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► To cite this version:

Oche Joseph Otorkpa, Anuniru Chinazom, Ahmed Shahidah Adamu. Drinking water quality parameters in Africa and the United States: Implications for public health. *Engineering Science & Technology Journal*, 2024, 5 (8), pp.2466 - 2478. 10.51594/estj.v5i8.1401 . hal-04700004

HAL Id: hal-04700004

<https://hal.science/hal-04700004v1>

Submitted on 17 Sep 2024

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Engineering Science & Technology Journal
P-ISSN: 2708-8944, E-ISSN: 2708-8952
Volume 5, Issue 8, P.No. 2466-2478, August 2024
DOI: 10.51594/estj.v5i8.1401
Fair East Publishers
Journal Homepage: www.fepbl.com/index.php/estj



Drinking water quality parameters in Africa and the United States: Implications for public health

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Article Received: 25-02-24

Accepted: 06-06-24

Published: 12-08-24

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ABSTRACT

This study provides a comparative overview of drinking water quality parameters in Africa and the United States, highlighting their implications for public health. Water quality encompasses physical, chemical, biological, and radiological characteristics, with significant variations influenced by source conditions and treatment processes. In Africa, inadequate infrastructure, pollution, and limited resources result in high levels of microbiological contaminants and chemical pollutants, leading to a high burden of waterborne diseases. Pathogens such as *Escherichia coli* and protozoan parasites like *Cryptosporidium* and *Giardia* are prevalent, contributing to substantial morbidity and mortality. Chemical contamination, including nitrates, pesticides, and heavy metals, exacerbates these issues. Conversely, the United States benefits from advanced water treatment technologies and stringent regulations, yet challenges persist. Issues such as lead contamination from aging pipes, emerging pollutants like PFAS, and localized contamination events continue to pose risks. Although regulatory frameworks like the Safe Drinking Water Act and proposed enhancements to the Lead and Copper Rule aim to mitigate these problems, maintaining and upgrading

infrastructure remains critical. This study highlights the need for targeted interventions and policy improvements. For Africa, investing in infrastructure and treatment technologies is crucial, while in the U.S., addressing lead and emerging contaminants requires ongoing vigilance and investment. Further research is needed to assess the effectiveness of interventions, understand long-term health impacts, and develop sustainable solutions for enhancing global water quality and public health.

Keywords: Drinking Water Quality, Africa, United States, Microbiological Contaminants, Chemical Pollutants, Public Health, Waterborne Diseases.

INTRODUCTION

Water quality refers to the physical, chemical, biological, and radiological characteristics of water, as measured against established standards and criteria, it encompasses parameters such as clarity, taste, odor, temperature, pH, and the presence of contaminants or pollutants (Vasistha & Ganguly, 2020). Drinking water quality can vary significantly depending on the condition of the source water and the treatment processes it undergoes (Gilca, Teodosiu, Fiore, & Musteret, 2020).

Over 80% of sewage from human activities is released into rivers and oceans without treatment, leading to environmental pollution and the spread of over 50 diseases. Poor water quality is linked to 80% of diseases and contributes to 50% of child deaths globally (Lin, Yang, & Xu, 2022).

Access to clean and safe drinking water is fundamental to human health and well-being. Despite advancements in technology and policy, significant disparities in water quality exist between different regions of the world, notably between Africa and the United States (U.S). These disparities can have profound implications for public health, as contaminated water is a major vector for numerous diseases and health conditions. In Africa, many communities face challenges such as inadequate infrastructure, pollution, and limited resources, which compromise water quality and increase the risk of waterborne diseases (Matchawe, Bonny, Yandang, Mafo, & Nsawir, 2022; Kombo Mpindou, Escuder Bueno, & Chorda Ramon, 2021). Conversely, the

The U.S., generally benefits from advanced water treatment systems and stringent regulatory standards, yet still contends with issues like aging infrastructure, lead contamination, and emerging pollutants (Nataraj, 2022).

Available data indicates that that Americans prioritize drinking water quality and water pollution as their foremost environmental concerns, reflecting ongoing apprehensions about threats to water quality and safety (Gallup, 2023).

This study aims to provide a comprehensive comparison of drinking water quality parameters in Africa and the United States, highlighting key differences and their implications for public health. By examining factors such as microbiological contamination, chemical pollutants, and physical characteristics of drinking water, we seek to identify the main public health challenges associated with water quality in these regions. Furthermore, this analysis will explore the effectiveness of current regulatory frameworks and public health interventions in mitigating these challenges. Understanding the complexities of drinking water quality across diverse settings is crucial for developing targeted strategies that ensure safe water for all populations, thereby improving global public health outcomes.

METHODOLOGY

This study employs a comparative analysis of drinking water quality parameters between Africa and the U.S., utilizing both qualitative and quantitative approaches. Data were collected from a variety of sources, including peer-reviewed articles, government reports, and international databases. A comprehensive search of academic databases such as PubMed, Scopus, and Google Scholar identified relevant studies on drinking water quality in both regions, using keywords like "drinking water quality," "waterborne diseases," "chemical pollutants," "microbiological contamination," and "public health implications." In addition, reports from governmental and international agencies, such as the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the African Development Bank (AfDB), were reviewed. Information was also extracted from established databases including the WHO Global Health Observatory, EPA's Safe Drinking Water Information System (SDWIS), and national water quality monitoring programs in African countries. The study considered several limitations, such as variability in data availability and quality, differences in data coverage periods, and potential biases in reporting. This study relied on publicly available data and did not involve human subjects or animal testing, with all data sources appropriately cited and credited.

COMPARATIVE ANALYSIS OF WATER QUALITY PARAMETERS

Microbiological Contamination

In Africa, drinking water sources are often compromised by high levels of microbiological contaminants, including *Escherichia coli*, total coliforms, and other pathogenic bacteria (Odonkor & Mahami, 2020). Studies have shown that the most frequently identified microbial contaminants of drinking water in Africa are *Escherichia coli*, *Klebsiella spp.*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, with *Vibrio cholerae* and *Salmonella spp.* also being notable contaminants (Otorokpa, 2019; El-Liethy & Abia, 2020), a significant proportion of water samples from many parts of Africa exceed the World Health Organization's (WHO) recommended benchmark which is zero colony-forming-units per 100 ml of water sample (Lapworth et al., 2020; PHN, 2022).

A scoping review of studies from 17 African countries, covering the period from 1990 to January 2020, found *Cryptosporidium* prevalence ranging from 6 to 100% in surface water, 4 to 100% in tap water, and up to 100% in wastewater and sludge. *Giardia* was reported in 47 studies, with prevalence ranging from 2.4% in surface water, 1% to over 70% in tap water, and 28% to 100% in wastewater. *Cyclospora cayetanensis* showed lower prevalence, while *Entamoeba* was found at 78% in surface water and 100% in wastewater (Siwila et al., 2020).

Drinking water in the U.S., generally meets stringent safety standards, with regular monitoring and treatment processes reducing microbiological risks (Ford, 1999). However, localized issues, such as those associated with failing infrastructure or specific contamination events still pose risks. A microbial contamination analysis of 72 drinking water samples from water vending machines (WVMs), soda fountains (SFs), and tap water (TW) in fast-food restaurants in the U.S., revealed the presence of heterotrophic plate count (HPC) bacteria in 20% of WVM samples, 25% of SF samples, 33.3% of TW samples, and 76% of swab samples. Additionally, total coliforms were detected in 20% of WVM samples, 88% of swab samples, 41% of SF samples, and 50% of TW samples. Quantitative PCR (qPCR) analysis identified genetic material from six selected pathogenic microorganisms—*Salmonella spp.*,

Listeria monocytogenes, *Pseudomonas aeruginosa*, *Campylobacter jejuni*, *Escherichia coli*, and *Enterococcus faecalis*—in samples from WVMs, SFs, and TWs, with varying concentrations and levels of predominance (Hile, Dunbar, & Sinclair, 2023). Furthermore, a microbial health risk assessment of regulated drinking waters in the U.S., revealed that the health risks associated with drinking tap water are significantly higher than those for bottled water, with tap water linked to approximately 195 million illnesses over the past decade compared to fewer than a dozen cases for bottled water (Edberg, 2015). *Giardia* and *Cryptosporidium* both protozoan parasites, that can cause gastrointestinal illnesses in humans and animals are listed by the United States Environmental Protection Agency (EPA) as the major protozoan contaminant of drinking water in the U.S., (EPA, 2024).

Chemical Contaminants

About 75% of Africa's drinking water is sourced from groundwater, which is often utilized with minimal or no purification (PACN, 2010). Chemical contamination of drinking water in Africa is often linked to agricultural runoff, industrial activities, and inadequate waste disposal, leading to elevated levels of nitrates, pesticides, and heavy metals like lead and arsenic (Isukuru et al., 2024).

Data collected from 2001 to 2021 for 22 of the 54 countries on the African continent revealed that pesticides, pharmaceuticals, endocrine-disrupting chemicals, personal care products, per- and polyfluoroalkyl substances (PFAS), and microplastics were frequently detected in both conventional and non-conventional water sources across these countries (Shehu, Nyakairu, Tebandeke, & Odume, 2022). Although these contaminants can significantly impact health, chemical contamination is a less relevant factor in the determination of drinking water quality in Africa (Machado, Amorim, & Bordalo, 2022).

In the U.S., while overall water quality is more controlled due to advanced treatment technologies and regulations, issues such as lead contamination from aging pipes and the presence of emerging pollutant still present challenges. With an estimated 9.2 million lead pipes installed in the late 1800s to early 1900s still in active use across the U.S., studies have shown that lead, nitrate, and per- and polyfluoroalkyl substances (PFAS) are major drinking water contaminants, with lead issues exacerbated by outdated infrastructure, nitrate contamination from agricultural runoff, and PFAS known for their persistence and severe health impacts (Levin et al., 2024).

A recent study conducted by the U.S. Geological Survey (USGS) found that approximately 45% of tap water, relied upon by 71% of Americans for drinking, contains one or more types of PFAS. The study utilized a method developed by the USGS National Water Quality Laboratory to test for 32 individual PFAS compounds. The most frequently detected compounds were PFBS, PFHxS, and PFOA (Smalling et al., 2023). The study which involved collection of samples directly from kitchen sinks represents the most comprehensive assessment to date of PFAS contamination in both private wells and public water supplies.

Another major concern is the impact of antibiotics on drinking water quality, an analytical analysis of finished drinking waters in the U.S., using solid-phase extraction and liquid chromatography electrospray tandem mass spectrometry revealed various antibiotics, including fluoroquinolones, sulfonamides, lincomycin, tetracyclines, and macrolides, in source waters, with some persisting into finished drinking waters (Ye, Weinberg, & Meyer, 2007).

Physical Characteristics

Physical parameters such as turbidity and pH are also critical in assessing water quality. In Africa, high turbidity is often associated with inadequate filtration and can indicate the presence of suspended particles and pathogens (Verlicchi & Grillini, 2020). pH levels in African water sources can vary widely, influenced by natural and anthropogenic factors, studies have shown that drinking water pH in West Africa ranges from 4.25 to 6.22 (Amaibi et al., 2022), while in Northern Africa, pH values range from 7.37 to 8.05 (Atteya et al., 2023). In Central Africa, drinking water pH varies between 5.3 and 7.8 (Foto et al., 2016), and in Southern Africa, it ranges from 6.79 to 8.36 (Oputu & Akharamé, 2022). In Eastern Africa, drinking water samples exhibit a pH range of 5.0 to 8.9 (Ondieki et al., 2021).

In the United States, water treatment processes typically ensure that turbidity is minimized and pH is maintained within acceptable range of 6.5 to 8.5 recommended by the EPA (Wu et al., 2021). However, many studies have highlighted significant water quality issues, an investigation into drinking water chemistry and treatment systems in the U.S., revealed that 31% of samples with pH treatment exhibited pH levels below 6.5, the minimum value stipulated by drinking water regulations, indicating widespread maintenance problems (Ander et al., 2016). In addition, a case study of a drinking water reservoir in Florida, USA, found that most water quality parameters—such as color, turbidity, Secchi depth, pH, electrical conductivity, dissolved oxygen, total alkalinity, cations, anions, and lead—were below the standards for potable water set by Florida (Toor et al., 2013). In general variations can occur based on local water source characteristics and treatment efficacy

Implications for Public Health

The disparities in drinking water quality between Africa and the United States have profound public health implications that highlight the urgent need for targeted interventions and policies.

Disease Burden

In Africa poor water quality is a major contributor to high rates of waterborne diseases, such as cholera, dysentery, and typhoid fever. The frequent occurrence of pathogens in drinking water can lead to significant morbidity and mortality, particularly among children under five (Malebatja & Mokgatle, 2022). Waterborne diseases place a substantial burden on healthcare systems, often leading to severe health complications and fatalities (Prüss-Ustün et al., 2019). The high prevalence of protozoan parasites like *Cryptosporidium* and *Giardia* exacerbates the situation, contributing to persistent gastrointestinal illnesses and other health issues (Putignani & Menichella, 2010).

Although the U.S. generally has robust water safety measures, localized issues can still pose health risks. Contaminants like lead and PFAS can lead to chronic health conditions, such as developmental issues in children and cancer risks (Kadawathagedara, de Lauzon-Guillain, & Botton, 2018; Levin et al., 2024). The presence of pathogens in certain drinking water sources, despite overall low risks, can lead to outbreaks and health concerns, particularly in areas with failing infrastructure or specific contamination events (Craun et al., 2010).

Health Inequities

The disparities in water quality in Africa often correlate with socio-economic factors. Poorer communities are more likely to lack access to safe water sources and adequate sanitation facilities. This leads to higher rates of waterborne diseases and exacerbates health inequalities

(Armah et al., 2018). Women and children, who are primarily responsible for collecting water, may face additional health risks from carrying contaminated water and exposure to unsafe water sources (Brown, Cairncross, & Ensink, 2013).

In the U.S., vulnerable populations, including low-income communities and communities of color, are disproportionately affected by water quality issues (Acquah & Allaire, 2023). Aging infrastructure and lead contamination can have more severe impacts on these communities, leading to health disparities. Access to clean and safe drinking water is uneven, and marginalized communities may face higher risks due to environmental injustices (Allaire, Wu, & Lall, 2018).

Economic Impact

The economic impact of poor water quality is significant on Africa. The cost of treating waterborne diseases, lost productivity due to illness, and the need for healthcare resources strain already limited budgets (Hutton, Chase, & Kennedy-Walker, 2024). In addition, poor water quality can affect agricultural productivity and economic development, further entrenching poverty and economic instability (Le Pere & Ikome, 2009).

In the U.S., economic costs related to water quality issues include expenses for infrastructure repairs, healthcare costs associated with waterborne illnesses, and legal liabilities for contamination incidents (Beach, 2022). Addressing lead contamination and upgrading infrastructure can be costly but necessary investments to protect public health and ensure water safety (Peters et al., 2024).

Public Health Infrastructure

The lack of adequate water treatment facilities and sanitation infrastructure in Africa contributes to ongoing public health challenges (Wang et al., 2014; (Otokpa et al., 2024)). Investments in infrastructure, such as improved water treatment plants and sanitation systems, are critical for reducing disease burden and enhancing overall health outcomes (Ferreira, Grazielle, Marques, & Gonçalves, 2021).

While the U.S. has advanced water treatment technologies, maintaining and upgrading infrastructure is essential to address emerging contaminants and prevent health risks (Qu, Brame, Li, & Alvarez, 2013). This is important to avoid a repeat of the Flint, Michigan catastrophe, where the release of the more corrosive Flint River water through aging water service lines led to the leaching of lead from the corroded pipes. This exposed thousands of residents, including an estimated 8,000 to 9,000 children, to the hazardous effects of lead (Rockey et al., 2021). Regular monitoring and enforcement of safety standards are necessary to ensure continued protection of public health (Patel, Hecht, Craddock, Edwards, & Ritchie, 2020).

Regulatory Frameworks and Interventions

The effectiveness of regulatory frameworks plays a crucial role in managing drinking water quality. In the U.S., comprehensive regulations under the Safe Drinking Water Act (SDWA), coupled with advanced treatment technologies, contribute to generally high water quality (Wu, Cao, Tong, Finkelstein, & Hoek, 2021). In November 2023, the U.S. government proposed enhancements to the Lead and Copper Rule to accelerate the replacement of lead service lines (LSLs), and a report by Environmental Entrepreneurs and the United Association of Union Plumbers and Pipefitters estimated that a \$45 billion investment in replacing all LSLs in America could generate 56,080 jobs annually for a decade, strengthening economic

security for communities while improving the health of over 22 million affected individuals (American Progress,2024).

In Africa, improving water quality is hindered by limited resources and infrastructure, efforts to enhance water quality involve international aid, local initiatives, and capacity-building programs (Anghileri et al., 2024). Addressing these challenges requires targeted interventions and investments in infrastructure, education, and technology. To achieve this goal the Rural Water Supply and Sanitation Initiative (RWSSI), a flagship program of the African Development Bank (AfDB) was formed. It is designed to address Africa's rural water supply and sanitation crisis by targeting the improvement of access to safe water and sanitation in rural areas, with funding provided by the AfDB, bilateral and multilateral agencies, African governments, communities, and the RWSSI Trust Fund (AfDB)

Table 1

Comparative Overview of drinking water quality parameters in Africa and the United States

Parameter	Africa	United States
Microbiological Contamination	High levels of contaminants like E. coli, Cryptosporidium, and Giardia. High morbidity and mortality from waterborne diseases.	Generally low due to advanced treatment, but localized issues persist, such as those from failing infrastructure.
Chemical Contamination	High levels of nitrates, pesticides, and heavy metals due to agricultural runoff, industrial activities, and inadequate waste disposal.	Lead contamination from aging pipes, emerging pollutants like PFAS, and nitrates from agricultural runoff.
Physical Characteristics	High turbidity and variable pH levels, indicating inadequate filtration and contamination.	Typically controlled turbidity and pH maintained within EPA guidelines (6.5-8.5), but local issues can occur.
Disease Burden	High rates of waterborne diseases (cholera, dysentery, typhoid), significant morbidity and mortality, especially in children.	Chronic health conditions (developmental issues, cancer risks) from contaminants like lead and PFAS.
Health Inequities	Poor communities lack access to safe water, leading to higher rates of disease and health disparities.	Vulnerable populations (low-income, communities of color) disproportionately affected by water quality issues.
Economic Impact	High costs of treating diseases, lost productivity, strain on healthcare systems, and impact on agricultural productivity.	High costs for infrastructure repairs, healthcare, and legal liabilities from contamination incidents.
Public Infrastructure	Inadequate water treatment and sanitation facilities, requiring significant investments.	Advanced but aging infrastructure, requiring maintenance and upgrades to address emerging contaminants.

Regulatory Frameworks	Limited resources and infrastructure, dependent on international aid and local initiatives.	Comprehensive regulations (Safe Drinking Water Act), advanced treatment technologies, ongoing need for infrastructure investment.
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This table highlights the key differences and implications for public health between the two regions, showing the need for targeted interventions and policy improvements to ensure safe drinking water for all populations.

Further Research Needs

Further research is essential to address the persistent disparities and challenges in drinking water quality observed between Africa and the United States. In Africa, future studies should focus on evaluating the effectiveness of new and existing water treatment technologies in diverse rural settings, including the impact of community-led initiatives and international aid programs. Research should also explore innovative and sustainable methods for infrastructure development and maintenance, given the constraints of limited resources and funding. Additionally, comprehensive studies are needed to assess the long-term health impacts of waterborne diseases and to develop targeted interventions to reduce morbidity and mortality associated with poor water quality.

In the United States, further research should investigate the efficacy of emerging contaminants and their health effects, including a deeper analysis of the impact of lead and per- and polyfluoroalkyl substances (PFAS) on vulnerable populations. Studies should also examine the economic and health impacts of infrastructure improvements and regulatory changes, such as those proposed for the Lead and Copper Rule. Additionally, research should focus on the resilience of water systems to extreme weather events and climate change, as well as the effectiveness of public health campaigns in raising awareness and promoting safe drinking water practices. Addressing these research gaps will provide critical insights for developing effective policies and interventions to enhance water quality and public health globally.

CONCLUSION

In conclusion, this study sheds light on the stark disparities in drinking water quality between Africa and the United States, which have profound implications for public health. In Africa, inadequate infrastructure, pollution, and limited resources significantly compromise water quality, leading to high rates of waterborne diseases and health disparities. Despite efforts to improve water safety through initiatives like RWSSI, challenges remain due to insufficient infrastructure and funding. On the other hand, the United States benefits from advanced water treatment technologies and stringent regulations, yet issues such as aging infrastructure and emerging contaminants persist. While regulatory frameworks like the Safe Drinking Water Act and proposed enhancements to the Lead and Copper Rule aim to address these issues, maintaining and upgrading infrastructure is crucial to prevent incidents similar to the Flint water crisis.

Addressing these disparities requires a multifaceted approach. For Africa, investing in infrastructure, improving water treatment technologies, and enhancing local capacity are essential for mitigating health risks and improving water quality. However, the effectiveness of these interventions can be limited by financial constraints and political challenges. In the

U.S., while regulatory measures and technological advancements offer significant benefits, addressing problems like lead contamination and emerging pollutants necessitates continued investment and vigilant monitoring. Balancing these efforts with considerations of economic feasibility and public health priorities will be key to advancing global water safety and equity.

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