

A Focus on Active Chemicals in Sub-Saharan Africa

Subjects: **Environmental Sciences**

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Active chemicals are among the contaminants of emerging concern that are rarely covered in regulatory documents in sub-Saharan Africa.

Active chemicals (ACs)

Pharmaceutical load

Sub-Saharan Africa (SSA)

Environmental Toxicology

Drug-drug interactions

Wastewater

Mixture

Contaminants

1. Environmental Effects of Active Chemicals

The existence of different categories of active chemicals in the environmental matrices has been reported in some sub-Saharan African countries. These reports indicate the presence of the active chemicals, and point to a possibility of the ACs causing harm not only to human health but also to the natural environment. Most drugs reported were anti-inflammatories, antibiotics, antiretroviral drugs, analgesics, psychiatric treatment drugs, steroid hormones, diabetes treatment drugs, or hypertension drugs. Loads of active chemicals released into the environment after human, animal, and agricultural usage have been linked to both human and environmental health degradation. Although active chemicals are considered to be contaminants of emerging concern, they are currently neither monitored nor included in the environmental guidelines.

Chemicals that are environmentally persistent and have a tendency to bioaccumulate pose a great potential for environmental risk, especially when such chemicals come into contact with drinking water supplies and the food chain ^{[1][2][3]}. Various scholars have reported the effects of these substances and their potential for harm, including the development of AMR ^{[4][5][6][7]}, as well as effects on the sex of aquatic organisms ^{[8][9][10][11][12][13][14]}. The early years of research in the area of the effects of ACs placed more emphasis on the assessment of the acute effects as a result of individual substances, largely ignoring the effects that may be caused by combinations of these substances. Recently, however, there has been a shift in focus to chronic exposure and the assessment of the effects of drug mixtures ^{[12][14][15][16]}. It is important to study drug mixtures—commonly described as a ‘cocktail effect’—including drug-drug interactions leading to adverse effects. Usually, human subjects receive a prescription with instructions on how to properly use drug mixtures. For instance, patients should not mix ibuprofen with beta-blockers, or opioids with alcohol. However, other organisms in the ecosystem do not receive instructions from medical doctors. As a result, a fish reeling in an effluent containing a mixture of drugs and other contaminants in a polluted river will simply succumb to the adverse effects thereof.

2. Environmental Load of Active Chemicals

Active chemicals are now some of the main environmental pollutants and are abundant in water, soils, and other environmental media. Environmental risk assessment and routine environmental monitoring regulations do not include active chemicals, simply because acute risk assessments show insignificant human health hazards. However, the drawbacks of active chemicals extend beyond acute effects to delayed effects from bioaccumulation, amplified effects from drug-drug interactions, aggravation of drug resistance, and reduction in aquatic and terrestrial food production; this merits serious measures for public health protection [17]. Reports on the presence of active chemicals in the sub-Saharan African environment are still scarce, with only a few countries reporting [18][19], indicating a need for more research. Therefore, this review will aid in providing data that are necessary to indicate the presence and possible harm of active chemicals in the sub-Saharan African environment, and to inform current and future policymaking processes.

Occurrences of Active Chemicals in Other Parts of Africa

Apart from sub-Saharan African countries, South Africa is among the African countries with greater awareness and practice concerning environmental protection [18][20][21][22][23]. In most developed countries, the use of active chemicals is higher; thus, the load to the environment may also be higher. Occurrences of active chemicals in the South African environmental compartments are presented in **Table 1**. Additionally, research [24], has reported that pollutants arise not only from waste products but also from pharmaceutical products that have not been properly disposed of. The continuous exposure to unspecified sub-therapeutic doses of antibiotics presents a risk to humans and other animals.

Table 1. Occurrences of ACs in the South African environmental compartments.

Matrix	Substance (s)	Concentration (ng/L)	References
Wastewater	Clarithromycin	5–30	[23]
	Erythromycin	10–100	
	Sulfadimidine	0–10	
	Sulfamethoxazole	5–1000	
	Sulfapyridine	5–110	
	Chlortetracycline	90	
	Oxytetracycline	100	
	Trimethoprim	5–10,000	
Seawater	Ibuprofen	160	[20]

Matrix	Substance (s)	Concentration (ng/L)	References
	Naproxen	160	
Wastewater	Nevirapine and efavirenz	2100 ng/L 17,400 ng/L	[25]
Wastewater		117,000	
Surface water	Ibuprofen	84,600	[26]
Sediments		65,900	
Water	Concentrations were efavirenz > nevirapine > carbamazepine > methocarbamol > bromacil > venlafaxine.	164–593	[27]
Surface water	Antiretrovirals (ARVs)	26.5–430	[28]

onment is lacking. It is known that therapeutic consumption of active chemicals to promote human health is usually followed by excretion of these drugs via urine or fecal matter, due to their slight alteration of the human metabolism. The detection of several active chemical classes—including nonsteroidal 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 sub-Saharan Africa [18][20][29][30]. Moreover, general investigation and monitoring of active chemicals in different sub-Saharan African countries are required, and the necessary instrumentation for their trace quantification in environmental samples should be made available.

3.1. Kenya

Reports of the presence of active chemicals in the Kenyan environment are available [31][32][33]. Some exclusive data on the concentrations and loads of chemicals such as antibiotics, antivirals, analgesics, anti-inflammatories, and psychiatric drugs are presented in **Table 2**.

Table 2. Occurrences of ACs in the Kenyan environmental compartments.

Substances	Effluents	Surface Water (ng/L)	Sediments (ng/Kg)	References
Norfloxacin	4.2	1.6 to 4.9	248 to 776	
Trimethoprim	15.8	3.8 to 4.4	11 to 90	
Ciprofloxacin	5.3	2.5 to 2.8	4125 to 1225	
Sulfamethoxazole	956.4	96.9 to 142.6	542 to 896	[33]
Lamivudine	847.1	219.6 to 228.3	107 to 491	
Zidovudine	1.4	1.1 to 21	118 to 510	

Substances	Effluents	Surface Water (ng/L)	Sediments (ng/Kg)	References
Clavulanic acid	10–110			[23]
Erythromycin	100–150			
Sulfadimidine	0–5			
Sulfamerazine	2–20			
Minocycline	0			
Tetracycline	10–180			
Trimethoprim	5–100			
Lincomycin	5–80			

The presence or quantifiable levels of active chemicals was investigated in Uganda's environmental compartments [34][35][36]. The results indicate the presence of active chemicals belonging to multiple therapeutic categories, as presented in **Table 3**.

Table 3. Occurrences of ACs in the Ugandan environmental compartments.

Matrix	Substance	Concentration (ng/ L)	References
Lake Victoria water	Sulfamethoxazole	1–5600	[35]
	Trimethoprim	1–89 L	
	Tetracycline	3–70	
	Sulfacetamide	1–13	
	Erythromycin	10–66	
	Sulfamethazine	2–50	
	Carbamazepine	5–72	
	Ibuprofen	6–780	
	Diclofenac	2–160	
	Sulfamethoxazole	1–5600	

3.3. Tanzania

In Tanzania, as in other sub-Saharan countries, wastewater 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 [37][38][39][40][41][42][43]. Occurrences of the active chemicals in the Tanzanian environment are presented in **Table 4**.

Table 4. Occurrences of ACs in the Tanzanian environmental compartments.

Matrix	Substance	Concentration	References
Wastewater	Metronidazole	0.065–0.104 ppm	[40]
Msimbazi River waters	Metronidazole	0.0024 ppm	[42]
	Paracetamol	0.0060 ppm	
	Cetirizine	0.0073 ppm	
	Ibuprofen	0.0016 ppm	
	Ampicillin	bdl to 0.367 ppm	
Wastewater effluents	Ciprofloxacin	bdl to 0.037 ppm	[37]
	Sulfamethoxazole/trimethoprim	100%	
	Ampicillin/cloxacillin	100%	
AMR Lake Victoria water	Erythromycin	72.7%	[41]
	Tetracycline	90.9%	
	Nalidixic acid	63.6%	

3.4. 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 5**. Although the industrial release of these contaminants is possible, a report indicated only the presence of metalloid toxicants [44]. As there were only a few studies, there is a need to further investigate the presence of active chemicals and other emerging contaminants in the Zambian environment.

Table 5. Occurrences of ACs in the Zambian environmental matrices.

Matrix	Substance	Concentration	References
Urine	Sulfamethoxazole	7740 µg/L	[45]
	Trimethoprim	12,800 µg/L	
	Lamivudine	10,010 µg/L	
Surface water	Antibiotics	11,800 ng/L	
	Antivirals	49,700 ng/L	
Effluents	Antibiotics	100–300,400 ng/L	

Matrix	Substance	Concentration	References
	Antivirals	680–55,760 ng/L	
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