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OCCURRENCE OF ANTIBIOTICS IN WASTE WATERS, SURFACE WATERS AND SEDIMENTS IN KENYA: A REVIEW

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ABSTRACT

Antibiotic contamination in Kenyan water bodies poses significant threats to ecosystem health and public well-being. A review of 21 studies found that at least 14 types of antibiotics, particularly sulfonamides, are commonly detected. Concentrations are higher in heavily populated areas like Nairobi and in wastewater treatment plants. The presence of antibiotic-resistant genes is a concern, posing ecological and public health risks. Sediments and wastewater treatment plants are critical hot spots for antibiotic accumulation. Effective management strategies are needed to mitigate contamination and protect aquatic ecosystems and human health. Key areas for future research include the long-term ecological impacts and the effectiveness of current wastewater treatment interventions. The review emphasizes the urgent need for comprehensive understanding and management of antibiotic pollution in Kenyan aquatic ecosystems. By addressing this issue, it is possible to safeguard both environmental integrity and public health. The presence of antibiotic-resistant genes highlights the need for effective management strategies to mitigate contamination and protect human health.

KEYWORDS: antibiotics, Waste Waters, Surface Waters.

INTRODUCTION

The increasing prevalence of antibiotics in the environment has emerged as a crucial public health issue, prompting extensive research into their sources, distribution, and ecological impacts. Antibiotics, a class of antimicrobials specifically designed to inhibit bacterial growth, play a pivotal role in modern medicine and veterinary practices. With over 600 distinct types currently employed for various therapeutic applications, the annual global consumption of antibiotics has reached more than 200,000 tons, with projections suggesting a twofold increase by the year 2030. This widespread and often indiscriminate usage poses significant challenges, particularly concerning the rise of antimicrobial resistance (AMR), a situation exacerbated by inadequate waste management practices and insufficient treatment facilities.

Research indicates that antibiotics, once ingested by humans or animals, are not completely metabolized, leading to substantial excretion rates of the parent compounds—estimated between 30% to 90%—in both urine and feces. These excreted substances then enter the environment through various pathways, including wastewater treatment plants, surface runoff, and direct discharge from healthcare facilities(Larsson, & Flach, 2022). The inadvertent contamination of aquatic systems by antibiotics promotes not only chemical pollution but also the proliferation of antibiotic-resistant bacteria, which poses a pressing threat to global health. In Kenya, the scenario is particularly dire. The country's struggle with a high burden of infectious diseases, including those associated with Human Immunodeficiency Virus (HIV), has driven an escalation in antibiotic usage. Coupled with limited access to healthcare and rampant self-medication, particularly in informal settlements characterized by dense populations and inadequate sanitation, the introduction of antibiotics into the ecosystem becomes a near-inevitable outcome (Solymári, et al., 2022). Additionally, the impacts of antibiotic residue in wastewater, hospital effluents, and agricultural discharges further accentuate risks related to AMR and ecosystem disruption.

Despite existing research highlighting the global occurrence of antibiotics, there remains a significant gap in understanding the specific patterns and concentrations of these compounds within Kenyan waters and sediments. This review aims to synthesize current data on the prevalence and distribution of antibiotics across wastewaters, surface waters, and sediment in Kenya, exploring the implications for environmental sustainability and public health. Through an analysis of existing literature and studies focused on local contexts, this paper endeavors to illuminate the multifaceted challenges posed by antibiotic pollution in Kenya, fostering a deeper understanding of the urgent need for robust regulatory frameworks and effective waste management practices in mitigating this pervasive threat.

Fungi are a diverse group of organisms that inhabit every environment on Earth. While many fungi are harmless, a significant number are pathogenic to humans, causing various fungal infections known as mycoses. These infections can range from minor ailments like tinea to severe and life-threatening conditions such as cryptococcal meningitis. Managing these infections effectively requires the appropriate use of antifungal antimicrobials, which can be classified into four main categories: polyenes, azoles, echinocandins, and allylamines. Antifungal drugs operate through distinct pathways that disrupt the fungal cell structure, targeting ergosterol in the cell membrane and components of the cell wall, leading to cell lysis and death. The indications and contraindications for antifungal agents vary among the drugs based on their pharmacokinetics and pharmacodynamics. Polyenes like amphotericin B are primarily indicated for severe systemic mycoses but can cause significant adverse effects, including nephrotoxicity. In contrast, azoles such as fluconazole are often preferred for their broad antifungal spectrum and better tolerability but are also hepatotoxic. The adverse effects and toxicity profiles of these agents necessitate close monitoring. Azoles can lead to significant hepatic complications and electrolyte imbalances, while amphotericin B formulations have distinct safety profiles, with newer lipid formulations offering reduced nephrotoxicity. Healthcare teams play a crucial role in enhancing the effectiveness of antifungal therapy through improved care coordination among providers, pharmacists, and nurses (McKeny; Nessel & Zito, 2023). The emergence of drug-resistant fungal infections poses a significant threat to public health, necessitating the judicious use of antifungal agents. Antifungal stewardship programs are crucial in ensuring clinicians prescribe antifungals based on up-to-date evidence and local epidemiology. In recent years, a focus on developing new antifungal agents and strategies to combat increasing resistance has been a significant area of research.

Pharmaceuticals and antibiotics, when released into the environment, can lead to the development of antimicrobial resistance. In Africa, including countries such as Kenya, the use of antibiotics is widespread and often indiscriminate. A study by Faleye et al. (2018) highlighted the prevalence of antibiotic use and disposal at the household level in informal settlements of Kisumu, Kenya. The study found that antibiotics were used extensively to treat opportunistic diseases such as tuberculosis and pneumonia. In Kenya, informal settlement schemes are characterized by extremely high population, poor sanitation, and exposure to diseases, making it easier for antibiotics to enter the environment through surface runoff, excretion, and industrial discharge (Ngigi et al., 2020). Other methods antibiotics enter the environment include effluents from wastewater treatment plants, sewerage systems, pharmaceutical stockpiles, hospital effluents, animal husbandry, and human excrement (K'oreje et al., 2012). Studies have shown that antibiotics can persist in the environment, leading to possible long-term environmental and health consequences (Addis et al., 2024; Chemtai et al., 2023).

The occurrence and distribution of antibiotics in water bodies in Kenya have been investigated, with some studies highlighting the presence of antibiotics in wastewater treatment plants, hospital lagoons, and rivers within Lake Victoria Basin (Kimosop et al., 2016). To minimize the emergence of drug-resistant fungal infections, it is essential to adopt responsible use of antibiotics and to implement antifungal stewardship programs. Additionally, research into new antifungal agents and strategies to combat increasing resistance is ongoing, offering hope for improved outcomes for patients suffering from mycotic infections. In conclusion, the prevalence and distribution of antibiotics in water bodies in Kenya are a pressing concern. The judicious use of antibiotics and the implementation of antifungal stewardship programs are crucial in preventing the emergence of drug-resistant fungal infections. Research into new antifungal agents and strategies to combat increasing resistance holds promise for improved outcomes for patients suffering from mycotic infections.

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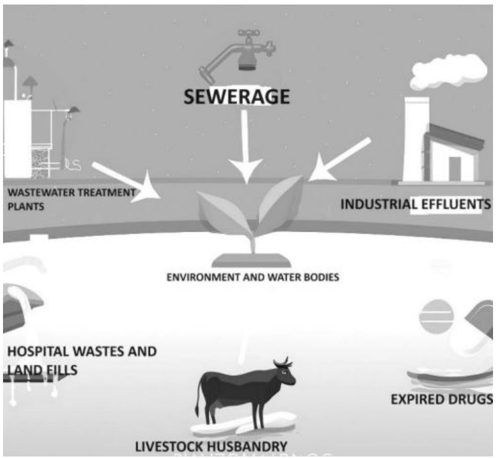

Fig 1: Pathways, major sources and distribution of antibiotics.

METHODOLOGY

2.1. Literature Search

A search of scientific databases, including PubMed, Google Scholar, and ResearchGate, was conducted to identify relevant studies. This was done between 18th February2024 and 30th April 2024 by the use of keywords such as "antibiotics," "water bodies," "Kenya," and "antibiotic contamination" were utilized. The search was limited to studies published between 2010 and 2024. A total of 47 published references were downloaded and subsequently only 21 publications were included in this review.

2.2. Inclusion Criteria and exclusion criteria

Studies were selected based on their relevance to the antibiotic contamination in Kenyan water bodies only. Only open source, peer-reviewed articles were used in this study. Only papers published in English were considered.

2.3. Quality Assessment

Quality of studies, was assessed based on study design, methodology, sample size, and reporting technique.

RESULTS AND DISCUSSION

Antibiotic contamination in Kenyan water bodies is a significant environmental concern, exhibiting varying contamination levels across different ecosystems. Recent studies indicate that high-density populations, particularly in urban areas like Nairobi, correlate with elevated antibiotic concentrations compared to less populated regions, such as Kabarnet (Ngigi, Magu, & Muendo, 2020). Sulphamethoxazole emerges as the most prevalent antibiotic in these water bodies, widely used for treating various bacterial infections and frequently available over the counter. It is often encountered in combination with trimethoprim in co-trimoxazole formulations (Patrick, Nessel, & Zito, 2023). Examination of wastewater treatment facilities reveals that these sites, along with sediments, exhibit higher antibiotic levels than surrounding rivers and open water bodies. This disparity is attributed to the accumulation of contaminants within treatment processes and the sediments (Larsson & Flach, 2022). Furthermore, seasonal variations significantly influence antibiotic concentrations, with drier periods showing higher levels due to reduced dilution. In contrast, the wet season tends to dilute antibiotic concentrations in water systems, resulting in lower observed levels (K'oreje et al., 2018). Overall, the occurrence of antibiotics in Kenyan aquatic environments reflects a pressing need for monitoring and management strategies to mitigate their environmental impact and the consequent risk of antibiotic resistance. Addressing this issue requires an integrated approach to water quality management and public health interventions (Chemtai, Kengara, & Ngigi, 2023; Solymári et al., 2022).

Table 1: A table of occurrence of antibiotics in water bodies and wastewater treatment plants in Kenya.

Antibiotic name	Sample matrix	Detected levels	Place of Study	Detection Period	References
Ciproflaxin	Wastewater effluents, Hospital effluents and ground water	0.42± 0.05	Kakamega Hospital	2014-2015	[18]
		< LOQ	Nabongo Domestic		
		0.06± 0.01	MMUST domestic		
		0.09 ± 0.03	Mumias Hospital		
		0.54 ± 0.02	Bungoma Hospital		
		< LOQ	Homabay		
		0.16 ± 0.05	Eldoret		
		0.10 ± 0.06	Kisii		
		0.07 ± 0.02	Busia		
		0.027 ± 0.03	Nyalenda		
	Surface water	72.5	Juja	2019	[19]
	Drain water	48.7± 20	Juja		
	Sediments	6670±500	Juja		
	WWTP	15,500±1000	Juja		
	Drain water	1.2 ± 0.01	Juja		
	Sediments	47.7 ± 30	Juja		
	WWTP	17.5±0.2	Juja		
	WWTP effluent	0.3	Machakos	2019	[20]
	River Mitheu down stream	0.5	Machakos		
	Mwania river	n.d	Machakos		
	River Sagana	0.2	Nyeri		
	River Chania	n.d	Nyeri		
	WWTP effluent	0.3	Kangemi		
	Meru WWTP	2.6	Meru		
	Kanyuru river	47.4	Meru		
Ampicillin	Hospital effluents, ground water and sewage outlets	0.18± 0.01	Kenyatta National Hospital	2018	[11]
		0.24± 0.01	Nairobi river (riverside)		
		0.18± 0.00	Mbagathi River (slum)		
		0.24± 0.01	Ngong River		

		0.20 ± 0.00	Multimedia University Sewage outlet		
	Wastewater effluents, Hospital effluents and ground water	0.61 ± 0.08	Kakamega Hospital	2014-2015	[18]
		0.06 ± 0.01	Nabongo Domestic		
		0.07 ± 0.02	MMUST domestic		
		0.16 ± 0.05	Mumias Hospital		
		0.35 ± 0.06	Bungoma Hospital		
		0.07 ± 0.03	Homabay		
		0.34 ± 0.08	Eldoret		
		0.12 ± 0.05	Kisii		
		0.08 ± 0.03	Busia		
		0.36 ± 0.04	Nyalenda		
	WWTP	2.04-2.94 µg/l	Kabarnet	2020	[1]
		1.01-1.34 µg/l	Kisii		
Amoxicillin	Wastewater effluents, Hospital Effluents and ground water	0.12 ± 0.02	Kakamega Hospital	2014-2015	[18]
		0.06 ± 0.01	Nabongo Domestic		
		0.06 ± 0.01	MMUST domestic		
		0.06 ± 0.01	Mumias Hospital		
		0.07 ± 0.01	Bungoma Hospital		
		<LOQ	Homabay		
		0.08 ± 0.01	Eldoret		
		<LOQ	Kisii		
		< LOQ	Busia		
		0.07 ± 0.01	Nyalenda		
	Drain water	1.2 ± 0.01	Juja	2019	[20]
	Sediments	47.7 ± 30	Juja		
	WWTP	17.5±0.2	Juja		
	WWTP effluent	1.6(0.3)	Machakos		
	River Mitheu down stream	0.9	Machakos		
	Mwania river	4.6	Machakos		
	River Sagana	n.d	Nyeri		
	River Chania	n.d	Nyeri		
	WWTP effluent	1.24	Kangemi		
	Meru WWTP	1.40	Meru		
	Kanyuru river	7.8	Meru		
	WWTP	1.34-1.84 µg/l	Kabarnet	2020	[1]
	WWTP	0.09 µg/l	Kisii	2020	[1]
Chloramphenicol	Wastewater effluents, Hospital Effluents and ground water	0.07 ± 0.01	Kakamega Hospital	2014-2015	[18]
		<LOQ	Nabongo Domestic		
		<LOQ	MMUST domestic		
		0.07 ± 0.01	Mumias Hospital		
		0.08 ± 0.02	Bungoma Hospital		
		0.06 ± 0.01	Homabay		
		0.08 ± 0.02	Eldoret		
		<LOQ	Kisii		
		<LOQ	Busia		
		<LOQ	Nyalenda		
Sulphamethoxazole	Hospital effluents, ground water and sewage outlets	20.59 ± 0.01	Kenyatta National Hospital	2018	[11]
		0.8 ± 0.01	Nairobi river (riverside)		
		1.16± 0.06	Mbagathi River (slum)		
		2.05 ± 0.04	Ngong River		
		7.80 ± 0.14	Multimedia University Sewage outlet		

	WWTP discharge point	5750 ± 700	Juja	2020	[19]
	Drain water sample	108 ± 200	Juja	2020	[19]
	Sediments	4040 ± 300	Juja	2020	[19]
	River	9.2. µg L-1	Nairobi river	2010	[15]
		9.6 µg L-1			
		22 µg L-1			
	River water and wwtps	(0.5–10.8 µg L-1)	Nzoia Basin	2015	[17]
	WWTP effluent	8.5	Machakos	2019	[20]
	River Mitheu down stream	56.6	Machakos		
	Mwania river	3.4	Machakos		
	River Sagana	nd	Nyeri		
	River Chania	16.3	Nyeri		
	WWTP effluent	1.3	Kangemi		
	Meru WWTP	17	Meru		
	Kanyuru river	n.d	Meru		
	WWTP	1.11 -1.29 µg/l	Kabarnet	2020	[1]
	WWTP	0.14-0.18 µg/l	Kisii	2020	[1]
Sulfurdiazin	Hospital effluents, ground water and sewage outlets	15.71 ± 0.44	Kenyatta National Hospital	2018	[11]
		0.47± 0.01	Nairobi river (riverside)		
		<0.07	Mbagathi River (slum)		
		<0.07	Ngong River		
		<0.07	Multimedia University Sewage outlet		
Penicillin	Hospital effluents, ground water and sewage outlets	<0.22	Kenyatta National Hospital	2018	[11]
		<0.22	Nairobi river (riverside)		
		<0.22	Mbagathi River (slum)		
		<0.22	Ngong River		
		<0.22	Multimedia University Sewage outlet		
Oxacillin	Hospital effluents, ground water and sewage outlets	0.18± 0.01	Kenyatta National Hospital		
			Nairobi river (riverside)		
		0.21 ± 0.01	Mbagathi River (slum)		
		0.16 ± 0.06	Ngong River		
		0.17 ± 0.01	Multimedia University Sewage outlet		
Nafcillin	Hospital effluents, ground water and sewage outlets	<-0.11	Kenyatta National Hospital	2018	[11]
		0.50 ± 0.01	Nairobi river (riverside)		
		<-0.11	Mbagathi River (slum)		
		1.04± 0.01	Ngong River		
		0.54 ± 0.01	Multimedia University Sewage outlet		

Dicloaxicillin	Hospital effluents, ground water and sewage outlets	<0.12 (LOD)	Kenyatta National Hospital	2018	[11]
		<0.12 (LOD)	Nairobi river (riverside)		
		<0.12 (LOD)	Mbagathi River (slum)		
		<0.12 (LOD)	Ngong River		
		<0.12 (LOD)	Multimedia University Sewage outlet		
Tetracyclin	Hospital effluents, ground water and sewage outlets	<0.12 (LOD)	Kenyatta National Hospital	2018	[11]
		<0.12 (LOD)	Nairobi river (riverside)		
		<0.12 (LOD)	Mbagathi River (slum)		
		<0.12 (LOD)	Ngong River		
		<0.12 (LOD)	Multimedia University Sewage outlet		
sulfadoxin	River water and wwtps	(60–1040 ng L-1)	Nzoia Basin	2015	[17]
Trimethoprim	River	3.2 µg L-1	Nairobi river	2010	[15]
		2.5 µg L-1			
		ND µg L-1			
	WWTP effluent	0.3	Machakos	2019	[20]
	River Mitheu down stream	0.1	Machakos		
	Mwania river	ND	Machakos		
	River Sagana	ND	Nyeri		
	River Chania	ND	Nyeri		
	WWTP effluent	0.5	Kangemi		
	Meru WWTP	0.1	Meru		
	Kanyuru river	N.d	Meru		
	Drain water samples	37.7	Juja	2019	[19]
	Sediments	2340 ±400	Juja	2019	[19]
	River	1890±200	Juja	2019	[19]
	WWTP	0.14-0.09 µg/l	Kabarnet	2020	[1]
	WWTP	0.06-0.05 µg/l	Kisii	2020	[1]
Norflaxacin	Drain water	37.5 ± 20	Juja	2020	[19]
	Sediments	6010 ± 500	Juja	2020	[19]
	WWTP	1930 ± 0.1	Juja	2020	[19]
	WWTP effluent	0.5	Machakos	2019	[20]
	River Mitheu down stream	2.2	Machakos		
	Mwania river	0.11	Machakos		
	River Sagana	ND	Nyeri		
	River Chania	26.0	Nyeri		
	WWTP effluent	0.8	Kangemi		
	Meru WWTP	1.2	Meru		
	Kanyuru river	ND	Meru		

Ecological Consequences

The widespread contamination of aquatic ecosystems by antibiotics has far-reaching ecological consequences, including impacts on aquatic organisms and biodiversity loss (Li et al., 2022; Zhang et al., 2017). In Kenya, various studies have investigated the occurrence and removal efficiencies of antibiotics in wastewater treatment plants and surface waters, revealing high risks of antibiotic resistance development (Wendott et al., 2024; Ngumba et al., 2020). The transfer of resistant microbial and bacterial genes to human or animal hosts can lead to resistant sicknesses and diseases, resulting in increased mortality (Ngumba et al., 2020). The presence of antibiotics in water and soil poses a threat to human and animal health, as well as the environment. Studies have found high levels of antibiotics in waste water treatment plants, hospital lagoons, and rivers in Kenya (K'Oreje et al., 2018; Kimosop et al., 2016). The discharge of these antibiotics into the environment can lead to the development of antibiotic-resistant bacteria, posing a significant risk to human health (Pappas et al., 2009). The removal efficiencies of antibiotics in wastewater treatment plants are generally low, with some studies reporting removal rates as low as 20-30% (Wendott et al., 2024; Ngumba et al., 2020). This highlights the need for improved wastewater management practices to mitigate the risks associated with antibiotic contamination. The risks associated with antibiotic contamination in Kenya are further exacerbated by the presence of pharmaceuticals in wastewater and surface waters (Chemtai et al., 2023; Kairigo et al., 2020). These compounds can also contribute to the development of antibiotic-resistant bacteria and pose a threat to human and environmental health. In conclusion, the widespread contamination of aquatic ecosystems by antibiotics in Kenya poses a significant risk to human and animal health, as well as the environment. Improved wastewater management practices, including enhanced removal efficiencies of antibiotics in wastewater treatment plants, are essential to mitigate these risks.

CONCLUSION

The use of antibiotics has increased significantly worldwide in the treatment of bacterial infections. Presently, a lot of misuse has also been reported in both animal and the health sector. This review, presents to the best of my knowledge for the first time, consolidated results on the occurrence of antibiotics in different matrixes in Kenya. The study also shows that in densely populated areas and waste water treatment plants, the presence of antibiotics are higher than other places placing a significant risk on antimicrobial resistance genes and bacteria.

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