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Impacts of Sewage Wastewater on Groundwater Quality and Health Risk in Makoko, Lagos, Nigeria

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ABSTRACT

This research assessed the groundwater quality in a range of shallow wells and boreholes in the Makoko community. A combined eight water samples were gathered from these origins, and their pH, electrical conductivity (EC), total dissolved solids (TDS), hardness, chloride content, and heavy metals (Cr, Cu, Fe, Pb, and Zn) were examined. The collected data underwent statistical analysis and were compared to the established criteria of the World Health Organization (WHO-2017) and the Nigerian Standard for Drinking Water Quality (NSDWQ-2007). The results showed higher levels of EC, TDS, chloride, iron (Fe), and zinc (Zn) in some shallow wells than in boreholes, exceeding acceptable limits set by WHO and NSDWQ. Significantly elevated EC and TDS levels were observed in sewage wastewater from shallow wells, indicating a substantial amount of contamination in the groundwater. Lack of sewage systems infrastructures and unmonitored wastewater discharge into waterways are causing increased groundwater pollution, as highlighted by the findings. This presents a significant danger to both the health of people and their surroundings. It is essential for the community to work together to prevent inappropriate sewage disposal, as the government needs to prioritize implementing efficient sewage waste management practices and ensuring proper monitoring, particularly in areas with bad sewage systems infrastructures.

Keywords: Physiochemical parameters; Heavy metals; Sewage; Wastewater; Water quality standards; Water pollution; Sewage waste management; Human health; Shallow wells; Boreholes; Makoko.

1. Introduction

Uncontaminated natural groundwater can still be found in numerous regions worldwide. Nonetheless, recent research indicates that human activities have heightened the chance of groundwater pollution. These actions have changed the characteristics of groundwater, making it difficult to fulfil users' requirements. Normally, septic systems receive sewage that consists of waste from toilets (39%), laundry (20%), bathing (25%), and kitchen sinks (16%) [1]. Traditional septic tanks are created to handle sewage that includes bacteria, viruses, nitrates, inorganic substances, and different organic compounds [2,3]. A notable danger occurs when raw sewage seeps into the ground or pollutes surface water during flooding or leaching. Water is crucial for maintaining life and promoting good health [4]. Urban development and industrial growth have caused contamination of shared water sources like surface water and rainwater due to waste produced by industries and pollutants from homes. As a result, groundwater has emerged as an essential supply of fresh water [4]. Nevertheless, it has slowly become contaminated over the years due to different factors. Pollution can manifest in solid, liquid, or gaseous forms, and liquid pollutants are especially worrying due to their ability to easily seep into and spread through the soil to reach aquifers. Factors like the subsurface's geological composition, porosity, and permeability impact the magnitude of groundwater pollution. Septic systems depend on anaerobic bacteria to break down or convert the waste in the tank [5,6]. Groundwater contamination can happen when sewage effluents circumvent the earth's natural geological filters and other adsorption mechanisms. If untreated household wastewater is not effectively controlled by authorities, it can create serious health dangers for the public [7]. Traditional septic tanks have been discovered to discharge concerning amounts of biological pollutants, including Total Heterotrophic Bacteria (THB), Fecal Coliform Bacteria (FCB), Total Coliform Bacteria (TCB), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD) [8]. Furthermore, heavy metals are frequently found in wastewater, such as copper (Cu), cadmium (Cd), chromium (Cr), mercury (Hg), iron (Fe), zinc (Zn), molybdenum (Mo), vanadium (V), manganese (Mn), and boron (Bo) [9]. Individual household sewage systems, including septic tanks, soakaways, cesspools, and sewerage systems, are frequently utilized in various underdeveloped and developing nations for the disposal of domestic wastewater [10]. But the quality of groundwater could be greatly affected by the release of household sewage into these systems, causing contamination from both organic and inorganic sources [11]. The aims of this research are to evaluate how sewage wastewater impacts groundwater sources in the Makoko community, Lagos State, through analysing physical and chemical properties as well as levels of heavy metals. The results will offer important insights to leaders and stakeholders in Makoko, helping them to put in place preventive measures to avoid possible waterborne disease outbreaks.

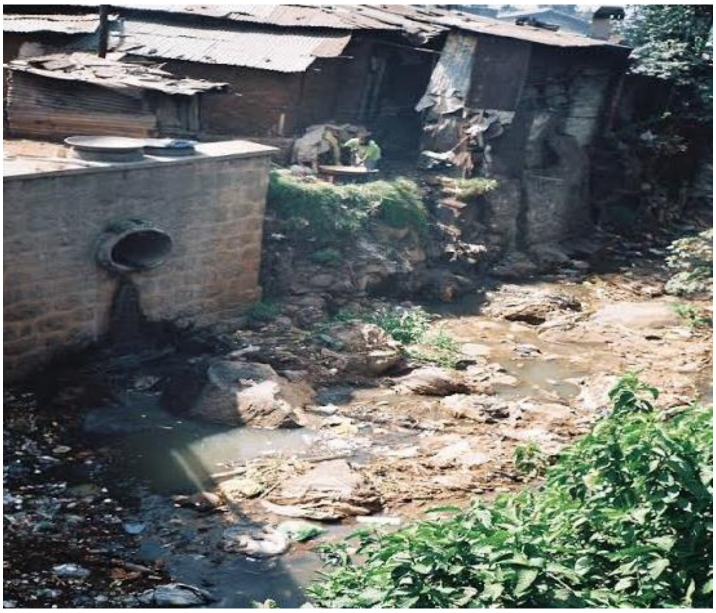

Figure 1. Example of septic tank

1.1. Study Objectives

1. To assess pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), hardness, chloride content, and heavy metals (Cr, Cu, Fe, Pb, Zn) in groundwater samples from shallow wells and boreholes in Makoko.

2. To analyze and compare the results against the World Health Organization (WHO-2017) and Nigerian Standard for Drinking Water Quality (NSDWQ-2007) to determine compliance.

3. To determine the presence and concentration of contaminants and identify trends or anomalies to pinpoint potential sources of contamination, with a focus on differences between shallow wells and boreholes.

4. To investigate the effect of sewage wastewater on groundwater quality, particularly by examining EC and TDS levels in shallow wells to identify contamination patterns linked to sewage discharge.

5. To examine the implications of contamination levels on human health and the environment, emphasizing the role of inadequate waste management practices and improper sewage disposal.

6. To recommend strategies to improve groundwater quality, including community initiatives to prevent improper sewage disposal and government actions for better waste management and sewage infrastructure development.

1.2. Literature Review

Ogunlaja et al. [12] evaluate the impact of sewage pollution on groundwater quality in urban Nigeria, focusing on contamination levels and implications for public health.

Akinbile et al. [13] investigate the effects of sewage effluents on groundwater quality in Ilorin, examining specific pollutants and their concentration levels.

Adewale et al. [14] analyze groundwater contamination due to domestic sewage, highlighting the environmental and health impacts in southwestern Nigeria.

Onyemelukwe et al. [15] assess how different methods of sewage disposal affect groundwater resources in Enugu State, focusing on pollution sources and mitigation strategies.

Akinlua et al. [16] provide a detailed assessment of how sewage pollution affects groundwater in Lagos, considering both microbial and chemical contaminants.

Ali et al. [17] explore the impact of sewage pollution on groundwater quality in Abuja, with a focus on health risks associated with contaminated water.

1.3. The Study Area

Makoko is a historic and densely populated informal settlement located on the northern edge of the Lagos Lagoon in Yaba, Lagos, Nigeria. This vibrant community is situated at approximately latitude 6^{0}49’47’’ N and longitude 3^{0}38’65’’ E (Figure 2).

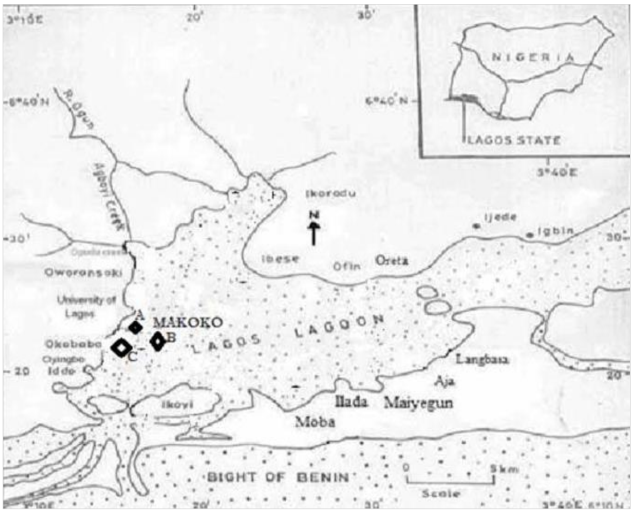

Figure 2. Geological map of the study area

The study area is known for its unique stilt houses and bustling waterways. Makoko presents a complex interaction between human habitation and the coastal environment. Makoko is part of the coastal plain of Lagos, characterized by low-lying, flat terrain that is typical of coastal environments. Makoko, located just above sea level, is susceptible to flooding due to its flat topography and geological setting, rooted in the Lagos Basin. The soils are primarily sandy and silty, with organic matter in areas closer to the lagoon. Makoko's hydrogeology is influenced by its proximity to the Lagos lagoon and coastal dynamics. The shallow water table and flat topography contribute to waterlogging and flooding, especially during rainy seasons and high tides. Groundwater in Makoko is often brackish due to saltwater intrusion, posing challenges for residents who rely on shallow wells and surface water from the lagoon. The active interaction between groundwater and surface water also increases the risk of waterborne diseases and health problems. The community's limited availability of public utilities further complicates access to clean, potable water.

2. Material and Method

Prior to taking samples, the depth of the groundwater and the bottom of the shallow well were determined using a clean dipping meter to avoid any contamination between different wells or boreholes. Samples of groundwater were gathered in sterilized 75-cl plastic bottles in order to prevent contamination. The samples were correctly labeled, refrigerated, and tested within three hours of being collected in order to stay within the laboratory's specified time limit for preserving sample integrity [18]. Samples were obtained from point-of-use taps for the boreholes and collected using a plastic fetcher until all physico-chemical parameters stabilized for the well. Sterile sample bottles were utilized for the purposes of direct sampling. TDS, hardness, and EC were measured on site at every sampling point. The testing was done at the Water Quality Laboratory at Geoearth Project Limited, with total coliform analysis performed at the microbiology laboratory. Moreover, the samples were examined for levels of various heavy metals, such as iron, copper, chromium, lead, and zinc. The standards of water quality assessment were based on the NSDWQ [19] and guidelines from the WHO [20].

3. Results

Tables 1-2 and Figures 3-5 presented below showcase the analysis of descriptive statistics and summarization of the measured parameters for water quality.

The shallow well water has a pH range of 4.81 to 7.91, with an average value of 6.16. Likewise, boreholes have pH values ranging from 6.71 to 7.25, with an average of 7.00, which falls within the recommended ranges by WHO (6.10–8.0) and NSDWQ (6.5–8.5).

Tables 1-2 display the range of minimum and maximum EC values for shallow wells, which vary from 1081 to 1690 uS/cm with an average of 1309.63 uS/cm; for total dissolved solids (550 mg/L to 821 mg/L with an average of 651.88 mg/L); for hardness (80 mg/L to 210 mg/L with an average of 141.13 mg/L); for chloride (232 mg/L to 1180 mg/L with an average of 540.25 mg/L); whereas boreholes range from (150 uS/cm to 1181 uS/cm with an average of 775.88 uS/cm); (450 mg/L to 710 mg/L with an average of 589.5 mg/L); (57 mg/L to 113 mg/L with an average of 85 mg/L); and (140 mg/L to 341 mg/L with an average of 220.5 mg/L), respectively.

Table 1. Physiochemical and Heavy metal data of Shallow well in the study area

Samples	pH	EC (uS/cm)	TDS (mg/L)	Hardness (mg/L)	Cl (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Zn (mg/L)
MA_1	5.72	1120	614	210	280	0.016	0.91	0.31	0.0014	2.22
MA_2	6.02	1320	550	130	302	0.022	0.54	0.23	0.0031	3.11
MA_3	6.21	1081	588	80	232	0.041	0.73	0.39	0.0045	2.82

MA_4	6.95	1440	701	168	271	0.052	0.85	0.19	0.0019	3.08
MA_5	4.81	1150	821	172	1180	0.049	0.34	0.28	0.0028	2.59
MA_6	5.55	1231	660	90	1091	0.056	0.79	0.25	0.0029	2.34
MA_7	6.85	1690	682	159	520	0.045	0.98	0.36	0.0061	2.59
MA_8	7.19	1445	599	120	446	0.039	0.49	0.19	0.0079	1.6
Minimum	4.81	1081	550	80	232	0.016	0.34	0.19	0.0014	1.6
Maximum	7.19	1690	821	210	1180	0.056	0.98	0.39	0.0079	3.11
Mean	6.16	1309.63	651.88	141.13	540.25	0.040	0.70	0.28	0.0038	2.54
NSDWQ	6.5-8.5	1000	500	150	250	0.05	1	0.3	0.01	3
WHO	6.10-8.0	900	500	NV	NV	0.05	2	0.3	0.01	15

Table 2. Physiochemical and Heavy metal data of Boreholes in the study area

Samples	pH	EC (uS/cm)	TDS (mg/L)	Hardness (mg/L)	Cl (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Zn (mg/L)
MA_1	6.71	150	610	110	170	0.02	0.31	0.21	0.0012	1.92
MA_2	6.82	320	450	98	210	0.012	0.44	0.11	0.0022	2.11
MA_3	7.01	1181	513	80	232	0.031	0.76	0.09	0.0015	2.72
MA_4	7.05	840	630	73	190	0.022	0.65	0.29	0.0019	1.88
MA_5	6.91	750	710	84	321	0.041	0.88	0.18	0.0026	2.28
MA_6	7.25	1031	520	65	341	0.016	0.73	0.22	0.0049	2.33
MA_7	7.15	890	602	57	160	0.025	0.91	0.26	0.0081	2.91
MA_8	7.09	1045	681	113	140	0.033	0.29	0.17	0.0072	1.98
Minimum	6.71	150	450	57	140	0.012	0.29	0.09	0.0012	1.88
Maximum	7.25	1181	710	113	341	0.041	0.91	0.29	0.0081	2.91
Mean	7	775.88	589.5	85	220.5	0.025	0.62	0.19	0.0037	2.27
NSDWQ	6.5-8.5	1000	500	150	250	0.05	1	0.3	0.01	3
WHO	6.10-8.0	900	500	NV	NV	0.05	2	0.3	0.01	15

Tables 1 and 2 display the results of the analysis of heavy metals in shallow well and boreholes. Fe concentrations in shallow well water vary from 0.19 mg/L to 0.39 mg/L, while Zn concentrations range from 0.16 to 3.11 mg/L. In boreholes, Fe levels range from 0.09 mg/L to 0.29 mg/L, and Zn levels range from 1.88 mg/L to 2.91 mg/L. These values can be compared to the NSDWQ standards of 0.03 mg/L for Fe and 3.00 mg/L for Zn, as well as the WHO standards of 0.30 mg/L for Fe and 15 mg/L for Zn.

4. Discussion

The mean pH values of shallow well-water and boreholes indicate slightly acidic concentrations in comparison to the standards set by WHO and NSDWQ. Slightly acidic, it falls within WHO water quality standards but exceeds NSDWQ limits in Tables 1 and 2. The EC, TDS, Hardness, and Chloride levels in shallow well water exceed the allowable limits set by both WHO and NSDWQ standards, indicating contamination in the community's water

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resources due to increased dissolved ions (Table 1). Additionally, the elevated chloride levels in the groundwater quality imply pollution from sources such as the lagoon and sewage wastewater [21]. This also enhances the possibility of water corrosion, impacting the quality of drinking water and ultimately impacting mortality rates and aquatic plants and animals due to acidification of the surrounding well water. The chloride level in borehole water may indicate a higher level of control measures during drilling compared to shallow well water in the study area. Nonetheless, the EC and TDS levels in the Makoko shallow well water samples exceed the accepted limits set by the NSDWQ (1000) and WHO (500) with readings of 1309.63 u S/mg and 651.88 mg/L, respectively (Table 1). This indicates a certain degree of pollution in the quality of groundwater.

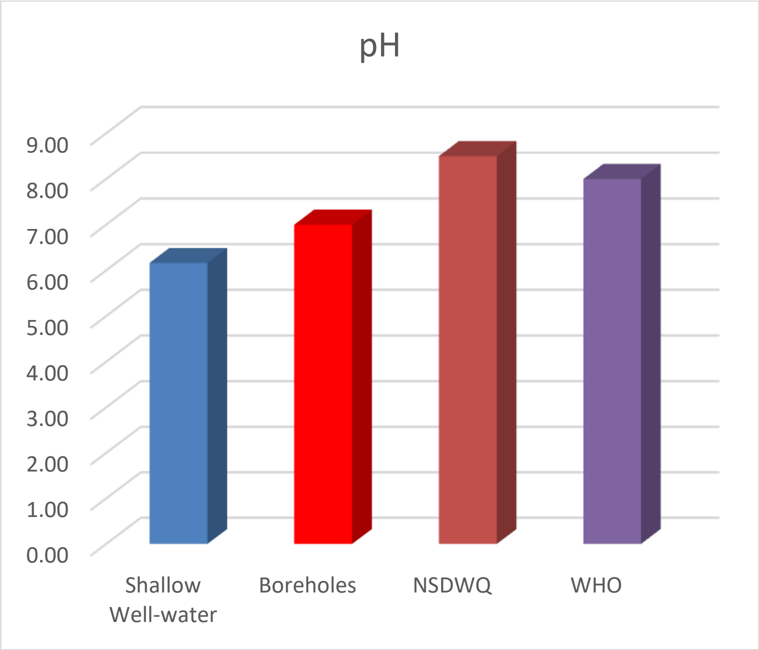

Figure 3. Mean pH of Shallow wells and Boreholes of the Study area

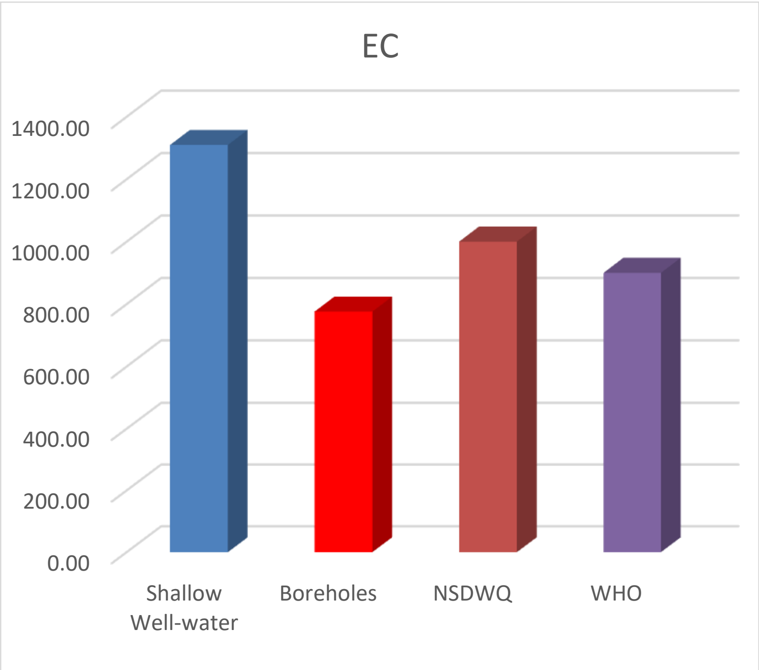

Figure 4. Mean EC of Shallow wells and Boreholes of the Study area

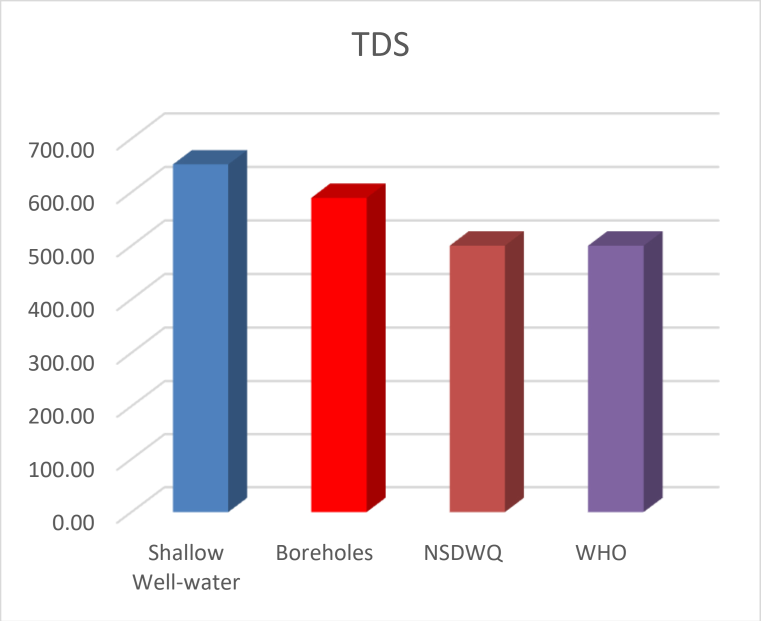

Figure 5. Mean TDS of Shallow wells and Boreholes of the Study area

The research also found small amounts of heavy metal pollution (iron and zinc) in the water from a few shallow wells in the Makoko community when compared to the water from boreholes. Based on Figure 6 and Tables 1-2, iron (Fe) and zinc (Zn) levels were elevated in shallow well-water compared to other heavy metals, notably in boreholes, surpassing acceptable thresholds [22]. This shows that the shallow wells in Makoko have groundwater that is not safe for drinking [23]. The contamination is probably coming from being close to the lagoon and runoff from the surface, potentially endangering public health.

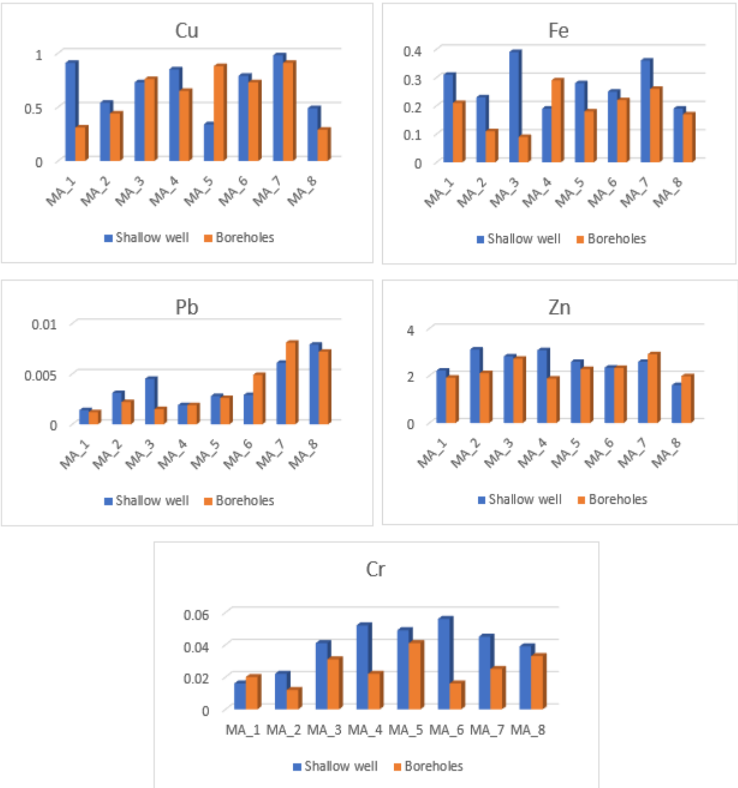

Figure 6. Comparison of Heavy Metals for both shallow wells and boreholes

5. Conclusion

Groundwater sources are increasingly at risk from different pollutants caused by uncontrolled discharge of sewage and possibly stormwater runoff, which could harm the quality of drinking water and pose a threat to the progress made in improving access to drinking water worldwide. The physico-chemical parameters in borehole water samples in Makoko community are mostly in line with WHO and NSDWQ standards, with only the EC levels (MA_3, MA_6, and MA_8 with 1181 uS/cm, 1031 uS/cm, and 1045 uS/cm, respectively) showing significant deviation. TDS levels also deviate significantly, except for MA_3 with 450 mg/L. Nevertheless, certain concentrations of the physico-chemical parameters were discovered to be elevated in shallow wells compared to boreholes, particularly in EC, TDS, and chloride levels. Some possible reasons for that observation could include the untreated sewage waste amount and proximity to a lagoon.

The elevated chloride levels in groundwater quality indicate contamination from sewage sources. This also enhances the water's potential to corrode, resulting in poor drinking water quality, which ultimately impacts mortality rates and aquatic life due to water acidification in the vicinity. The pH levels found in the groundwater samples from the research sites indicate slightly acidic levels in their natural state. This could be explained by the dense population in the areas being studied. An additional source of groundwater pollution can come from the presence of heavy metals (iron and zinc) in certain Makoko shallow wells. This research shows that inadequate, well-designed, eco-friendly sewage systems and uncontrolled discharge of sewage into water bodies can result in severe groundwater pollution, endangering both human health and the environment. This means that both community residents and the government must work together to prevent random dumping and sewage inflow and to ensure proper sewage management and monitoring in poorly constructed areas.

Groundwater sources are increasingly threatened by contaminants from unchecked sewage discharge and stormwater runoff, compromising drinking water quality and hindering global efforts to ensure safe water access. In the Makoko community, the lack of proper sewage systems has led to significant groundwater contamination with pollutants like chloride and heavy metals.

6. Future Recommendations

To address these issues, it's crucial to consider the following for future prospects:

1. Improve sewage waste management by developing modern, environmentally friendly systems that treat wastewater effectively.

2. Implement robust monitoring and regulatory frameworks to track contamination, enforce standards, and prevent illegal dumping.

3. Upgrade and expand sewage infrastructure, particularly in vulnerable areas near sensitive environments like lagoons, to prevent overloading and better handle contaminants.

4. Educate residents on the importance of proper sanitation practices, waste disposal, and water conservation to foster behavior change and increase public participation in protecting groundwater sources.

5. Establish small-scale, localized sewage treatment plants in densely populated areas to reduce pressure on

centralized systems and treat wastewater more effectively before discharge.

6. Engage private sector partners in funding and implementing sewage infrastructure projects, fostering innovation, and improving the quality of wastewater management services.

These steps, supported by collaboration among authorities, communities, and stakeholders, are essential for protecting groundwater quality, safeguarding public health, and preserving the environment.

Declarations

Source of Funding

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Competing Interest and Ethics

The authors declare no competing financial, professional, or personal interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contributions

Both the authors took part in literature review, research, and manuscript writing equally.

Availability of data and material

Supplementary information is available from the corresponding author upon reasonable request.

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