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Research Article

ASSESSMENT OF GROUNDWATER QUALITY FOR HUMAN CONSUMPTION IN YENAGOA METROPOLIS

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Abstract

Groundwater contamination is a significant environmental concern globally, affecting the availability and quality of drinking water. This study aimed to evaluate the physicochemical properties and heavy metal contamination in groundwater sourced from selected boreholes in Ovom, Yenibebel, and Yenaka communities within Attisa Clan, Yenagoa metropolis, Bayelsa State, Nigeria. The analysis followed standard World Health Organization (WHO) guidelines to determine the water's suitability for human consumption and safeguard public health. The physical parameters assessed included electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), and total hardness (TH), while chemical parameters included total alkalinity (TA), pH, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), chloride (Cl), fluoride (F), nitrate (NO3), phosphate (PO4), and sulfate (SO4). Heavy metals, such as calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), chromium (Cr), cadmium (Cd), and lead (Pb), were also analyzed. The results revealed that the physical parameters were within the permissible limits of the Nigerian Standard for Drinking Water Quality (NSDWQ) and WHO standards. However, the Hazardous Pollution Index (HPI) indicated that the groundwater from Ovom and Yenibebel had elevated cadmium concentrations above the recommended limit of 0.003 mg/L, rendering the water unsafe for consumption. Conversely, water from Yenaka was deemed safe for human use. It is recommended that regular monitoring of groundwater quality in Yenagoa be conducted to ensure the health and well-being of the population, with particular focus on addressing cadmium contamination in affected areas.

Keywords: Water quality, Heavy metals, Contamination, Public health, Groundwater,

Introduction

Water pollution, solid waste management, and climate change are three of the most pressing environmental challenges the world faces in the 21st century. Among these, water pollution remains one of the most significant and pervasive concerns due to its direct and indirect impact on human health, ecosystems, and economic development. Water pollution can occur in both groundwater and surface water sources, with contamination levels in groundwater becoming a particularly alarming issue. Groundwater is one of the Earth's most vital resources, providing approximately 99% of the planet's freshwater and serving as the primary source of drinking water for a substantial portion of the global population. As urbanization, industrialization, and agricultural activities continue to intensify, the contamination of groundwater has emerged as a key environmental problem with far-reaching consequences for human health and sustainable development.

Groundwater is the most accessible and abundant freshwater source on Earth, providing nearly half of all drinking water, 40% of irrigation water, and approximately one-third of water used in industrial activities (United

Nations Water, 2018; Upmanu et al., 2020). Given its vital role in supporting human life, any threat to groundwater availability and quality should be considered a global concern. Yet, despite its importance, this critical resource is increasingly being depleted and contaminated at an alarming rate, a trend that has triggered widespread concern about the long-term sustainability of groundwater supplies.

The depletion and contamination of groundwater are caused by both natural and anthropogenic factors. Natural contamination occurs when groundwater interacts with soils and rocks along its flow path, dissolving various substances such as sulfates, iron, fluorides, arsenic, radionuclides, and manganese. These substances can severely degrade the quality of the water, making it unsuitable for consumption or other uses (Basu et al., 2014; Pandey et al., 2016; Suba Roa et al., 2020). Additionally, saltwater intrusion, which occurs when rising sea levels push saltwater into groundwater sources, is another natural threat to groundwater quality. However, the primary drivers of groundwater contamination are human activities, which have a far more significant impact on the quality and availability of this crucial resource.

Anthropogenic causes of groundwater pollution are diverse and wide-ranging. One of the most significant contributors is industrial waste, which often finds its way into groundwater through poorly managed injection wells or leaking hazardous waste disposal sites. Furthermore, agricultural practices, including the excessive use of fertilizers, pesticides, and herbicides, have been linked to groundwater contamination. These chemicals, when leached into the ground, can lead to dangerous levels of nitrate and other contaminants in drinking water sources (Guanxing & Dongya, 2021). Urban waste, including landfill leachate and effluents from sewage systems, is also a major contributor to groundwater pollution, particularly in densely populated urban areas (Christopherson, 2002; Egbo & Eremasi, 2022). The leakage of domestic sewage and industrial wastewater into groundwater reserves is a significant concern for water quality in many regions around the world.

Another emerging concern is the impact of climate change on groundwater resources. Changes in weather patterns, such as increased temperatures, irregular rainfall, and the occurrence of extreme hydrological events, can significantly disrupt groundwater recharge. As climate change exacerbates these conditions, the rate at which groundwater is replenished may decrease, leading to further depletion of water supplies. This phenomenon is particularly concerning in regions that are already facing challenges related to water scarcity and pollution.

The contamination of groundwater poses significant risks to both human health and the environment. Numerous studies have shown that polluted groundwater can harbor a wide range of harmful substances, including heavy metals, nitrates, fluoride, and persistent organic pollutants, all of which can have severe health consequences when consumed. Exposure to high levels of fluoride in drinking water, for example, can lead to dental and skeletal fluorosis, a condition that affects the bones and teeth. Nitrate contamination in drinking water, particularly in infants, can lead to Methemoglobinemia, also known as "blue baby syndrome," which interferes with the ability of the blood to carry oxygen and can be fatal if left untreated (Limus, 2017). Heavy metals, such as arsenic, lead, and mercury, are another significant concern. Chronic exposure to these toxic substances can result in gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, and even cancer (Bernhoft, 2012; Tsai et al., 2017; Cobbina et al., 2015). The long-term effects of exposure to heavy metals, especially when combined with other contaminants, can have devastating impacts on human health and well-being.

Access to clean and safe drinking water is a fundamental human right, and it is widely recognized as an essential determinant of public health. The availability and accessibility of potable water directly influence the well-being of individuals and communities, making it a key indicator of sustainable development. Well-being, in this context, refers to the conditions that ensure a healthy, balanced, and diverse ecosystem capable of supporting human life and other species (Robert et al., 2005). As such, the protection and sustainable management of water resources are critical for promoting the health and well-being of individuals, particularly in regions where access to safe drinking water is limited.

In many developing countries, including Nigeria, the quality of water sources is a growing concern, particularly in urban areas where rapid population growth and industrialization have placed significant pressure on local water supplies. In Yenagoa, the capital of Bayelsa State, the absence of a reliable public water supply system has led residents to depend heavily on boreholes as their primary source of drinking water. However, despite the reliance on borehole water, its quality is often unknown, and the water sources remain vulnerable to contamination from various anthropogenic activities. In particular, the presence of agricultural runoff, industrial waste, and urban waste leachate poses a significant threat to the safety and potability of borehole water in these communities.

In the Attisa Clan of Yenagoa, the quality of water from boreholes in communities such as Ovom, Yenibebel, and Yenaka has raised concerns about the potential risks to public health. While boreholes are generally considered a safer alternative to surface water sources, they are not immune to contamination, particularly when the groundwater table is polluted by industrial or agricultural runoff, or when the borehole construction is inadequate. As a result, residents in these communities are at risk of consuming unsafe water, which can lead to various waterborne diseases and other health complications.

This study seeks to assess the potability of borehole water in selected communities within Attisa Clan, Yenagoa, Bayelsa State. Specifically, the study will examine the water quality in the Ovom, Yenibebel, and Yenaka communities, which are heavily reliant on boreholes for their daily water needs. The primary objective of this study is to evaluate the potential risks associated with consuming borehole water in these communities, in order to provide insights into the health implications of relying on groundwater sources that may be contaminated by various pollutants.

Given the importance of safe drinking water to human health, this study will also explore the broader implications of water pollution on sustainable development, particularly in developing countries where access to clean water is limited. The findings of this research will contribute to a better understanding of the challenges associated with groundwater contamination in urban and rural areas, and provide valuable information for policymakers, local governments, and communities in their efforts to improve water quality and protect public health.

In conclusion, groundwater contamination represents a significant global challenge that threatens the availability of safe drinking water, with far-reaching consequences for human health, environmental quality, and sustainable development. As the demand for freshwater continues to grow, it is essential to address the sources of groundwater pollution and develop strategies to protect this vital resource for future generations. This study aims to contribute to this effort by assessing the quality of borehole water in Yenagoa, Bayelsa State, and providing evidence-based recommendations for improving water management practices and ensuring access to safe drinking water for all.

2.1 MATERIAL AND METHOD

2.1 **Area of the study**.

The area of the study is Ovom, Yenibebel and Yenaka communities in Attisa Clan of Yenaoa Local Government Area of Bayelsa State. Attisa of one of the four Clans in Yenaoa L. G. A. Yenagoa city is the capital of Bayelsa State, located in South-South region of Nigeria. The city is situated on the bank of Ekoli River, which is one of the major river courses making up the Niger Delta Rivers, according to (Koinyan, Nwankwoala and Eludoyin, 2013). Yenagoa city is geographically located in latitude $4^{o}55^{I}$ 36.30N and Longitude $6^{o}16^{I}$3.50E according to satellite map (www.latitude.to) .

2.2 Methods.

Boreholes water samples were collected into pre-washed sampling plastic bottles from nine different sampling locations in Ovom, Yenibebel and Yenaka communities in Attisa Clan of Yenagoa metropolis. Three Water samples were collected from three different sampling locations in each community. All the samples collected were properly labeled and put in cooling box stuffed with ice block and then transported to the laboratory for analysis. Samples were analysed following standard analytical procedure of the World Health Organisation (WHO)

2.2 **Data analysis**.

2.3 **Groundwater quality index (GWQI)**

The groundwater quality index (GWQI) which reflects the composite influence of the different water parameters was evaluated using the weighted arithmetic water quality index equation

$$[(WQI\ (Qi = 100[Vi\text{-}v0]/[si\text{-}v0])(\ Wi=k/s_i \quad k= 1/\sum 1/s_i)]. \qquad (1)$$

Where: Qi is the sub-index of the ith parameter and Wi is unit weight of the ith parameter, V_i, v_0 *and* s_i *are the analysed value, ideal value and the standard values of the* ith parameter respectively.

The weighted arithmetic model was adopted for this study because it incorporate the most commonly measured water quality parameters prescribed by water standards.

2.4 **Heavy metals Pollution Index (HPI)**

The heavy metal pollution Index (HPI) was evaluated using the equation of Mahan et al. (1996)

$$[(HPI=\sum_{ni} = \sum Qi\ WI/\sum Wi) \qquad 2$$

Where each of the terms in the equation is as described in equation (1) above

3.1 RESULTS AND DISCUSSIONS

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Parameters	Ovom			Yenibebel			Yenaka			Drinking Water Standards	
	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3	NSDQW	WHO
EC	397.0	401.0	398.30	217.30	144.0	162.33	179.0	579.0	479.0	1000	
TDS	198.50	200.50	201.50	108.50	72.0	99.38	88.50	289.50	138.75	500	1000
TSS	0.05	0.04	0.06	0.07	0.06	0.063	0.05	0.04	0.04		
TH	88.0	98.0	95	62.0	39.0	56.25	50.0	140.0	130.0	150	
Ph	6.60	6.50	6.30	8.0	6.90	7.18	6.10	6.70	6.30	6.5-8.5	
TA	65.0	75.0	72.0	61.0	62.0	60.23	60.0	91.0	67.75		
Cl	58.0	54.0	57.0	10.0	11.0	11.03	11.0	40.0	32.75	250	250
F	0.95	1.20	1.13	0.97	0.80	0.89	0.68	1.50	1.43	1.5	1.5
NO_3	0.137	0.135	0.140	0.140	0.143	0.142	0.131	0.124	0.123	50	10
SO_4	3.20	3.21	3.17	3.25	2.52	3.18	.2.91	2.90	2.87	100	250
PO_4	1.20	1.21	1.24	2.55	2.57	2.64	1.32	1.30	1.34		
DO	4.30	4.35	4.51	3.84	3.90	3.78	2.76	3.43	3.31.		
COD	156.95	158.78	155.90	140.16	142.35	137;81	100.74	125.20	106.86		
BOD	92.67	93.74	94.12	82.75	84.05	82.57	59.48	73.92	80.31		
Ca	31.143	29.273	30,21	7.170	7.232	7.400	7.36	22.26	11.09	25	
Mg	15.572	14.636	15.10	3.585	3.616	3.605	3.68	11.131	9.27	20	
Fe	0.119	0.210	0.12	0.420	0.320	0.345	0.364	0.268	0.292	0.3	0.3
Cd	0.044	0.036	0.041	0.019	0.009	0.020	0.001	0.003	0.003	0.003	0.003
Cr	0.003	0.002	0.002	0.001	0.002	0.002	0.003	0.002	0.002	0.05	
Cu	0.100	0.019	0..067	0.032	0.024	0.030	0.043	0.010	0.035	1	2

Pb	0.032	0.024	0.028	0.00	0.010	0.001	0.003	0.006	0.004	0.01	0.01
∑Wi											0.9821
∑QiWi	0.0275	0.0351	0.0260	0.0316	0.0271	0.0283	0.0241	0.0283	0.0263		
WQI	**0.0275**	**0.0351**	**0.0260**	**0.0316**	**0.0271**	**0.0283**	**0.0241**	**0.0283**	**0.0263**		

3.1 **Results**

Results of the laboratory analysis of boreholes water from **Ovom, Yenibebel** and **Yenaka** communities and a summary of water quality index assessment based on the weighted Arithmetic water quality index are presented in Table 3.1

Table 3.1: Results of boreholes water quality analysis and summary of water quality index evaluation of water from Ovom, Yenibebel and Yenaka

The water quality characterization and rating of the drinking suitability of the water samples collected from Ovom, Yenibebel and Yenaka as per the weighted Arithmetic water quality index method are presented in Table 3.2

Table 3.2: Water Quality Rating as per Weight Arithmetic Water Quality Index Method of water samples from Ovom, Yenibebel and Yenaka.

WQI Value	**Grading**	**Rating of water quality**	**Communities**	**Rating of water quality of the various sampling points**		
0 – 25	A	Excellent water quality		Point 1	Point 2	Point 3
26 – 50	B	Good water quality	**Ovom**	Excellent water quality	Excellent water quality	Excellent water quality
51 – 75	C	Poor water quality	**Yenibebel**	Excellent water quality	Excellent water quality	Excellent water quality

76 – 100	D	Very poor water quality	Yenaka	Excellent water quality	Excellent water quality	Excellent water quality
Above 100	E	Unsuitable for drinking				

The results of the computation of the Heavy metal pollution index (HPI) of the boreholes water samples from Ovom, Yenibebel and Yenaka are presented in Table 3.3.

3.3: Heavy metal pollution index (HPI) of water samples from Ovome, Yenibebel and Yenaka

	Ovom			**Yenibebel**			**Yenaka**			$W_i = \frac{k}{Sn}$
	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3	
Mg	15.572	14.636	15.10	3.585	3.616	3.605	3.68	11.131	9.27	
Fe	0.119	0.210	0.12	0.420	0.320	0.345	0.364	0.268	0.292	0.007
Cd	0.044	0.036	0.041	0.019	0.009	0.020	0.001	0.003	0.003	0.7
Cr	0.003	0.002	0.002	0.001	0.002	0.002	0.003	0.002	0.002	0.042
Cu	0.100	0.019	0..067	0.032	0.024	0.030	0.043	0.010	0.035	0.0021
Pb	0.032	0.024	0.028	0.00	0.010	0.001	0.003	0.006	0.004	0.21
$\sum Wi)$										0.9821
$\sum Qi\ WI$	1,094.43	890.91	1,0159.30	444.40	231.92	469.75	30.74	83.40	79.26	
$\sum Qi\ WI / \sum WI$	1,137.54	926.01	1,055.95	462.95	241.06	488.25	31.95	86.69	82.38	
HPI	**1,094.43**	**890.91**	**1,0159.30**	**444.40**	**231.92**	**469.75**	**30.74**	**83.40**	**79.26**	

3.2 Discussions

The quantitative measure of water parameters are the determinants of water quality for human use. In this study, four physical, ten chemical and six heavy metals water quality parameters where analysed in water samples collected from nine boreholes randomly selected from Ovom, Yenibebel and Yenaka communities in Attisa Clan of Yenagoa metropolis the Bayelsa State capital. The physical parameters measured include; Electrical conductivity (EC), total dissolved solid (TDS), total suspended solid (TSS) and total hardness (TH). Chemical parameters analysed include; total alkalinity (TA), pH, Dissolved oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Chloride (Cl), Fluoride (F), Nitrate (NO_3), Phosphate

(PO_4), Sulphate (SO_4). Heavy metals analysed include; Calcium (Ca), Magnesium (Mg). Iron (Fe), Copper (Cu) Chromium (Cr), Cadmium (Cd) and Lead (Pb). The results of the analysis of the water quality parameters are presented in Table 3.1. The results indicate that the physical parameters measurements were lower than the limits set in the Nigeria standard quality for drinking water (NSDQW) and the world Health Organisation (WHO) standard, in all the sampling points. The EC measurement ranges between 144.0 and 579.0µscm$^{-1.}$ [1] .The TDS measurements ranges between72.0 mg/l and 289.50 mg/l. TH ranges between 39.0 and 140.0 mg/l. TSS ranges between 0.04mg//l and 0.07mg/l. pH, TA, Cl, F, NO_3, SO_4, PO_4, Mg, DO, COD and BOD in all the boreholes water analysed were also lower than the standard limit set by the Nigeria Drinking water quality standard. The pH measurements range between 6.10 and 8.0. The total alkalinity (TA) ranges between 60mg/l and 91.0mg/l. The Chloride (Cl) concentrations range between 10.0 mg/l and 58.mg/l. The Fluoride (F) measurements range between 0.80mg/l and 1.5mg/l.The nitrate
(NO_3) measurements range between, 0.123mg/l and 0.143mg/l. The sulphate (SO_3) measurements range between 2.52mg/l and 3.21mg/l. The Phosphate measurements range between, 1.20 mg/l and 2.64mg/l. The Dissolved Oxygen (DO) measurements range between, 2.76 mg/l and 4.51mg/l. The chemical Oxygen demand (COD) measurements range between 100.74 mg/l and 158.78mg/. The Biochemical Oxygen demand (BOD) measurements range between 59.48mg/l and 94.12 mg/l. Ca range between 7.170 mg/l and 31.14 mg/l.
The results of the heavy metals analysis are presented in Table 3.2. The results indicated that Mg concentration range between 3.585 mg/l and 15.57 mg/l, Fe range between 0.119mg/l and 0.420 mg/l, Cd range between 0.001 mg/l and 0.044 mg/l, Cr range between 0.001mg/l and 0.003 mg/l, Cu range between0.010 mg/l and 0.10 mg/l. While Pb range between 0.00 mg/l and 0.032 mg/l. These results show that Cd concentration exceeded the recommended limit. Followed by Pb. The results of heavy metals analysis of the study varies with that reported by Tariwari (2015) who reported heavy metals concentration higher than Nigeria standard and WHO limits, in Epie Communities. However the results of the study agree with the results of (Agbalagba *et al*., 2011). The results also aligned with Egbo and Eremasi (2022) who conducted similar studies in Epie Communities.
Heavy metal pollution index (HPI) evaluation for borehole water in all the sampled locations in (Ovom, Yenibebel and Yenaka) indicate that (Ovom has HPI of **1,094.43**, **890.91** and **1,0159.30** at points 1, 2, and 3 respectively, showing they are all above the critical value of 100.The results also show that water sampled from Yenibebel have HPI values of**444.40**, **231.92** and **469.75** at points 1, 2 and 3 respectively. Waters samples from Yenaka have HPI of **30.74**, **83.40** and **79.26** at points 1, 2 and 3 respectively. These results indicate that all the boreholes water samples from Ovom and Yenibebel are unsafe for drinking with respect to heavy metals pollution. While the samples collected from Yenaka all have HPI lower than the critical value of (100) meaning they are all safe for drinking The higher HPI recorded at Ovom and Yenibebel are due to impact of Cadmium which exceeded the limit in these two communities. The results of HPI evaluation in Ovom and Yenibebel are significantly higher than the results reported by (Alagoa and Eguakun, 2020). Egbo and Eremasi, (2022a) and Egbo and Eremasi, (2022b) who reported HPI of (107.51, 41.43, 56.25 and 157.41, 72.00, 159.06, in Akenfa and Agudama-Epie respectively. 30.01, 49.49, 25.93 and 100.26, 235.90, 51.20 in Akenpai and Edepie respectively.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 **Conclusions**

Physicochemical and biological characteristic are key indices for measuring the quality of water for human consumption. The physicochemical measurements obtained in this study followed by the water quality index evaluation is a clear indication that boreholes water sampled from Ovom, Yenibebel and Yenaka communities have excellent qualities for drinking. However, heavy metals pollution index (HPI) evaluation indicates that the water samples collected from Ovom and Yenibebel are not safe for drinking due to high Cadmium concentration. The waters from Yenaka are good and safe for human consumption.

4.2 **Recommendations**

The researchers recommend that private boreholes water quality should be monitored regularly to detect any variation from the recommended standard with view to protecting public health and wellbeing. Water Boreholes owners in Bayelsa State should up scale their water treatment process with view to reducing the Cadmium concentration in order to protect public health.

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