RESEARCH ARTICLE

Overview of potential adverse effects of human pharmaceuticals in Africa aquatic ecosystem

Vanessa Edwige Tchadji Mayoudo, Estella Tembe-Fokunang, Charles Ntungwen Fokunang, Serg Hubert Zebaze Togouet, Omgba Yves Tabi, Nene Ahidjo, Olivia Fossi Tankoua, Samuel Ngum

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ABSTRACT

Drugs are used for the treatment of various medical conditions in humans, wild animals, livestock, and plants, finding their way into rivers, lakes, and drinking water systems. In these environmental conditions, they can have undesirable effects on both aquatic and human health. There has been a steady increase on the availability of information on contamination of water sources caused by pharmaceuticals in some African countries. The objective of this study was to conduct data mining on published works on the occurrence of human pharmaceuticals in Africa. All available data using different search engines, web data, google scholar was assembled to generate useful information. The results revealed that twenty-eight countries have well documented information on pharmaceutical aquatic contamination. There is a gap of information concerning their occurrence in aquatic biota. This study also focused to produce results that gives an overview on the human pharmaceutical in aquatic environment in Africa.

Key Words: *Human Pharmaceuticals; Africa; Water; Aquatic Biota, Ecosystems*

INTRODUCTION

Consumption of pharmaceuticals is increasing worldwide to sustain the health of humans and animals. These compounds constitute a large group of over 4000 chemicals that are primarily used for therapeutic purposes in both humans and animals. Pharmaceuticals and their metabolites find their way into the environment through various mechanisms including direct disposal of intact drugs into the environment, excretion of human and animal wastes on the ground, direct release from the manufacturing industries, veterinary and agricultural practices [1,2]. In addition, due to their high polarity and solubility, they can move through traditional Wastewater Treatment Plants (WWTPs) and get discharged into the environmental water bodies as effluents [3]. Pharmaceuticals are one of the most persistent groups of pollutants in the environment which could ultimately pose a serious health risk to humans and aquatic biota. Bioaccumulation studies have shown the presence of these compounds in various tissues of fish including muscles, gills, blood plasma, brain and liver [4-7]. Prolonged exposure of these compounds promotes antibiotic resistance which could hugely affect public health [8,9]. Pharmaceuticals are regarded as Contaminants of Emerging Concern (CEC) that exist in lower concentrations in various surface waters. They exclusively own intrinsic features that could further pose a threat to the community even at trace levels. Few reports have been recently documented about their adverse effects including endocrine disruption, chronic toxicity as well as the development of new strains within microorganisms which could be resistant against antibiotic action [10, 11]. This calls for a proper monitoring of their occurrence and distribution in various environmental water bodies. The occurrence of pharmaceuticals in river water was first reported in 1970s and since then, the monitoring of pharmaceuticals in the aquatic environment has become of interest in the wastewater treatment researches [12]. The different routes of environmental pollution by pharmaceuticals have been illustrated in Figure 1.

For a better understanding of the likely effects of these pharmaceutical exposures, it is important to have knowledge of their concentrations and global distribution in the environment. This is the motivational basis to review on the distribution and occurrence of pharmaceuticals in different water compartments within the targeted African region. The objective of this study was to conduct data mining on published works on the occurrence of human pharmaceuticals in Africa. All available data, using different search engines, web data, google scholar, was assembled to generate useful information. This study also focused to produce results that give an overview on the human pharmaceuticals in aquatic environment in Africa.

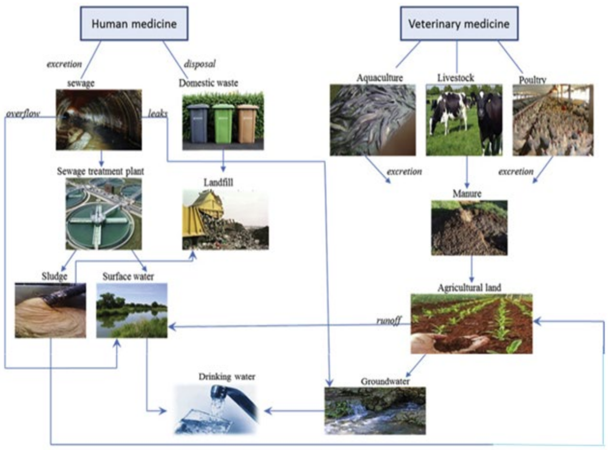

Figure 1) *Different routes of environmental pollution by pharmaceuticals [1]*

MATERIAL AND METHODS

The study target included all the 54 countries of the African Union. The scope of this literature review and data mining was mapped out on the African countries. The countries of interests were selected based on the availability of published data on the presence of pharmaceuticals and/or their transformation by products in the environmental matrices. The environmental matrices considered included wastewater, drinking water, sediments, rivers, lakes, hospital waste, macroinvertebrates, fish. This review includes studies from 2000 to 2022. The search keywords were "active chemicals, transformation by products or metabolites, environmental contaminants, human pharmaceuticals" and each country of Africa. The result was databases that were extracted from studies of all African countries.

RESULTS

Pharmaceuticals in African water bodies and sediments

A twenty years' data showed that only 28 out of the 54 African countries have studies on the human pharmaceuticals' occurrence in environmental compartments. It is known that therapeutic consumption of active chemicals to promote human health is usually followed by excretion of these drugs via urine or faecal matter, due to their slight alteration of the human metabolism.

Department of Pharmacotoxicology and Pharmacokinetics, Faculty of Medicine and Biomedical Sciences, University of Yaoundé, Cameroon

Correspondence: Charles Ntungwen Fokunang, Department of Pharmacotoxicology and Pharmacokinetics, Faculty of Medicine and Biomedical Sciences, University of Yaoundé, Cameroon.; E-mail: Nanomedsci@medicalres.org

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The detection of several active chemical classes including non-steroidal anti-inflammatories, antibiotics, antiretrovirals, anti-epileptics, steroid hormones, and anti-malarial drugs, has been reported in water resources, influents, and effluents in some countries in Africa [13-23]. Occurrences of active chemicals in Africa water bodies are reported in Tables 1 to 14.

Kenya

Reports of the presence of active chemicals in the Kenyan environment are available [19-21, 23]. Some exclusive data on the concentrations and loads of chemicals such as antibiotics, antivirals, analgesics, anti-inflammatories, and psychiatric drugs are presented in Table 1.

TABLE 1

Occurrence of Pharmaceuticals in Kenya aquatic ecosystem

Substances	Effluents	Surface Water (ng/L)	Sediments (ng/Kg)	References
Norfloxacin	4.2	1.6-4.9	246-776	[21]
Trimethoprim	15.8	3.8-44	11-90	
Ciprofloxacin	5.3	2.5-2.8	125-1225	
Sulfamethoxazole	956.4	96.9-142.6	542-896	
Lamivudine	847.1	219.6-228.3	107-491	
Zidovudine	1.4	1.1-21	118-510	
Clavulanic acid	10-110			[24]
Erythromycin	100-150			
Sulfamidin	0-5			
Sulfamerazin	2-20			
Tetracyclin	10-180			
Trimethoprim	5-100			
Lincomycin	5-80			

Uganda

The presence of quantifiable levels of active chemicals was investigated in Uganda's environmental compartments [22-24]. The results indicate the presence of active chemicals belonging to multiple therapeutic categories, as presented in Table 2.

TABLE 2

Occurrence of pharmaceuticals in Uganda aquatic ecosystem

Matrix	Substance	Concentration (ng/L)	References
Lake Victoria Water	Sulfamethoxazole	1-00	**[22]**
	Trimethoprim	1-89	
	Tetracyclin	3-70	
	Sulfacetamide	1-13	
	Erythromycin	10-66	
	Sulfamethazin	2-50	
	Carbamazepin	5-72	
	Ibuprofen	6-780	
	Diclofenac	2-160	

Tanzania

In Tanzania, as in other sub-Saharan countries, waste water treatment plants are not designed for the removal of emerging contaminants such as active chemicals. Wastewater stabilization ponds are utilized to partially treat the effluents from industries, residential areas, and hospitals. Therefore, when effluents are released into the ecosystem, the chemical load is increased [23, 25-28]. Occurrences of the active chemicals in the Tanzanian environment are presented in Table 3.

TABLE 3

Occurrence of pharmaceuticals in Tanzania aquatic ecosystems

Matrix	Substance	Concentration (ppm)	References
Wastewater	Metronidazole	0.065-0.104	[26]
Msimbasi river waters	Metronidazole	0.0024	[28]
	Paracetamol	0.006	
	Cetirizine	0.073	
	Ibuprofen	0.0016	
Waste water effluents	Ampicillin	Bld-0.367	[25]
	Ciprofloxacin	Bld-0.037	

Bld: below detection limit

Zambia

According to the available information, Zambia's environmental compartments were mostly affected by the presence of active chemicals from the classes of antibiotics and antivirals, as presented in Table 4. As there were only a few studies available, there is a need to further investigate their presence in the Zambian environment [23,26].

TABLE 4

Occurrence of pharmaceuticals in Zambia aquatic ecosystem

Matrix	Substance	Concentration (ng/L)	References
Surface water	Sulfamethoxazole	7740000	[27]
	Trimethoprim	12800	
	Lamivudine	10010	
	Antibiotics	11.8	
	Antivirals	49700	
Effluents	Antibiotics	100-300.4	[27]
	Antivirals	680-55.76	

Zimbabwe

Various toxic effects on Zimbabwe aquatic life have been reported as a result of water contamination by industrial and municipal effluents [23-31] (Table 5). Industrial processes and domestic products are of diverse nature and therefore, urban effluents are often contaminated with various anthropogenic endocrine-disrupting chemicals that may interfere with the reproductive physiology of the aquatic fauna [25].

TABLE 5

Occurrence of pharmaceuticals in Zimbabwean aquatic ecosystem

Substances	STPs	Ugunza	Matsheumhlope	Kihami	References
17β-estradiol equivalent	33	237	9	2	[31]
Dihydrotestoterone equivalent	55	-	-	-	
Androgenic	93	-	-	-	

*Concentrations are in ng/L

Mozambique

Reports of occurrence of active chemicals in the Mozambican environmental compartments are available [32]. The active chemicals identified are presented in Table 6. Remnants of these substances, their metabolites, and their transformation products have detrimental effects on the ecosystems.

TABLE 6

Occurrence of pharmaceuticals in Mozambican aquatic ecosystem

Matrix	Substance	Concentration (ng/L)	References
Surface water	Sulfamethoxazole	12	[29]
	Oxytetracyclin	1000	
	Trimethoprim	800	
	Azithromycin	8	
	Clavulanic acid	5-20	
	Erythromycin	20-1000	
	Sulfapyridine	800-1300	

Ethiopia

The recent identification of pharmaceuticals [23, 33] in the Ethiopian environment is presented in Table 7.

TABLE 7

Occurrence of pharmaceuticals in Ethiopian aquatic ecosystem

Matrix	Substance	Concentration (ng/L)	References
Hospital water	Albendazole	210	[33]
	Caffeine	320	
	Trimethoprim	780	
Waste water	Trimethoprim	500	
	Ciprofloxacin	10-300	
Water	Trimethoprim	7800	
	Caffeine	3200	
	Albendazole	2100	

Nigeria

Nigeria, as many others sub-Saharan African countries, releases wastewater from hospitals, agriculture, industrial production, and aquaculture into urban waste stabilization ponds. Most wastewater treatment schemes in Nigeria are not designed for the removal of organic contaminants such as active chemical compounds [23, 34-36]. Occurrences of emerging organic pollutants (EOPs) have been reported, including active chemicals [35, 36] (Table 8). Therefore, urban wastewater is the main source of chemical load.

TABLE 8

Occurrence of pharmaceuticals in Nigerian aquatic ecosystem

Matrix	Substance	Concentration	References
River water	Phenazone	< to 0.01 μ/L	[35]
	Trimethoprim	< to 0.01 μ/L	
	Estrone	< to 0.01 μ/L	
	Estriol	< to 0.01 μ/L	
	Acetylsalicylic acid	< to 0.02 μ/L	
	Carbamazepin	< to 0.02 μ/L	
	Diclofenac	< to 0.02 μ/L	
	Roxithromycin	< to 0.02 μ/L	
	Indomethacin	< to 0.02 μ/L	
	Erythromycin	< to 0.06 μ/L	
	Clofibric acid	< to 0.02 μ/L	
Borehole	Diclofenac	0.39 mg/L	[34]
Treated tape	Arhemether	0.62 mg/L	
	Diclofenac	0.17 mg/L	
	Artemether	0.04 mg/L	
Well water	Diclofenac	8.84-1100 μg/L	[34]
	Ofloxacin	0.73, 0.24 and 0.08 ng/L	
Hospital wastewater and landfill leachate	Acetamidophenol	Bdl–30.1 ng/L	[37]
	Oxybenzone	1.0-1.1 ng/L	
	Triclocarban	39.3-47.2 ng/L	
Bdl: below detection limit			

Ghana

Reports on Ghana indicate the presence of active chemicals in the environment that may adversely affect human and environmental health. The status of environmental occurrences of active chemicals in Ghana is presented in (Table 9). Anthropogenic activities contribute to the presence of these substances in the environment. In some areas of Ghana, antibiotics, analgesics, drugs for diabetes, anti-malarial drugs, cardiovascular drugs, and anthelmintic drugs are widely used, and may increase the chemical load in the environment [23, 38].

TABLE 9

Occurrence of pharmaceuticals in Ghana aquatic ecosystem

Matrix	Substance	Concentration (ng/L)	References
Hospital wastewater effluent/influent, river water, and in vegetables	Tetracycline	10-300	[37]
	Trimethoprim	10-200	
	Clavulanic acid	5-14	
	Azithromycin	2-12	
	Erythromycin	10-110	
	Metronidazole	247-420	
	Ciprofloxacin	11.352-15.733	
	Erythromycin	7944-10.613	
	Trimethoprim	94-4826	
	Tetracyclin	58-116	
	Oxyeracyclin	75-252	
	Chlortetracyclin	16-24	
	Amoxicillin	2-6	
	Ampicillin	107-324	
	Cephalexin	1052-1557	
	Sulfasalazine	2315-3590	

Cameroon

Reports of contamination of the Cameroonian environmental compartments are available; the risk factors leading to contamination have also been identified, for example, the practices that lead to pollution from anthropogenic activities, such as the disposal of municipal and agricultural waste [14, 15, 17, 23]. Occurrences of active chemicals in waters in Cameroon contamination of urban and peri-urban tropical watersheds are presented in Table 10.

Table 10

Occurrence of pharmaceuticals in Cameroon aquatic ecosystem

Matrix	Substances	Concentration (ng/L)	References
Hospital wastewater	Diphenhydramin	377	[14, 15]
	Paracetamol	211926	
	Clarithromycin	88	
	Propranolol	298	
	Cimetidine	34000	
	Hydroxy omeprazole	5000	
	Ibuprofen	141000	
	Tramadol	76000	
	o-desmethyl tramadol	141000	
	Eryhromycin anhydrate	7000	
	Ciprofloxacin	24000	
	Metformin	154000	
	Sucralose	13070	
	Azithromycin	390	
	Sulfamethoxazole	162	
	Trimethoprim	265	
	Caffeine	5800	
	Carbamazepine	940	
	Atenolol	427	
Peri-urban surface water	Carbamazepine	23.8	[17, 23]
	Ibuprofen	74.2	
	Codeine	6.6	
	Diclofenac	55.6	
	Acetaminophen	13.6	
	Sulfamehoxazole	36.8	
	Atenolol	2	
Urban surface water	Carbamazepin	102.6	[17] [14] [23]
	Ibuprofen	119.8	
	Codein	11	
	Diclofenac	145.4	
	Acetaminophen	691.6	
	Sulfamethoxazole	20.8	
	Atenolol	5.4	
	Ofloxacin	9	
Ground water	Carbamazepine	63.8	[17] [14]
	Ibuprofen	103.6	
	Diclofenac	109.4	
	Acetaminophen	27	
	Sulfamehoxazole	328.6	

Botswana

In Botswana, active chemicals were found as a result of the accumulation of antibiotic resistance determinants in wastewater treatment facilities, and their subsequent release into the water ecosystems downstream [38] . In the environmental compartments of Botswana, high frequencies of potentially pathogenic microorganisms were observed. The antibiotics that were identified are presented in Table 11.

TABLE 11

Occurrence of pharmaceuticals in Botswana aquatic ecosystem

Matrix	Antibiotics	Percentage	References
Wastewater influent effluent, and downstream environment	Ampicillin	54	[38]
	Penicillin	85	
	Erythromycin	76	
	Cephalosporin	69	
	Sulfamethoxazole	54	
	Trimethoprim	85	

South Africa

South Africa is the country having the highest number of publications on the occurrence of pharmaceuticals in water, surface water, seawater, wastewater and even in sediments [1, 13, 16, 18, 23, 29, 39-46]. The main results are summarized in Table 12.

TABLE 12

Occurrence of pharmaceutical in South Africa aquatic ecosystem

Matrix	Substance (s)	Concentrations	References
Wastewater	Clarithromycin	5-30 ng/L	[29]
	Erythromycin	10-100 ng/L	
	Sulfadimidine	0-10 ng/L	
	Sulfamethoxazole	5-1000 ng/L	
	Sulfapyridine	5-110 ng/L	
	Chlortetracycline	90 ng/L	
	Oxytetracycline	100 ng/L	
	Trimethoprim	5-10,000 ng/L	
Sea water	Ibuprofen	160 ng/L	[18, 46]
	Naproxen	160 ng/L	
Waste water	Nevirapine	2100 ng/L	[40]
	Efavirenz	17,400 ng/L	
Waste water	Ibuprofen	117,000 ng/L	[39]
Surface water	Ibuprofen	84,600 ng/L	
Water	Concentrations were efavirenz > nevirapine > carbamazepine > methocarbamol > bromacil > venlafaxine.	164–593ng/L	[41]
Surface water	Antiretrovirals (ARVs)	26.5–430 ng/ L	[42]
Sediments	Diclofenac	92.08 -171.89 ng/g	[46]
	Acetaminophen	34.28–67.92 ng/g	
	Carbamazepine	33.27-61.20 ng/g	
	Phenytoin	8.89-56.55 ng/g	
	Sulfamethoxazole	18.5 ng/g	

Others African countries

Only one study was found for countries such as Angola, Benin, Burkina Faso, Republic of Congo Brazzaville, DRC Congo, Ethiopia, Gambia, Ghana, Ivory Coast, Lesotho, Liberia, Mali, Morocco, Rwanda, Sierra Leone, South Sudan, Tunisia [23]. Table 13 is the summary of that study. All the samples were coming from rivers of these countries.

'Other'=Antifungal, antimalarial, antiviral/-retroviral, benzodiazepine, calcium channel blocker, diuretic, histamine H2 receptor antagonist, opioid, oral contraceptive, selective oestrogen receptor modulator and β2 adrenergic receptor agonist (anti-asthma).

Pharmaceuticals in aquatic biota

Research work in Africa on detection and quantification of human pharmaceuticals in fish and invertebrates are rare. We found only 3 online publications. One was done on sea invertebrates. Two others concerned fish from a lagoon and fish for human consumption Table 14.

Table 13

Occurrence of pharmaceuticals in others African countries

Pharmace-uticals	Analgesics	Antibiotics	Anticonvulsants	Antidepressants	Antihyperglycaemics	Antihistamines	β-blockers	Other**
Angola	##	#	870	4,91	#	0	128	##
Benin	194	8,62	0	0	#	0	0	0
Burkina Faso	0	#	8,7	0	#	0	27,3	146
Republic of Congo Brazzaville	##	#	19,2	0	#	28,3	22	381
DRC Congo Bukavu	##	#	73,3	0	#	0	37,6	##
DRC Congo Kinshasa	##	#	64,8	0	#	0	0	##
Ethiopia	##	#	640	0	#	24,3	125	##
Gambia	15,3	0	0	0	0	0	0	0
Ghana	##	#	219	0	#	##	69,6	##
Ivory Coast	155	0	0	0	0	0	0	0
Lesotho	181	#	40	0	#	12,9	45,7	199
Liberia	##	#	2,39	0	78,4	0	0	33,3
Mali	##	#	15,7	0	#	0	27,8	##
Morocco	4,76	72,8	112	0	#	27,1	0	44,9
Rwanda	79,9	#	0	0	50,4	0	0	22,9
Sierra Leone	0	0	0	0	0	0	0	28,1
South Sudan	##	#	30,1	0	#	12,9	0	198
Tunisia	##	#	##	#	#	##	460	##

Concentrations are in ng/L

TABLE 14

Occurrence of pharmaceuticals in aquatic biota

Aquatic biota	Substances	Concentrations	References
Invertebrates (Sea snail, Limpets, Mussels, Starfish, Sea urchins)	Diclofenac	67.67–780.26 ng/g	[46]
	Carbamazepine	22.32–81.76 ng/g	
	Sulfamethoxazole	35.85–272.09 ng/g	
	Lamivudine	14.02–47.98 ng/g	
	Acetaminophen	17.53–131.08 ng/g	
	Phenytoin	21.51–131.22 ng/g	
Fish in South Africa (Snoek, Bonito, Panga, Hottentot)	Diclofenac	551.8-1812 ng/g	[47]
	Acetaminophen	17.95-33.26 ng/g	
	Phenytoin	55.67-22.2 ng/g	
	Sulfamethoxazole	36.34-688.6 ng/g	
	Carbamazepine	5.16-22.9 ng/g	
	Caffeine	2.3-64.78 ng/g	
Fish in Nigeria (Sole, Tilapia, Grouper, Catfish, Silver catfish, Croaker, Red snapper)	Tramadol	0.8 ng/g	[48]
	Trimethoprim	0.1-19.2 ng/g	
	Fluoxetine	3.2-27.1 ng/g	

DISCUSSION

Assessment of the environmental risk posed by pharmaceuticals and their metabolites has become a major focus in recent years because of their continuous introduction into aquatic systems. In the African context, the fact that water is classified as a scarce resource, makes the situation even more critical as there are relatively few water resources [1]. Although pharmaceuticals may be present in aquatic environments in low concentrations, their extensive use, high reactivity with biological systems, continuous release and relatively low degradation makes them pseudo-persistent in aquatic environments. The potential effects to the environment and public health are chronic rather than acutely toxic, and depend on exposure, that is, bioavailability, susceptibility to the compound in question, and the degradability of the compound [1]. Pharmaceuticals can therefore pose potential environmental and public health issues that are of importance to Africa.

Environmental impacts

Pharmaceuticals are designed to interfere with specific metabolic, enzymatic, or cell-signalling mechanisms at low concentrations through a specific mode of action in humans. The persistence of pharmaceuticals in the environment and chronic exposure to these chemical stressors can have ecotoxicological effects on non-target organisms [6]. The nature of the aqueous environment, together with the physicochemical properties of the pharmaceuticals, also play an important role as they determine whether the pharmaceuticals will succumb to the processes (including the employed treatment) or persist in the environment [2, 6]. For example, fluoroquinolones, sulfonamides, trimethoprim and cephalosporins are resistant to microbial biodegradation and tend to persist in the environment and other environmental compartments [7]. Fluoroquinolones also have strong adsorptive properties and tend to accumulate on sediments and other organic matter thus elevating their persistence in environmental matrices. In addition, the presence of antimicrobial compounds in the waste water at particular levels can reduce and/or inhibit the growth of sludge bacteria that are involved in bio transforming drugs and degrading organic matter. This inhibition can decrease the efficiency of the waste water treatment plan and may result in contamination of receiving water bodies [3, 5]. Toxicity studies of fish, daphnia and algae have been used to predict environmental concentrations and ecological risk of most pharmaceuticals [7]. The biological activity of pharmaceuticals released in aquatic systems has been observed in nature and laboratory investigations have shown that they cause both acute and chronic effects. For example, the antibiotics clarithromycin sulfamethoxazole, ofloxacin, lincomycin, enrofloxacin and ciprofloxacin have been reported to be toxic to freshwater algae [9]. Low concentrations (in nano grams/ litre) of the synthetic oestrogen 17-alpha-ethinyloestradiol often used in contraceptive pills have been shown to enlarge fish livers and affect the sexual characteristics of male fish in surface water [8]. The anti-inflammatory drug diclofenac also seems to be cause for concern for aquatic organisms [8, 11]. A study done by Fent et al, [12] that diclofenac was associated with the disappearance of the Orient white backed vulture in India and Pakistan. In mammals, diclofenac has been reported to affect the liver and kidneys. Furthermore, propranolol (a β-blocker) detected in North-eastern Spain was reported to have toxic effects on zooplankton and benthic organisms [7] .

Public health impacts

Drinking water and consumption of aquatic organisms are two ways in which humans can be exposed to pharmaceuticals that pollute the aquatic environment. Therefore, possible risks of exposure for human health are a subject of concern, especially for the countries that use surface water as their main source of drinking water. Several quantitative pharmaceutical risk assessment studies on exposure to trace levels of pharmaceuticals in drinking water, conducted in different parts of the world, have shown very low risks to human health based on toxicological data [49, 50]. However, these studies do not rule out possible effects on human health as some studies are often been based on limited sets of monitoring data which do not consider long-term effects of exposure and have limited knowledge on the mixed effects of pharmaceuticals in drinking water consumed by humans [8, 50]. In addition, some studies focus on pharmaceutical concentrations in surface water only, and not drinking water, to assess human health risk, assuming that drinking water treatment plants do not remove any of the pharmaceuticals [51, 52].

Another risk is the development of resistance to antimicrobial compounds. The presence of antibiotics in treated waste water is increasing and will lead to higher mortality and morbidity as untreatable infectious diseases increase [52]. Antimicrobial resistance has become a great challenge in clinical therapy mainly because it compromises the effectiveness of antibiotics, resulting in therapeutic failure, elevated health costs, and increased morbidity and mortality rates [53]. For example, pathogens such as multidrug resistant *Klebsiella pneumoniae* cannot be treated with any antibiotic currently on the market [52] . Moreover, the overuse and misuse of antibiotics may cause a risk to human health by promoting antibiotic resistant bacteria and antibiotic resistance genes in aquatic environments [2, 5]. This occurs as a result of the high selective pressure imposed by antibiotics on bacteria. The bacterial community, that can withstand this antimicrobial pressure, will survive and multiply, leading to more resistant strains in the aquatic environments [53]. The resistant genes can be horizontally transferred from animal to human pathogens and also across different classes of antibiotics used in veterinary and medical contexts, especially when the antibiotics have the same mechanism of action [11]. This is a major health concern.

Research gaps and future perspectives in Africa

The presence, persistence and toxicity of pharmaceuticals in the aquatic environment are an important subject that needs to be extensively investigated to help prevent effects on the environment and human health. There is a lack of baseline studies in Africa to counter any effects that can be caused by the presence of pharmaceuticals in African water systems. Africa has particular challenges, such as a high burden of malaria and infectious diseases. This point to a high use of antimalarial drugs and antibiotics, resulting in relatively high concentrations being released into aquatic environments. Therefore, there is a need to quantify and determine their fate, and extrapolate their possible long-term effects on the environment and public health. There have been few studies conducted in Africa on pharmaceutical drugs in water and their biodegradation profile.

Currently, water treatment processes in Africa cannot remove pharmaceuticals completely, resulting in their discharge into water bodies. There is a need for research to determine how these sewage treatments are efficient in removing different types of pharmaceuticals. This can also be applied to drinking water plants that use potentially contaminated surface water as their source. This will help redesign treatment plants that can exhaustively remove pharmaceuticals that can be toxic or harmful to the environment and human beings. Most quantitative pharmaceutical risk assessments have focused on urban areas, neglecting the rural populations that mostly use impurified water for drinking. Therefore, studies in rural areas in Africa will provide relevant information on the occurrence and fate of pharmaceuticals in the environment that can be compared to studies in urban areas. These pharmaceuticals affect human and aquatic life. Several studies suggest diverse negative effects on aquatic life that are exposed to these trace amounts of pharmaceuticals in their habitats.

Health-care waste disposal is another way by which environment is polluted. When health-care waste is placed in landfills or buried, contamination of groundwater may occur and may result in the spread of some pathogens. If landfills are insecure, expired drugs may come into contact with children and scavenging animals. Evidence suggests that the presence of antibiotics in waste water may be contributing to antibiotic resistance, and if these antibiotics are present in waste water for a longer period, they may cause genetic effects in humans and aquatic life. It is therefore essential that health-care facilities dispose of all waste in accordance with national, provincial, regional and municipal regulations and legislation. Hence, it is essential to raise public awareness and encourage consumers to adopt proper disposal practices for unwanted pharmaceuticals.

CONCLUSION

This work reviewed studies available on the distribution and occurrence of human pharmaceutical in Africa environmental compartments. We found reports on 28 over 54 African countries. Most of the studies were done on the water bodies: drinking water, lake, rivers, waste water and sediments. Studies on pharmaceuticals occurrence in aquatic organisms were scarce and were only found in Nigeria and South Africa. The results intended to reveal, in Africa, the countries with well documented information on pharmaceutical aquatic contamination as well as there is a gap of information concerning their environmental and public health impact. More studies need to be conducted on aquatic ecosystems in Africa in order to understand and confirm aquatic biota and human health risk. Furthermore, there should funded research and development to optimise water treatment technologies and to improve national, provincial, regional and municipal regulations and legislation.

AUTHOR'S CONTRIBUTIONS

This work was carried out in collaboration among all authors. Authors

FCN, VETM, ETF, SHZT designed the study; Authors OYT, NA, OFT, SN did data mining and organisation; authors FCN, VETM sorted information and contributed in writing of the first draft. All authors read and approved the final draft.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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