC) and partitioning (log KOW) characteristics, they also have a prolonged half-life in both water and soil, which makes them susceptible to persistence in the environment. Despite this, neonicotinoid insecticides have not been thoroughly investigated in African water sources (Morrissey et al., 2015). K'oreje and colleagues (2019) found that pesticide concentrations in Africa vary from 0.1 ng/L to nine micrograms per liter of water for fungicides, 0.2 ng/L to fourteen micrograms per liter for herbicides, and 0.06 ng/L to 69 micrograms per liter for insecticides. Different consumption patterns, regulatory frameworks, hydrological and climatic conditions, sampling locations and times, differences in chemical, physical, and biological properties (such as ionizability, polarity, and water solubility) of each compound, and different methods of determination are all associated with the observed differences (Otieno et al., 2013; Teklu et al., 2015; Struger et al., 2017).

Since 1976, the use of organochlorine compounds such as lindane, heptachlor, endrin, endosulfan, dieldrin, DDT, and aldrin has been prohibited in a number of African countries at various points in time. However, recent detections of organochlorine compounds in surface water have demonstrated their continued introduction into the environment, persistence in the environment, and lax enforcement of bans (Fianko et al., 2011; Pest Control Products Board, 2017; Affum et al., 2018). Although DDT limited use in public health for the control of mosquitoes as part of the effort to combat malaria is allowed in a few countries, such as Kenya, it is not permitted in the majority of nations (Pest Control Products Board, 2017). Except for a few specific compounds, the pesticide concentrations reported in Africa are similar to those recently reported in other parts of the world, including India (Yadav et al., 2015), China (Grung et al., 2015), South Asia (Ali et al., 2014), and Brazil (Albuquerque et al., 2016), with the exception of some specific compounds.

Treated drinking water and groundwater

Groundwater is used as drinking water in a number of African countries, sometimes without any treatment at all. Residents who drink from polluted water, particularly when the water is contaminated with CECs, are unquestionably at risk of developing health issues in the future. CECs are often removed from drinking water using methods that are similar to those used for conventional drinking water treatment (e.g., chlorination, sand filtering, flocculation, and so on) (Troger et al., 2018; Sultana et al., 2018). There have been reports of pesticides and PPCPs being detected in Zambian groundwater (Ngumba, 2018; Sorensen et al., 2015) Phycoerythrin was detected in South Africa (Rimayi et al., 2018b; Dalvie et al., 2003), Nigeria (Olaitan et al., 2014), Kenya (Madadi, 2017; K'oreje et al., 2016), Ghana (Fosu-Mensah et al., 2016), and Ethiopia (Mekonen et al., 2016) at quantities ranging from Moreover, in treated drinking water samples from South Africa (Wanda et al., 2017; Van Zijl et al., 2017), Nigeria (Olaitan et al., 2017), Ethiopia (Mekonen et al., 2016), and Algeria (Kermia et al., 2016), they have been found at quantities ranging from 0.02 ng/L to 34 g/L. On the continent of Africa, Figure 1 depicts the amount of medicines and personal care items, as well as pesticides, found in wastewater, groundwater, surface water, sewage, drinking water, and sediments.

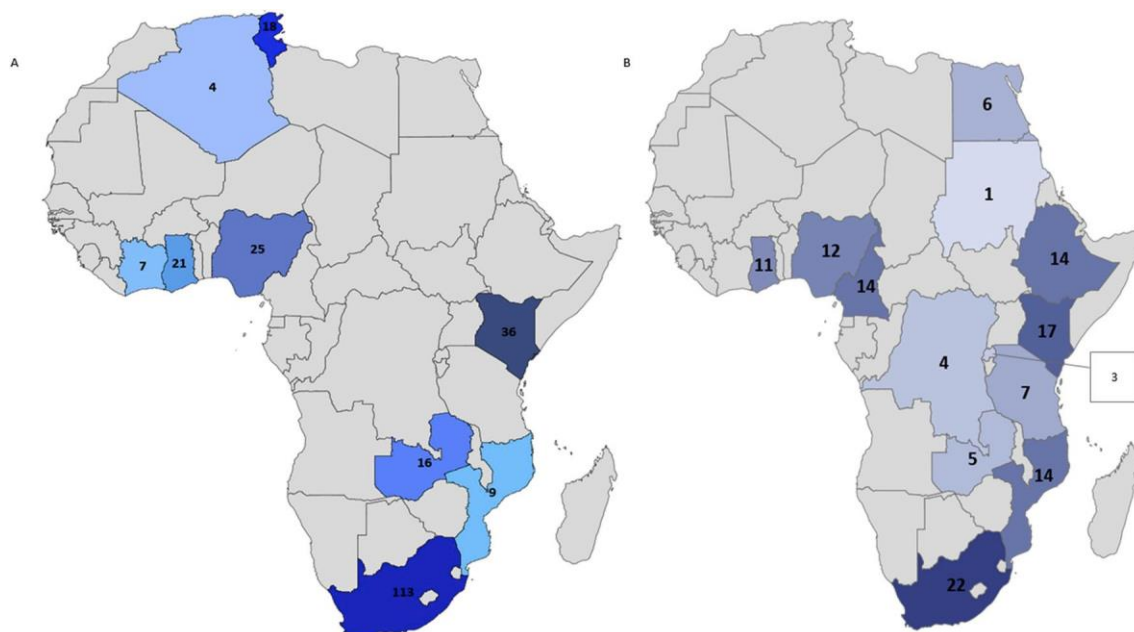


Figure 1. Number of pharmaceuticals and personal care products (A) and pesticides (B) in wastewater, groundwater, surface water, sludge, drinking water, and sediments in Africa. The grey colour shows regions with no available data during this study (K'oreje et al., 2019)

According to the data collected from drinking water and groundwater sources throughout Africa, PPCPs concentrations in drinking water and groundwater are lower than those in surface water. Despite this, investigations have shown pesticides and polycyclic aromatic hydrocarbons (PAHs) at levels comparable to those found in surface water and wastewater (Olaitan et al., 2017; Mekonen et al., 2016). Maximum quantities of ibuprofen (4 g/L) and paracetamol (18 g/L) have been found in Nigerian treated water and groundwater, respectively (Olaitan et al., 2017), as well as concentrations of nevirapine (1.6 g/L) in Kenyan groundwater (K'oreje et al., 2016). In spite of the fact that the likely sources and causes of these high concentrations have not yet been identified in detail, the studies were carried out in pharmaceutical industry sites, informal settlement areas, and healthcare institutions, all of which are known to be contaminated with PhACs before the samples were taken. Antimalarial

medicines (sulfadoxine, chloroquine, and amodiaquine) have been found in high quantities in treated water and groundwater in Africa (about 11 g/L) (Olaitan et al., 2017). This goes a long way toward demonstrating the usual patterns and diversities of PPCPs in aquatic systems across Africa. According to reports from Ethiopia, the highest 2,4-dichlorophenoxyacetic acid (2,4-D) concentration found in treated drinking water was greater than the maximum allowable concentrations (0.1 g/L MCLs) for drinking water found in Europe (Mekonen et al., 2016; Li and Jennings, 2018). The majority of research concentrate on wells with shallow depths, which are often poorly protected and, as a consequence, are very susceptible to contamination (Sorensen et al., 2015). Furthermore, due of the existence of natural macropores in shallow wells, these wells are often shielded from fast vertical and horizontal routes, making them vulnerable to contamination (Lapworth et al., 2017).

Emerging pollutant from wastewater in Africa

PCPs (21 percent), antiretrovirals (26 percent), stimulants and psychiatric medications (36 percent), anti-inflammatory/analgesic medicines (38 percent), and antibiotics (43 percent) are the PhACs that have been researched the most extensively. Sulfamethoxazole, ibuprofen, and diclofenac are some of the most often researched drugs in this area. There are significant differences in concentrations between effluent and influent, with variations in effluent primarily resulting from differences in treatment technologies used, such as activated sludge, wastewater chlorine disinfection, stabilization pond, and so on (Madikizela et al., 2017b), and differences in influent primarily resulting from differences in consumption patterns due to climatic conditions, poaching, and other factors (Madikizela et al., 2017a) (Segura et al., 2015; aus der Beek et al., 2016; Awuchi et al., 2020a). The investigations on the performance of activated sludge systems in Africa, which mostly focused on certain steroids and anti-inflammatory/analgesic medications, revealed that removal rates varied from 30 to 95 percent, with just a few “negative” removals for diclofenac being seen.

In general, anti-inflammatory/analgesic medications have the highest recorded influent concentrations, followed by lamivudine and caffeine (more than 100 g/L for paracetamol, naproxen, ibuprofen, and diclofenac), owing to their widespread availability and widespread use (Hughes et al., 2013). Effluent is characterized by the presence of very resistant antiretrovirals (zidovudine, lamivudine, efavirenz, and danunevir concentrations higher than 10 g L). It is linked with their low consumption and dosage that hormones have the lowest maximum concentration (less than 1 g/L) in effluent and influent (Williams-Frame and Carpenter, 2009). In terms of PCPs, at least nine different chemicals have been identified in wastewaters from Africa (Montes-Grajales et al., 2017). The presence of PCP at levels ranging from 20 ng/L to 128 g/L has been found in recent research (Haman et al., 2015; Montes-Grajales et al., 2017), indicating that the substance is widespread in Africa.

Plastic Pollution as Emerging Pollution in Africa

Africa is rated as second most polluted regions on earth (Environmental Sustainability – African Impact, 2020). Recently, the overwhelming influence plastic wastes have on wildlife and communities in Africa has been noted. Ten rivers around Africa and Asia contain 90 percent of plastics which find their way into our oceans (Environmental Sustainability – African Impact, 2020; Awuchi et al., 2020b). Within the coast of South Africa, there are more than 3,000 particles of plastics per km². At least a million tons of plastics is trashed in South Africa per annum. Around 500 waste shipping containers have been reported to be dumped in Africa each month. However, only 10 percent of trash generated within Africa was recycled (Angnunavuri et al., 2020; Environmental Sustainability – African Impact, 2020). Several towns within the continent of Africa have no authorized services for waste collection, which

means no where to trash plastic wastes. In Southern, East, and West Africa, the increased access to FMCGs and high rates of population growth means more individuals use single-use plastics, which usually end up in streets, rivers, waterways, forests, etc. Regrettably, several destinations in Africa, including Nigeria, Uganda, Kenya, Zambia, Burundi, South Sudan, and Eritrea, suffer from non-existent or practically ineffective systems of waste recycling or management. What this entails is that waste and litter, including plastic wastes, have to be managed by the residents themselves who usually resort to burying, burning, or in typical instances, simply dumping them on the road side and in waterways. Along with inadequate levels of education and increasing costs of living in Africa, this has catastrophic impacts on public health and the fragile wildlife in Africa (Angnunavuri et al., 2020; Environmental Sustainability – African Impact, 2020). Microplastics and nanoplastics are becoming serious course for concern recently in Africa and other parts of the world. Figure 3 shows how plastic particles are transported.

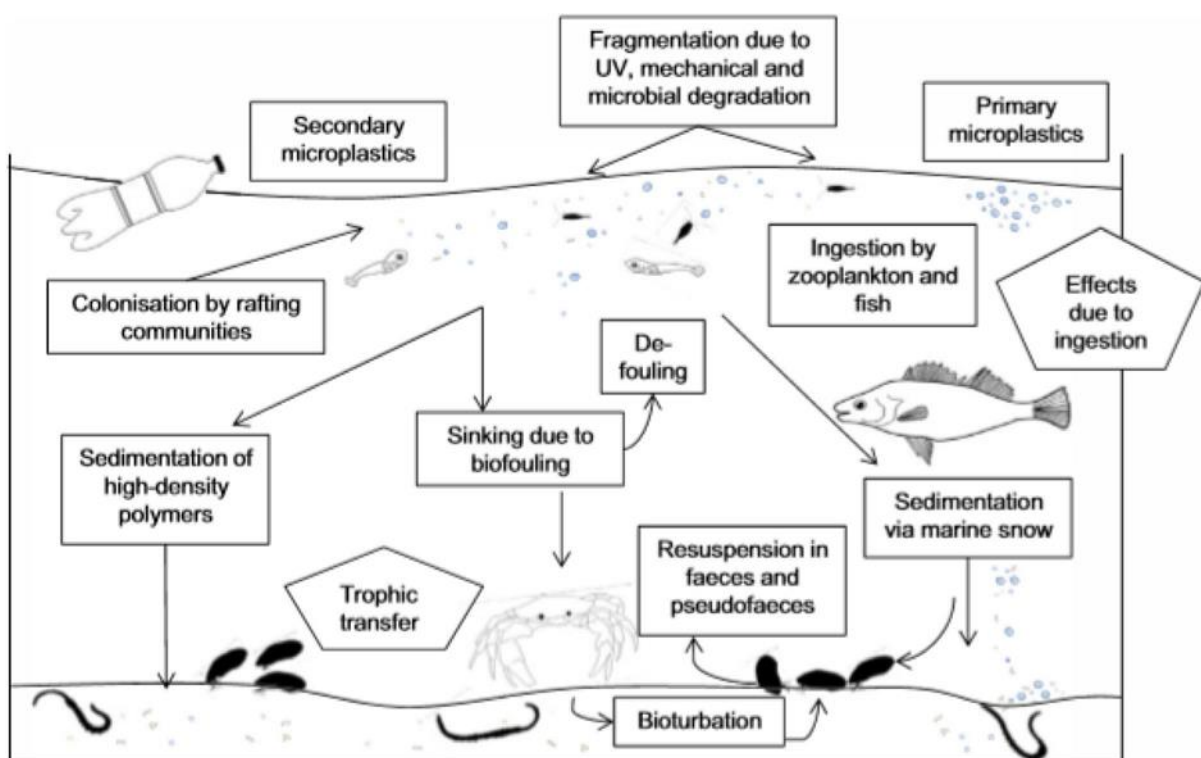


Figure 2. Pathways for the plastic transportation (Adapted from [Wright et al., 2013])

In spite of the all these statistics, several countries in Africa are in fact at frontline of fighting against plastics and their devastating environmental impacts. African nations such Morocco, Uganda, Rwanda, Tanzania, and Kenya, among others, have entirely banned the use of plastic bags, while some countries, such as South Africa, impose high fees or taxes for purchasing plastic bag in markets, including supermarkets (Environmental Sustainability – African Impact, 2020)

Conclusion

Contaminants of emerging concerns (CECs) have been among the major challenges in Africa. Identification of CECs, including pharmaceuticals, plastic wastes, pesticide residues, fungal toxins, and personal care products, have been documented in Africa. Based on extent and period of existence of the ban enforcement, there may be significant variation in their detection. Several emerging pollutants have been reported in sediments, surface water, drinking water,

groundwater, wastewater, land deposits, and air. More studies are required to identify how to prevent or control these emerging pollutants.

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