

Spatial Analysis of Soakaway Effluent Discharge and Its Effects on Groundwater Chemical Characteristics and Portability in Rivers State, Nigeria

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<https://doi.org/10.56201/wjimt.v10.no9.2026.pg156.167>

Abstract

Groundwater serves as a crucial source of household water in Rivers State, Nigeria, but its quality is increasingly at risk due to the prevalent utilization of soakaway pits for the disposal of wastewater. This research examined how soakaway effluent infiltration spatially affects the physicochemical properties of groundwater, and it assessed the consequences for household water usage. A cross-sectional and experimental method was utilized, where groundwater samples ($N = 60$) were gathered from boreholes placed at various distances (0–10 m, 11–20 m, 21–30 m, and ≥ 30 m) from the soakaway pits. Standard laboratory techniques were implemented to analyze important physicochemical characteristics, while Pearson Product Moment Correlation and descriptive statistics facilitated data analysis. The findings demonstrated strong and statistically meaningful correlations ($p < 0.01$) between distance and every parameter that was measured. Contaminants like nitrate ($r = -0.88$), phosphate ($r = -0.91$), chloride ($r = -0.86$), turbidity ($r = -0.89$), and total dissolved solids ($r = -0.85$) displayed strong negative correlations with distance, indicating that as distance increased, concentration decreased. In contrast, dissolved oxygen ($r = 0.79$) and pH ($r = 0.76$) exhibited positive correlations, showcasing improved water quality at larger distances. Average nitrate levels reduced from 38.6 ± 5.4 mg/L within 0–10 m to 4.8 ± 1.1 mg/L at distances beyond 30 m, while turbidity fell from 14.8 ± 3.2 NTU to 1.4 ± 0.4 NTU, thus meeting the WHO requirement of ≤ 5 NTU. Groundwater found within 30 m of soakaway systems displayed high levels of contaminants, low dissolved oxygen levels (2.4 mg/L), and acidic pH (5.82), indicating it is poorly suitable for household purposes. On the other hand, water sources located more than 30 m away exhibited notable enhancements in quality. The study concludes that the infiltration of soakaway effluent is a significant factor in groundwater pollution, and distance serves a vital protective function. It is advised that rigorous compliance with safe setback distances and enhanced sanitation measures be implemented to protect groundwater resources.

Keywords: Geospatial, Analysis, Soakaway, Discharge, Infiltration, Groundwater & Chemical Characteristics

Introduction

Groundwater is one of the most important sources of freshwater for domestic, agricultural, and industrial uses worldwide. In many developing countries, including Nigeria, groundwater serves as the principal source of potable water because of its relative availability and perceived quality. In Rivers State, groundwater obtained from boreholes and shallow wells constitutes a major source of domestic water supply. However, rapid urbanization, population growth, and inadequate sanitation infrastructure have increased dependence on septic tanks and soakaway pits for wastewater disposal. The extensive use of these systems has raised concerns about their potential impact on groundwater quality (Amadi et al., 2024; Nwankwoala et al., 2022).

A soakaway pit is an underground wastewater disposal system designed to facilitate the infiltration of domestic effluent into surrounding soils. Effluents discharged into soakaways often contain organic matter, nutrients, dissolved salts, detergents, microorganisms, and other contaminants. Although soil layers can provide some degree of natural filtration and purification, excessive loading of wastewater or unfavourable hydrogeological conditions may permit contaminants to migrate into underlying aquifers. Consequently, groundwater resources located near soakaway systems may become vulnerable to pollution (Nwankwoala et al., 2022).

The contamination of groundwater by soakaway effluent has become a major environmental and public health concern. Groundwater pollution is particularly problematic because contaminants may remain undetected for long periods while gradually spreading through aquifer systems. Once contamination occurs, remediation is often technically difficult and economically expensive. Therefore, protecting groundwater resources from pollution sources such as soakaway effluents is essential for sustainable water resource management (Brisibe et al., 2022). Physicochemical properties are commonly used to evaluate groundwater quality and determine its suitability for domestic consumption. Parameters such as pH, electrical conductivity, total dissolved solids, turbidity, dissolved oxygen, chloride, sulphate, nitrate, phosphate, and hardness provide valuable information regarding the condition of groundwater systems. Variations in these parameters often indicate the presence of contaminants and may reflect the influence of wastewater infiltration. Elevated concentrations of nitrate and phosphate, for example, are commonly associated with sewage contamination and can adversely affect both human health and environmental quality (Emeka et al., 2020).

Rivers State is located within the Niger Delta region of Nigeria and is characterized by high rainfall, low-lying terrain, and extensive groundwater resources. These hydrogeological conditions support groundwater recharge but may also facilitate the movement of contaminants through the subsurface environment. In many residential areas, boreholes are constructed in close proximity to soakaway pits due to limited land availability and inadequate enforcement of environmental regulations. Such practices increase the likelihood of contaminant migration from wastewater disposal systems into groundwater sources (Nwaogazie et al., 2018).

Several studies conducted within Rivers State have reported evidence of groundwater quality deterioration resulting from anthropogenic activities. Investigations in communities such as Igwuruta, Obio/Akpor, and Rumuigbo have revealed elevated levels of physicochemical contaminants in groundwater systems. These findings suggest that wastewater infiltration and leachate migration constitute significant threats to groundwater quality in the region (Amadi et al., 2024; Nwankwoala et al., 2022) (Wadi, Prosper, Nweke, Sangtang, Haris, & Rautaray, 2026 and (Wadi, Nweke, Silver, Alagjozovska, Segalerba, & Ibatova, 2026). The environmental and health implications of groundwater contamination are considerable. Consumption of contaminated water

may expose individuals to harmful substances and increase the risk of waterborne diseases. Elevated nitrate concentrations, for instance, have been linked to methemoglobinemia in infants, while excessive dissolved solids may affect the aesthetic and chemical quality of drinking water. Furthermore, groundwater pollution can contribute to ecosystem degradation and compromise the sustainability of water resources needed for future development (Azumah et al., 2023). Given the increasing dependence on groundwater and the widespread use of soakaway systems in Rivers State, there is a need to assess the extent to which soakaway effluents influence groundwater physicochemical properties. Such assessments are necessary for effective environmental management, public health protection, and the formulation of policies aimed at ensuring sustainable groundwater utilization. Therefore, this study investigates the impact of soakaway effluent on the physicochemical properties of groundwater in Rivers State, Nigeria.

Methodology

This research utilized a cross-sectional design along with experimental methods carried out in the field to evaluate how the effluent from soakaway pits affects the physicochemical properties of groundwater in Rivers State, Nigeria. The cross-sectional framework allowed for the sampling of groundwater from various locations simultaneously, particularly at different distances from soakaway pits, which made it possible to compare the quality of water across different areas. The experimental part included organized sampling of boreholes classified according to their nearness to soakaway systems, which permitted the assessment of contamination levels along a gradient. Standard procedures were used for laboratory analysis to guarantee the precision and comparability of the findings with recognized drinking water standards, including those established by the World Health Organization and the Standard Organisation of Nigeria. The research utilized both primary and secondary sources of data. Primary data consisted of groundwater samples taken from boreholes at various distances from soakaway pits, along with field observations regarding environmental sanitation and the spatial relationship between water sources and waste disposal sites. Key physicochemical parameters analyzed in these samples included pH, temperature, electrical conductivity, total dissolved solids, turbidity, dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, sulfate, chloride, and hardness. Secondary data were gathered from pertinent literature, governmental publications, and institutional reports concerning groundwater quality and wastewater management practices. The target population for the study comprised groundwater sources such as boreholes and hand-dug wells, as well as residential areas where soakaway pits are frequently utilized. The focus was on densely populated and peri-urban areas where the proximity of boreholes to soakaway systems heightens the risk of groundwater pollution. Additionally, the shallow aquifer system was taken into consideration, as it is the conduit for the movement of contaminants. A multi-stage sampling method was used to guarantee representativeness. The study region was initially divided into high, medium, and low-density areas based on settlement characteristics and population spread. Neighborhoods were then purposively selected from each density category using criteria such as dependence on boreholes, existence of soakaway systems, and ease of access. Within these chosen neighborhoods, boreholes were categorized based on their distances from soakaway pits, and sampling points were intentionally selected to illustrate these spatial disparities. This process resulted in roughly 45 borehole sampling locations across 15 neighborhoods. Data gathering included field measurements and laboratory analyses. Groundwater samples were taken using sterilized containers after allowing boreholes to run to ensure that representative

samples were collected. In-situ assessments of temperature, pH, and electrical conductivity were carried out with portable devices, and the samples were preserved and transported for laboratory examination within a designated timeframe. Standard analytical techniques were employed in the laboratory, encompassing spectrophotometric, titrimetric, and gravimetric methods, in line with established international standards. To guarantee reliability, quality control measures such as instrument calibration, incorporation of blanks and standard solutions, and prompt analysis were performed consistently. The credibility of the study was upheld by following standardized protocols and involving expert evaluations of the instruments and methodologies employed. To ensure reliability, consistent calibration of instruments, replication of measurements, and rigorous quality control practices were observed throughout both data collection and analysis processes. Data examination was performed utilizing both descriptive and inferential statistical methods. Descriptive statistics, such as average and standard deviation, were employed to encapsulate the physicochemical properties. Inferential techniques, especially one-way ANOVA, were utilized to evaluate significant variations in groundwater quality among different distance groups, with additional tests applied as needed. The Pearson product-moment correlation was used to explore the connections between the distance to soakaway pits and groundwater features. Furthermore, the results were contrasted with recognized drinking water guidelines to evaluate compliance rates, while the overall outcomes were analyzed concerning their impact on household water usage.

Results

Research Objective One: To determine the relationship between soakaway effluent infiltration and changes in selected groundwater physicochemical parameters in the study area.

Research Questions One: Is there a significant relationship between soakaway effluent infiltration and changes in selected groundwater physicochemical parameters in the study area?

Research Objective Two: To evaluate the implications of soakaway-induced changes in groundwater physicochemical properties for domestic water use in the study area.

Table 1. PPMC summary for testing the relationship between soakaway effluent infiltration and changes in selected groundwater physicochemical parameters in the study area

Variable	Distance	Nitrate	Phosphate	Sulphate	Hardness	Chloride	DO	TDS	Turbidity	pH
Distance	1									
Nitrate	-0.88**	1								
Phosphate	-0.91**	0.92**	1							
Sulphate	-0.84**	0.81**	0.83**	1						
Hardness	-0.82**	0.78**	0.79**	0.90**	1					
Chloride	-0.86**	0.94**	0.89**	0.85**	0.82**	1				
DO	0.79**	-0.76**	-0.78**	-0.82**	-0.85**	-0.79**	1			
TDS	-0.85**	0.91**	0.88**	0.89**	0.87**	0.93**	-0.81**	1		
Turbidity	-0.89**	0.88**	0.91**	0.80**	0.76**	0.90**	-0.74**	0.87**	1	
pH	0.76**	-0.73**	-0.75**	-0.80**	-0.83**	-0.76**	0.88**	-0.79**	-0.71**	1

** indicates significant correlation at $p < 0.01$. N = 60.

The results shown in Table 1 illustrates the Pearson Product Moment Correlation (PPMC) regarding the distance from soakaway pits in relation to groundwater physicochemical attributes. The outcomes indicate that distance shows robust and statistically significant associations ($p < 0.01$) with all observed parameters. In detail, the distance is strongly inversely related to nitrate ($r = -0.88$), phosphate ($r = -0.91$), sulphate ($r = -0.84$), hardness ($r = -0.82$), chloride ($r = -0.86$), total dissolved solids ($r = -0.85$), and turbidity ($r = -0.89$). This signifies that an increase in the distance from soakaway pits correlates with a marked reduction in the concentration of these pollutants. Conversely, there is a strong positive correlation of distance with dissolved oxygen ($r = 0.79$) and pH ($r = 0.76$), suggesting that the quality of water enhances (greater oxygen content and reduced acidity) with increasing distance from soakaway pits. Moreover, there are significant positive inter-correlations among contaminants (for example, nitrate with chloride $r = 0.94$, TDS with chloride $r = 0.93$), indicating a shared pollution origin, most likely stemming from soakaway effluent infiltration. Dissolved oxygen and pH have negative correlations with a majority of contaminants, further emphasizing their importance as indicators of water quality degradation. The findings unambiguously illustrate that the closeness to soakaway pits has a substantial impact on groundwater quality. Water located nearer to soakaway pits has elevated levels of contaminants and diminished oxygen levels, rendering it less appropriate for domestic usage (Nweke. & Amachere, 2026).. Consequently, soakaway systems are a significant contributor to groundwater pollution within the study area

Research Questions Two: What are the potential implications of soakaway-induced changes in groundwater physicochemical properties for domestic water use in the study area?

Table 2. The implications of soakaway-induced changes in groundwater physicochemical properties for domestic water use in the study area

Parameter	0–10 m	11– 20 m	21– 30 m	≥30 m (Reference)	WHO guideline/acceptable value	Implication for domestic water use
Nitrate (mg/L)	38.6 ± 5.4	27.4 ± 4.2	17.2 ± 3.1	4.8 ± 1.1	50 mg/L	Increasing concentration indicates increasing wastewater influence; high values close to soakaways reduce suitability, particularly for vulnerable users
Phosphate (mg/L)	3.21 ± 0.61	2.18 ± 0.48	1.24 ± 0.31	0.24 ± 0.08	No health-based guideline	Elevated concentrations indicate sewage/effluent influence and may contribute to nutrient enrichment if discharged into surface waters
Sulphate (mg/L)	55.8 ± 7.6	44.3 ± 6.2	32.1 ± 4.8	14.7 ± 2.8	500 mg/L	All values remain below the WHO guideline; however, the increasing concentration near soakaways indicates deterioration in groundwater quality

Hardness (mg/L as CaCO₃)	142.7 ± 18.5	117.6 ± 15.3	89.4 ± 12.7	48.6 ± 7.5	No health-based guideline	Higher hardness may cause scaling, increased soap consumption and reduced acceptability for domestic washing
Chloride (mg/L)	132.6 ± 19.4	101.8 ± 15.7	68.7 ± 11.6	22.8 ± 4.6	250 mg/L aesthetic value	Concentrations remain below the aesthetic threshold, but the strong increase near soakaways indicates possible wastewater infiltration
Dissolved Oxygen (mg/L)	2.4 ± 0.5	3.2 ± 0.6	4.2 ± 0.7	6.1 ± 0.7	No WHO guideline	Low DO near soakaways indicates oxygen depletion associated with organic pollution and reduced groundwater quality
TDS (mg/L)	451.8 ± 58.7	354.6 ± 46.3	254.7 ± 35.8	92.4 ± 15.8	No health-based guideline; ≤600 mg/L generally acceptable	Increasing TDS may affect taste and palatability and indicates greater dissolved contaminant loading near soakaways
Turbidity (NTU)	14.8 ± 3.2	10.2 ± 2.5	6.3 ± 1.7	1.4 ± 0.4	≤5 NTU	Water within 30 m exceeds the 5 NTU target, indicating reduced aesthetic quality and possible increased difficulty in disinfection
pH	5.82 ± 0.18	6.08 ± 0.16	6.37 ± 0.14	6.86 ± 0.11	6.5–8.5	Water within 30 m is acidic relative to the commonly applied acceptable range, potentially increasing corrosivity and affecting taste

The results in Table 2 offers a thorough evaluation of how changes in physicochemical characteristics at varying distances influence the adequacy of groundwater for household use. The results reveal that groundwater quality significantly declines at shorter distances (0–10 m and 11–20 m). For example, nitrate levels are highest in proximity to soakaways (38.6 ± 5.4 mg/L) and diminish progressively with increased distance, reflecting the growing impact of wastewater near the source. Although still meeting WHO standards, the heightened nitrate concentrations nearby soakaways present potential health hazards, particularly for sensitive groups such as infants. Phosphate levels are similarly elevated near soakaways, suggesting a strong influence from sewage or effluent, which could lead to nutrient pollution. Turbidity values surpass the acceptable threshold of 5 NTU within a distance of 30 m, indicating poor visual quality and potential risks of microbial contamination, which can affect water safety and treatment.

In a similar vein, total dissolved solids (TDS) and chloride levels rise closer to soakaways, indicating greater concentrations of dissolved contaminants, which might impact flavor and acceptability. Hardness levels are also elevated near soakaways, potentially resulting in scaling and greater soap usage, thus reducing the appropriateness for domestic washing purposes.

Dissolved oxygen concentrations are at their lowest around soakaways (2.4 mg/L), which points to a decline in oxygen levels caused by organic pollutants, while pH readings are acidic (below 6.5) within a radius of 30 m, indicating water that is corrosive and potentially harmful to pipes and taste. Conversely, groundwater found at distances of 30 m or more displays significantly enhanced quality, featuring diminished contamination levels, increased dissolved oxygen, and pH that approaches neutrality, thus rendering it better suited for household purposes. The results demonstrate that contamination from soakaways has evident detrimental effects on domestic water quality, especially in areas within 30 m of soakaway systems. Water located nearby tends to have elevated pollution levels, acidity, turbidity, and lowered oxygen saturation, making it more hazardous and unsuitable for drinking and domestic applications. On the other hand, as distance increases, water quality greatly improves, indicating that maintaining proper separation between boreholes and soakaway systems is essential for ensuring a safe domestic water supply.

Hypothesis

H₀₂: There is no significant relationship between soakaway effluent infiltration (measured by distance from soakaway pits) and changes in groundwater physicochemical properties in the study area.

Table 3: Summary of Pearson Product Moment Correlation (PPMC) between Distance from Soakaway Pits and Groundwater Physicochemical Parameters

Parameter	Correlation with Distance (r)	p-value	Decision	Interpretation
Nitrate	-0.88	<0.01	Significant	Strong inverse relationship
Phosphate	-0.91	<0.01	Significant	Very strong inverse relationship
Sulphate	-0.84	<0.01	Significant	Strong inverse relationship
Hardness	-0.82	<0.01	Significant	Strong inverse relationship
Chloride	-0.86	<0.01	Significant	Strong inverse relationship
Dissolved Oxygen	0.79	<0.01	Significant	Strong positive relationship
TDS	-0.85	<0.01	Significant	Strong inverse relationship
Turbidity	-0.89	<0.01	Significant	Very strong inverse relationship
Ph	0.76	<0.01	Significant	Strong positive relationship

Table 3 outlines the Pearson Product Moment Correlation (PPMC) findings that illustrate the connection between the distance from soakaway pits and the physicochemical properties of groundwater in the research area. The findings suggest that nitrate ($r = -0.88$), phosphate ($r = -0.91$), sulphate ($r = -0.84$), hardness ($r = -0.82$), chloride ($r = -0.86$), total dissolved solids ($r = -0.85$), and turbidity ($r = -0.89$) demonstrate strong negative correlations that are statistically significant with respect to distance ($p < 0.01$). This indicates that as the distance from soakaway pits increases, the concentration of these pollutants significantly declines. In contrast, dissolved oxygen ($r = 0.79$) and pH ($r = 0.76$) reflect strong positive correlations that are statistically significant with distance ($p < 0.01$), suggesting that as the separation from soakaway pits grows, water quality enhances, characterized by greater oxygen levels and a transition toward neutral pH values. The strength of the correlation coefficients implies that the infiltration of soakaway effluent

significantly impacts groundwater quality, especially at locations nearer to the soakaway systems. The extremely strong inverse correlations noted for phosphate and turbidity further underscore the influence of organic and particulate pollution originating from the soakaway sources. With all the physicochemical parameters analyzed showing statistically significant correlations with distance from soakaway pits at $p < 0.01$, the null hypothesis (H_{02}) is dismissed (Nweke, Ihejirika & Deebom, 2018). The results presented in Table 4.3 illustrate that the infiltration of soakaway effluent significantly alters groundwater physicochemical characteristics in the assessment area. Specifically, groundwater situated nearer to soakaway pits displays higher concentrations of pollutants such as nitrate, phosphate, chloride, turbidity, and total dissolved solids, along with reduced dissolved oxygen levels and increased acidity. As the distance from soakaway pits rises, these negative impacts lessen, resulting in better groundwater quality. Therefore, this study establishes that the closeness to soakaway pits is a crucial factor determining the suitability of groundwater for household use, with regions in proximity being more susceptible to contamination and related health hazards.

Discussion of the findings

The results displayed in Table 4.1, which summarizes the PPMC analysis of the link between soakaway effluent infiltration and groundwater physicochemical characteristics, along with Table 4.3, detailing the Pearson Product Moment Correlation between distance and groundwater quality aspects, showcase potent and statistically meaningful associations between the proximity to soakaway pits and every evaluated physicochemical aspect ($p < 0.01$). The negative correlations identified for nitrate ($r = -0.88$), phosphate ($r = -0.91$), sulphate ($r = -0.84$), hardness ($r = -0.82$), chloride ($r = -0.86$), total dissolved solids ($r = -0.85$), and turbidity ($r = -0.89$) suggest that as one moves further from soakaway pits, the concentration of pollutants significantly declines. In contrast, the levels of dissolved oxygen ($r = 0.79$) and pH ($r = 0.76$) rise with increasing distance, indicating an enhancement in water quality as one moves away from sources of contamination. These results distinctly illustrate that the infiltration of soakaway effluent is a significant factor contributing to groundwater pollution in the studied region. The robust interconnections among pollutants, such as between nitrate and chloride ($r = 0.94$) and TDS and chloride ($r = 0.93$), imply a shared source of contamination, likely from the leakage of domestic wastewater originating from soakaway systems. This trend is in line with the observations made by Egbai and Nwankwoala (2013), who noted heightened levels of nitrate, chloride, and total dissolved solids in groundwater sources situated near septic systems in various areas of Rivers State, Nigeria, pointing to contamination from household wastewater. Likewise, Nwankwoala and Udom (2011) discovered that groundwater quality is considerably compromised in regions with inadequate waste disposal mechanisms, especially in locations where soakaways and septic tanks are in proximity to water supply sources. Further supporting these findings, Ako et al. (2014) reported that groundwater samples gathered near latrines and soakaway pits in Cameroon had markedly higher levels of nitrate and microbial contaminants compared to those obtained from farther away, thus affirming the impact of on-site sanitation systems on groundwater pollution. Additionally, Lapworth et al. (2017), in their worldwide examination of groundwater contamination, underlined that nitrate and chloride serve as important indicators of wastewater infiltration, particularly in developing nations that lack adequate sanitation infrastructure. The positive correlation between distance and dissolved oxygen found in this investigation is consistent with the findings of Edet and Okereke (2001), who indicated that groundwater near pollution sources typically shows decreased levels of

dissolved oxygen due to the microbial breakdown of organic materials. Similarly, the acidic conditions observed (lower pH levels near soakaways) substantiate the conclusions of Ehirim and Nwankwo (2010), who associated the acidification of groundwater with the decomposition of organic waste in subsurface regions. The results firmly support the dismissal of the null hypothesis (H_0), confirming that the infiltration of soakaway effluent significantly modifies the physicochemical properties of groundwater. The results underscore the vital importance of distance as a protective element for groundwater quality, emphasizing the necessity for the appropriate placement of soakaway systems in relation to boreholes.

The results shown in Table 2 (Implications of soakaway-induced changes in groundwater physicochemical properties for domestic water use) clearly indicate that the quality of groundwater is considerably degraded at shorter distances (0–30 m) from soakaway pits, carrying significant consequences for household consumption. The notable reduction in nitrate levels from 38.6 ± 5.4 mg/L at 0–10 m to 4.8 ± 1.1 mg/L at distances of 30 m or more highlights the strong impact of wastewater in the vicinity of soakaways. Even though these amounts are below the WHO recommended limit of 50 mg/L, the high levels close to soakaways might present health hazards, especially for infants, due to the risk of methaemoglobinaemia. This finding supports the WHO (2017) recommendations, which stress that even moderate levels of nitrate pollution can be detrimental to at-risk groups. Levels of phosphate also decline with increased distance, which mirrors patterns of sewage contamination. Although there is no direct health standard for phosphate, its presence is generally acknowledged as a sign of human-induced pollution. Appelo and Postma (2005) pointed out that increased phosphate concentrations in groundwater frequently stem from household wastewater and can indicate larger contamination problems. Turbidity readings that surpass 5 NTU within 30 m imply poor water quality and possible microbial contamination, rendering such water unsafe for drinking without prior treatment. This aligns with the WHO (2017) guidelines, which note that elevated turbidity can hinder disinfection methods and elevate health risks.

Concurrently, Howard et al. (2006) discovered that shallow groundwater near sanitation facilities typically displays high turbidity and microbial contamination. The rise in total dissolved solids (TDS) and chloride levels nearby soakaways further corroborates the presence of dissolved pollutants, influencing the taste and overall acceptability of the water. This observation corresponds with Freeze and Cherry (1979), who identified chloride and TDS as essential indicators of groundwater pollution from human activities.

The low levels of dissolved oxygen found near soakaways (2.4 mg/L) suggest a depletion of oxygen due to organic waste, reinforcing Chapman (1996) who reported that reduced dissolved oxygen is a typical characteristic of contaminated water bodies. Furthermore, the acidic pH values (below 6.5) within 30 m imply a higher corrosive potential, which can harm plumbing systems and affect the palatability of the water. This supports findings from Hem (1985), which indicated that acidic groundwater is frequently associated with the breakdown of organic waste. Hardness levels, while not directly unsafe, are notably elevated near soakaways and might diminish water usability due to scaling issues and increased soap requirements. This observation is consistent with the insights from Todd and Mays (2005), who emphasized the practical challenges of hard water for households.

Conclusion

This research offers substantial empirical data indicating that the infiltration of soakaway discharge considerably affects groundwater chemical characteristics in the observed region. The results from the Pearson Product Moment Correlation indicated robust and statistically relevant associations between the distance from soakaway systems and all evaluated parameters ($p < 0.01$, $N = 60$). In particular, notable negative correlations were found between distance and significant pollutants, including nitrate ($r = -0.88$), phosphate ($r = -0.91$), sulphate ($r = -0.84$), chloride ($r = -0.86$), turbidity ($r = -0.89$), and total dissolved solids ($r = -0.85$), suggesting that higher contaminant levels are associated with shorter distances. On the other hand, positive correlations with dissolved oxygen ($r = 0.79$) and pH ($r = 0.76$) confirm an improvement in water quality with greater distances from soakaway systems.

Moreover, the results illustrate that groundwater located within 0–30 meters of soakaway systems is marked by high levels of pollutants, diminished dissolved oxygen (2.4 mg/L), acidic pH (5.82), and turbidity surpassing WHO recommendations (14.8 NTU > 5 NTU). While certain metrics like nitrate (38.6 mg/L) were under the WHO limit (50 mg/L), their high concentrations near soakaways can pose significant health hazards. In contrast, groundwater samples taken from a distance of 30 meters or more showed a marked enhancement in quality, featuring lower pollutant levels and physicochemical attributes nearing suggested guidelines.

In summary, this investigation validates that nearness to soakaway systems is a crucial factor influencing the quality of groundwater and its suitability for domestic use. The null hypothesis was discarded, confirming that soakaway discharge infiltration markedly modifies groundwater qualities. Therefore, insufficient distance between boreholes and soakaway systems represents a significant risk for groundwater contamination in Rivers State.

Recommendations

- i. It is advisable that regulatory bodies enforce a minimal separation distance of no less than 30–50 meters between soakaway systems and boreholes to mitigate the flow of contaminants into groundwater supplies.
- ii. Encouragement of modern wastewater management techniques such as lined septic tanks and centralized sewage treatment systems should be promoted to lessen the risk of subsurface effluent seepage.
- iii. Regular assessments of the physicochemical and microbial quality of groundwater sources should be established to promptly identify contamination and ensure alignment with WHO guidelines.

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