

ENVIRONMENTAL EFFECTS OF LANDUSE ON GROUNDWATER QUALITY IN IKEPODUN LOCAL GOVERNMENT AREA, KWARA STATE.

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Abstract

The paper examines the impact of land use types on groundwater quality in Irepodun Local Government Area, Kwara State. Twelve groundwater samples were collected from hand-dug wells and boreholes from various land uses in four wards of the study area. These samples were analysed for fifteen physicochemical and microbial parameters using standard laboratory analytical techniques and compared with the World Health Organisation recommended standards for drinking water. Tables were used in presenting the data and principal component analysis were carried out on the data generated. The result showed that groundwater quality varies in the sampled locations, and the physicochemical parameters analysed were within the WHO-recommended standards except for BOD, TDS, Mg, and Ca. The microbial analysis showed that THC ranges between $35-102 \times 10^{-2}$ and $24-64 \times 10^{-3}$ CFU/ml, while the TFC ranged from $1-5 \times 10^{-1}$ and $3-8 \times 10^{-2}$ CFU/ml. The study revealed that *Proteus mirabilis*, *Shigella* sp, *Pseudomonas aeruginosa*, and *Bacillus* sp. were the most prominent organisms observed in the water samples. The result of the PCA revealed that 17 variables were reduced to 5 orthogonal components which cumulatively explain 89% of the variance. The contributions of the components varied from 7.67% to 41.20%, each capturing the influence of various land uses on groundwater quality. The study recommends the integration of land use and water quality for effective decision-making and sustainable land-water management, thereby informing land use optimization and water pollution control policies to manage water resources for the current and future generations.

Keywords: Landuse; Groundwater; Water Quality; Environmental; PCA

Introduction

Groundwater is an essential resource necessary for the sustenance of human life and the maintenance of healthy ecosystems. Groundwater plays a vital role in the global water supply, providing approximately 30% of the world's freshwater resources (WWAP, 2020; Adelana, et al., 2011). Therefore, it aids in the sustainable development of nations (Zaki, et al., 2019). However, Sinha and Elango (2019) observed that groundwater degradation

has become an environmental problem globally due to its susceptibility to pollution both by natural and anthropogenic processes. According to Abanyie, *et al.*, (2023), groundwater quality is influenced by natural factors such as lithology, groundwater velocity, and quality of recharge water among others. The modification of natural landscapes for various purposes, such as agriculture, urbanization, and industrialization, can notably affect groundwater quality (Kumar *et al.*, 2020). Thus, groundwater resources are facing unprecedented threats due to increasing human activities. Land use exerts a great influence on groundwater quality (Gleeson *et al.*, 2020) as land use practices have a water resources footprint (Global Water Partnership, 2014). Therefore, the linkage between land use and groundwater is essential for groundwater governance and management because changes in land use have impact on aquifers.

As the population increases, groundwater continues to be an important source of water supply. This is due to the lack of access to public piped water, leading to high dependence and in most cases, overexploitation of privately dug boreholes and shallow wells. Thus, the resource is vulnerable to pollution and contamination from various sources, threatening their quality and safety. Land use activities produce both point source pollution and non-point source pollution. Sources of point source contamination (pollution from a single source) include industrial effluents, municipal solid waste, agricultural chemicals, oil spills, and urban surface runoff, among others. Non-point source pollution is widely distributed and cannot be traced to a particular source. These contaminants (point source pollution and non-point source pollution) can have harmful effects on human health and the environment, making it essential to manage and protect groundwater resources to ensure long-term availability and good quality.

Recent studies have highlighted the detrimental effects of land use on groundwater quality, including contamination with pollutants, changes in water chemistry, and decreased aquifer recharge (MacDonald *et al.*, 2020; Li *et al.*, 2020). For instance, agricultural activities have been linked to increased nitrate levels in groundwater (Hamilton *et al.*, 2020), while urbanization has been associated with elevated concentrations of heavy metals and organic pollutants (Li *et al.*, 2020). Despite these findings, the understanding of the complex relationships between land use and groundwater quality remains limited, particularly in the study area with diverse land use patterns and geological settings. It is against this background that the study examines the effect of land use on groundwater quality in Irepodun Local Government Area, Kwara State.

Methodology

Study Area

Irepodun Local Government Area in Kwara State is located between latitudes 7°59'30"N and 8°27'0"N North of the equator and longitudes 4°48'0"E and 5°10'0"E East of the Greenwich meridian. It covers a total area of 737 square kilometers (Adekanye, *et al.*, 2013). The headquarters is Omuaran and comprises several towns and villages. It has a

tropical climate with a rainy season from April to November and a dry season with Harmattan winds, and temperatures averaging 30°C (Ashaolu & Onundi, 2014). The study area exhibits a double maxima rainfall pattern with mean annual rainfall ranging from 1100-1500 mm (Ashaolu & Onundi, 2014). The area is located on gently sloping land formed from older sedimentary rocks. These underlying rocks make groundwater to be naturally exploitable and thus, contribute to the good yield of wells. The drainage pattern is characterized by short, rapid, and mostly seasonal rivers, with the Ossin River being the most notable watercourse (Ashaolu & Onundi, 2014). Groundwater is the dominant source of drinking in the study area.

The soil in the study area is composed of mineral-rich granite, quartz, feldspar, columbite, and tantalite, allowing for rapid water absorption and quick runoff. Irepodun LGA has a population of 147,333 (NPC, 2006).

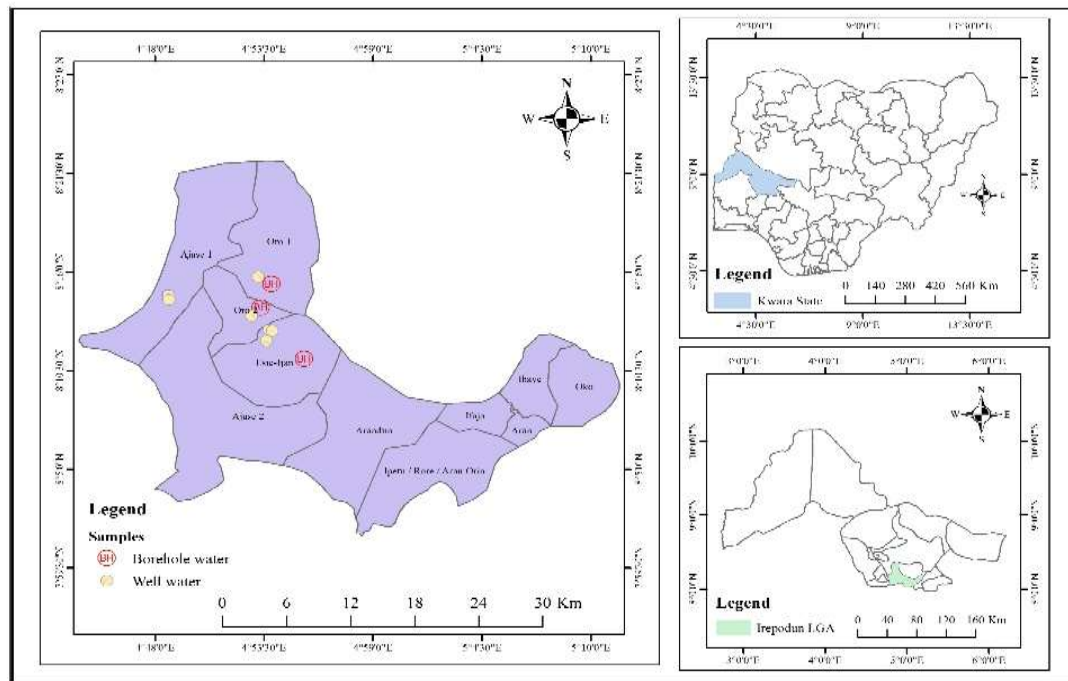


Figure 1: Sampled location in the study area

Source: Field Survey, 2022

Materials and Methods

The sampling technique employed in this study was purposive sampling. The purposive sampling technique was utilised in the study to deliberately select specific wards in the study area because of the local knowledge of the study area as representing a diverse land use pattern which might provide insight into potential contamination sources of

groundwater. Hence, a total of 15 water parameters were tested from 12 groundwater samples. The twelve (12) samples were purposely taken from four (4) different wards in the study area. Samples were taken from Oro Ward I, Oro Ward II, Esie Ijan Ward, and Ajase Ipo Ward I, all in the study area. The wards were numbered accordingly by giving them identification codes.

Water samples were tested for physicochemical and microbial parameters. Physicochemical parameters tested include temperature, turbidity, electrical conductivity, Total Dissolved Solids (TDS), pH, Total hardness, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Sulphate, calcium, magnesium, chloride, and nitrate. Two microbial parameters were tested, which include total viable heterotrophic count and total fungi count.

Water samples were collected in a 1-litre plastic bottle and labeled with appropriate identification codes indicating different land uses where water sources are located. Sample bottles were rinsed with distilled water before collecting the water samples. The samples were packed in an iced container and taken to the laboratory within 12 hours from the time of collection of samples. At the laboratory, samples had attained room temperature before carrying out analysis.

The water temperature was tested in situ by using a mercury-in-glass thermometer. In the laboratory, an E520pH meter was used to test for pH value, electrical conductivity meter for electrical conductivity, total dissolved meter ASTMD88803 for total dissolved solids, refractometer for nitrate, colorimeter for total hardness, spectrophotometer for chloride, nephelometry model 156 for turbidity, dissolved oxygen meter for dissolved oxygen and H196752 portable photometer was used for magnesium hardness and as well as calcium hardness. Furthermore, sulphate test kits were employed to test sulphate, the dilution method was used to determine biochemical oxygen demand (BOD), and the titrimetric method was also used to determine calcium and chloride.

As for the microbial parameters, total counts of heterotrophic microorganisms (bacteria) such as total fungi count, and total heterotrophic bacteria counts were isolated using Nutrient agar (NA) by pour plate method. An Aliquot of 0.1 ml of the 10^{-3} and 10^{-4} dilutions of the samples was used to incubate the plates in triplicates; the plates were incubated at 37°C for 48 hrs. Thereafter the mean counts of the bacteria colonies were taken. The bacteria isolates were further experimented with, to attain pure cultures. The pure cultures were then characterized and identified to determine the bacteria species using the standard microbial method.

The study employed the use of both descriptive and inferential statistics using the Statistical Package for Social Science version 20. Descriptive statistics such as tables were used to present the results of the test parameters at different stations of the study area. Principal component analysis was utilized to determine the parameters with the highest concentration value to indicate the contributions of the component variables. The result of the sample analysis was compared with the World Health Organization standard for

water quality (WHO, 2011). In addition, the coordinates of the sampling point were obtained by using a global positioning system (GPS) and these were mapped using Arc GIS 10.5 software (see Figure 1).

Results and Discussion

Identification, Classification, and Location of Land Use and Sources of Groundwater in Irepodun LGA.

In this study, various human activities were identified, classified, and presented under the broad land use categories (table 1). Likewise, groundwater sources were also classified and their geographical positions on Earth (coordinates) were recorded. The study revealed that the sources of groundwater in the study area are boreholes and wells with wells being the most prominent source (Table 1). The study further categorized human activities on land into different land uses such as public/institutional, residential, commercial, industrial open space, and agricultural land uses

Table 1: Sources and Location of Groundwater and Surrounding Land Use Classification

Groundwater sources and sample code	Latitudes	Longitudes	Surrounding human activities	Sampled community/ Wards	Categories of Land use
Borehole (S1)	8.2479475	4.5011339	Hospital	Ijomu Oro/ Oro ward I	Public
Well (S2)	8.2472902	4.5011339	House	Ijomu Oro/ Oro ward I	Residential
Borehole (S3)	8.23358	4.888681	Oro general market	Oro ward II	Commercial
Well (S4)	8.2296333	4.8891322	Compound House	Oro ward II	Residential
Well (S5)	8.213001	4.8954242	Compound House	Esie Ijan ward	Residential
Well (S6)	8.2027751	4.8934169	Bakery	Esie Ijan ward	Industrial
Well (S7)	8.212189	4.8981294	Esie market	Esie Ijan ward	Commercial
Borehole (S8)	8.18589	4.9250231	Ijan Otun	Esie Ijan ward	Residential
Well (S9)	8.2437971	4.8098923	Mosque	Ajase Ipo ward I	Public
Well (S10)	8.2455493	4.8103867	Farmland	Ajase Ipo ward I	Agricultural
Well (S11)	8.2449573	4.8111446	Refused dump /landfill	Ajase ipo ward I	Open space
Well (S12)	8.2445324	4.511771	Fuel station	Ajase ipo ward I	Commercial

Source: Field Survey, 2022

Water Quality Parameters Present in the Groundwater of the Study Area

The groundwater quality and its surrounding land uses are presented in Tables 2 and 3. The result shows that pH ranges between 7.3 and 8.07 with a mean value of 7.8, indicating a slightly basic or alkaline condition. The pH values observed in S8 and S10 of the study might be due to the type of underlying rock. Past studies (Dewangan, *et al.*, 2023; De Giglio, *et al.*, 2016) believed that pH values in water are influenced by several factors such as geological properties, human activities, biological processes, and climate change. Thus, the observed pH value could be due to the proximity of residential houses and farmlands to the location of groundwater sources, hence, the infiltration of wastewater from nearby houses and leachates of fertilizer and pesticides from farmlands could be responsible for the alkaline nature of these sample stations. However, the pH values for all the sample stations are within the recommended limit by WHO of 6.5-8.5 for groundwater. This result concurs with the study of Sarker, *et al.*, (2020) on groundwater quality in the Noakhali Region, Bangladesh with a pH value of 6.8-7.9. However, the result of the study is at variance with the study of Adeyi and Majolagbe (2014) on groundwater quality around dump sites with pH mean values in the acidic range and not within the recommended limits of 6.5 – 8.5 by the WHO.

Furthermore, the result of the electrical conductivity observed ranged from 10.22 and 886 μ S/cm (Table 2). Although it was moderately high at S7 and S8 with 886 and 686 μ S/cm respectively compared to other stations, it is still within the World Health Organization standard of 1000 μ S/cm. The total dissolved solids (TDS) values obtained from the sampling sites ranged from 111 to 855. The mean value of TDS in the study area is 484 mg/l which is within the World Health Organization's recommended desirable limit of 500 mg/l. However, some of the sample stations have high TDS values not within the desirable limit, indicating high levels of dissolved solids in the water. This may be due to urban runoff and human activities such as the discharge of domestic sewage from residential areas, oil seepage from fuel stations, and leachates from refuse disposal sites that infiltrate into the nearby sub-surface water. Thus, this result supports findings from previous studies that a high concentration of total dissolved solid is due to human activities such as effluent discharge from industries and refuse disposal (Phyllis, 2007; Lawal, *et al.*, 2022).

Table 2: Water Quality Parameters present in the groundwater of different land uses as compared to WHO (2011)

Parameters	(1) Oro ward 1	(2) Oro ward 1	(3) Oro ward 2	(4) Oro ward 2	(5) Esie ijan ward	(6) Esie ijan ward	(7) Esie ijan ward	(8) Esie ijan ward	(9) Ajase ipo ward	(10) Ajase ipo ward	(11) Ajase ipo ward	(12) Ajase ipo ward	W.H. O
pH value	7.56	7.88	7.55	7.30	7.60	7.76	7.90	8.07	8.04	8.07	7.88	7.87	6.5-8.5
E.C	125	10.22	17.00	65.10	12.72	33.10	886	684	14.53	22.10	17.08	16.68	1000µs/cm
TDS	62	512	850	325	636	116	443	342	725	111	855	835	500 mg/l
Turbidity (NTU)	0.097	1.940	2.626	1.190	2.015	1.114	1.641	1.484	2.149	1.082	2.630	2.295	<5NTU
Sulphate	18.72	18.60	25.88	22.36	9.12	25.28	19.12	18.20	18.16	19.88	23.72	19.40	250 mg/l
Nitrate	0.736	1.818	0.740	1.000	1.420	1.005	1.081	1.165	1.840	2.036	2.084	1.965	10 mg/l
Total hardness	63	215	63	126	252	130	142.8	189.0	227.6	286.4	288.5	273.8	100-500
Calcium hardness	11.22	76.95	6.41	20.84	65.73	28.86	22.45	46.49	80.16	96.19	110.62	80.16	75
Chloride	17.91	46.85	20.67	48.23	49.61	16.54	41.34	30.32	75.78	95.00	66.144	99.28	250 mg/l
D.O	30.40	32.00	51.70	38.40	30.40	32.00	32.10	40.00	38.40	38.40	43.20	38.40	3-5
B.O.D	17.60	14.40	43.70	24.00	17.60	16.00	19.20	25.60	28.80	20.80	32.00	17.20	6
Temperatur e	27.10	26.8 0	26.80	26.40	27.00	26.80	26.90	27.10	26.90	27.10	27.00	27.10	30°C
Magnesium hardness	51.78	130.05	56.59	105.16	186.27	101.34	120.35	142.51	147.44	190.21	177.88	193.64	50

Source: Field Survey, 2022

Turbidity values in the sample locations ranged between 0.097 and 2.630 NTU which is within the WHO <5 NTU. Low turbidity value recorded in all the sample locations signifies less suspended particles from the surrounding land uses or low occurrences of soil erosion which might infiltrate into the ground. Sulphate concentrations in groundwater in all the sampled locations were insignificant as the values ranged from 9.12 to 25.88 mg/l. The sulphate values were generally lower than the 250 mg/l limit stipulated by the World Health Organization for drinking water. Sulphate concentrations in groundwater may be linked to the geological nature of soil (Adeyi and Majolagbe, 2014) and human activities that threaten the quality of freshwater ecosystem drinking (Zak, *et al.*, 2021; Lamers, *et al.*, 2013). The nitrate values across the study area ranged between 0.736 to 2.084, which is within the World Health Organization's recommended limits. The presence of nitrate ions in groundwater may be due to the application of fertilizers to farmlands, discharge of untreated domestic waste, leachates from landfills, the level of clay present in the soil, and the low level of nitrifying bacteria (Gutiérrez, *et al.*, 2018; Adeyi and Majolagbe, 2014).

Total hardness in water depends on the geological formation and chemical weathering process. Hardness in water is dependent on calcium and magnesium ions. Calcium and magnesium are important nutritional elements needed for metabolic activities in humans (Adeyi and Majolagbe, 2014). In this study, total hardness values ranged from 63.0 to 288.5 mg/l; these values were within the World Health Organization's recommended limits across the sampled locations. However, calcium hardness values exceeded WHO standards in stations 2, 9, 10, 11, and 12, while magnesium values exceeded the recommended limits in all the sampled stations. According to (Balogun, *et al.*, 2012; Adeyi and Majolagbe 2014) high value of hardness in water may curtail its use for domestic activities such as washing as it limits lather formation, hence, consumes more soap. Therefore, hardness determines the suitability of water for usage and could cause gastrointestinal diseases and stone formations (Balogun, *et al.*, 2012).

The chloride values ranged from 16.54 to 99.28 mg/l, which conform with the World Health Organization's recommended standard of 250 mg/l, signifying relatively low chloride concentrations. Dissolved Oxygen was present in all the sample locations, and these values ranged between 30.4 and 51.7 mg/l. According to WHO (2011), there is no recommended health-based standard for DO, although, high DO values in water may cause corrosion of metal pipes. DO levels in water vary because of several factors such as temperature, salt content, organic decomposition, and atmospheric pressure. This study concurs with the result of Ayobahan *et al.*, (2014) that the level of DO concentration changes due to the presence of organic pollutants in water.

The temperature of groundwater in the study area ranges from 26.4°C to 27.1°C, hence, within the tolerable limit of 30°C of WHO. This indicates that there is no significant difference in temperature across the stations. High temperature in water increases the growth of microorganisms and may affect the taste, odour and colour of water (Nwachukwu, *et al.*, 2020; WHO, 2011). High temperatures could result in schistosomiasis and other related health conditions (National Research Council, 1993; Adeyi and

Majolagbe 2014). The values for the biochemical oxygen demand recorded in water samples of the study locations were all above the recommended standards for drinking water by the World Health Organization.

Microbial Analysis

The result of the microbial parameters showed the presence of bacteria in the water samples of the sampled locations. Table 3 shows total viable heterotrophic count in the water samples ranges between $35-102 \times 10^{-2}$ and $24-64 \times 10^{-3}$ CFU/ml, while the total fungi count ranged from $1-5 \times 10^{-1}$ and $3-8 \times 10^{-2}$ CFU/ml. The result of this study is in harmony with the findings of Keesari, *et al.*, (2015) that the total viable heterotrophic count is in the range between 1.8×10^3 and 3.3×10^4 CFU/mL in different aquifers in the Pondicherry Region on the east coast of India. Furthermore, the study identified the various bacteria that may be present in the water samples and showed that their distribution varies across the sampled locations (Tables 4 and 5). The study revealed that *Bacillus sp.*, *Proteus mirabilis*, *Shigella sp.*, and *Pseudomonas aeruginosa* were the most prominent organisms present in the water samples of the sampled locations. Therefore, the result of this study is in concurrence with the findings of Nwachukwu, *et al.*, (2020) that *Bacillus sp.* is a prominent microorganism that affects the quality of groundwater, especially boreholes as it accounted for 6 out of 10 bacterial counts observed in borehole water samples in Owerri West, Imo State. Hence, the study found that the values for total viable heterotrophic count and total fungi count were excessively above the WHO recommended guideline of zero. Therefore, this study indicates that all samples in the sample locations are potentially contaminated by microorganisms. This is because the nature of human activities surrounding the water sources such as the discharge of domestic sewage and the practice of open defecation around dumpsites as observed during the fieldwork exercise potentially contaminates groundwater quality in the study area. This implies that the water becomes polluted and life-threatening for consumption and domestic use as this can cause water-related diseases.

Table 3: Microbial Analysis

Groundwater sources and sample code	Total Heterotrophic Count		Total Fungi Count	
	10^{-2} CFU/ml	10^{-3} CFU/ml	10^{-1} CFU/ml	10^{-2} CFU/ml
Borehole (S1)	35	24	1	3
Well (S2)	69	27	1	4
Borehole (S3)	51	34	0	3
Well (S4)	84	52	2	4
Well (S5)	85	53	2	6
Well (S6)	96	67	3	7
Well (S7)	73	38	3	5
Borehole (S8)	89	57	2	5
Well (S9)	102	64	5	8
Well (S10)	94	59	4	6
Well (S11)	89	52	3	8
Well (S12)	78	46	4	7

Source: Field Survey, 2022

Table 4: Identification of bacteria isolates in water sample.

S/N	Gram's reaction	Mot	Cat.	In d.	M R	Oxid .	VP	Citr . Util .	Nitr . Red .	Glu	Suc	Malt .	
1	+	+	+	-	+	+	+	+	+	+	+	+	Bacillus sp.
2	-	-	-	-	+	-	-	+	-	-	-	+	Shigella sp.
3	-	+	+	-	+	-	-	+	+	+	-	-	Proteus mirabilis
4	-	-	+	-	+	-	+	+	-	+	+	+	Klebsiella sp.
5	+	-	+	+	+	-	-	-	-	+	+	+	Staphylococcus aureus
6	-	+	+	-	-	-	+	+	-	+	+	+	Enterobacter sp
7	-	+	+	+	-	+	-	-	+	+	-	-	Pseudomonas aeruginosa

Source: Field Survey, 2022

+Ve = Positive

-Ve = Negative

Table 5: Distribution of bacteria isolates in sample locations

Sample	Bacteria isolate distribution
1.	<i>Bacillus</i> sp., <i>Enterobacter</i> sp, <i>Staphylococcus aureus</i>
2.	<i>Proteus mirabilis</i> , <i>Shigella</i> sp
3.	<i>Proteus mirabilis</i> , <i>Bacillus</i> sp
4.	<i>Proteus mirabilis</i> , <i>Shigella</i> sp,
5.	<i>Pseudomonas aeruginosa</i> , <i>Enterobacter</i> sp., <i>Salmonella</i> sp.
6.	<i>Escherichia coli</i> , <i>Bacillus</i> sp., <i>Shigella</i> sp.,
7.	<i>Shigella</i> sp. <i>Proteus mirabilis</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella</i> sp.
8.	<i>Pseudomonas aeruginosa</i> , <i>Proteus mirabilis</i> , <i>Escherichia coli</i> .
9.	<i>Bacillus</i> sp. <i>Pseudomonas aeruginosa</i>
10.	<i>Enterobacter</i> sp <i>Proteus mirabilis</i>
11.	<i>Shigella</i> sp. <i>Bacillus</i> sp.,
12.	<i>Pseudomonas aeruginosa</i> , <i>Proteus mirabilis</i>

Source: Field Survey, 2022

Principal Component Analysis

The result of the principal component analysis is presented in Tables 6 and 7. The result revealed that 17 variables were reduced to 5 components which cumulatively explain 89% of the variance. The loadings of each component and their eigenvalues revealed that the contributions of the components varied from 7.67% to 41.20%.

Table 6: Total Variance Explained by Principal Component Analysis

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.436	43.741	43.741	7.436	43.741	43.741	7.005	41.209	41.209
2	3.221	18.949	62.690	3.221	18.949	62.690	3.025	17.792	59.001
3	2.224	13.084	75.774	2.224	13.084	75.774	2.259	13.288	72.289
4	1.226	7.213	82.987	1.226	7.213	82.987	1.537	9.040	81.328
5	1.022	6.014	89.001	1.022	6.014	89.001	1.304	7.673	89.001
6	.738	4.342	93.343						
7	.484	2.848	96.191						
8	.316	1.861	98.052						
9	.218	1.280	99.332						
10	.095	.561	99.893						
11	.018	.107	100.000						
12	2.623E-016	1.543E-015	100.000						
13	1.505E-016	8.851E-016	100.000						
14	3.636E-017	2.139E-016	100.000						
15	-1.271E-016	-7.478E-016	100.000						
16	-2.090E-016	-1.229E-015	100.000						
17	-3.430E-016	-2.018E-015	100.000						

Extraction Method: Principal Component Analysis.

Table 7: Component Matrix^a of the PCA

	Component				
	1	2	3	4	5
pH value	.650	-.136	.045	.488	.463
Electrical conductivity	-.202	-.243	.262	.879	.058
Total dissolved solids	.367	.743	-.326	.180	-.304
Turbidity (NTU)	.457	.739	-.263	.211	-.141
Sulphate	-.248	.507	.348	-.249	.623
Nitrate	.918	.020	-.319	-.078	.175
Total hardness	.952	-.072	-.218	.012	-.038
Calcium hardness	.915	.017	-.284	-.082	.127
Chloride	.844	.033	-.150	-.108	-.029
Dissolved oxygen	.035	.925	.162	.031	.142
Biochemical oxygen demand	-.110	.914	.220	.095	.007
Temperature	.045	.150	.778	.036	-.442
Magnesium hardness	.930	-.125	-.122	.081	-.177
THC 10-2 CFU/ml	.780	-.097	.428	-.043	.051
THC 10-3CFU/ml	.608	-.052	.694	-.163	-.056
TFC 10-1 CFU/ml	.808	-.201	.392	-.008	.039
TFC 10-2 CFU/ml	.870	.010	.301	-.075	-.037

Extraction Method: Principal Component Analysis.

5 components extracted.

Component 1: This component contributes 41.20% which explains the highest amount of variance, indicating that it reflects the most significant sources of variation among the variables. In other words, it represents the most critical factors influencing water quality in the study area. Hence, it is highly loaded on 8 variables which are pH, nitrate, total hardness, calcium hardness, chloride, magnesium hardness, total heterotrophic count, and total fungi count. The component defining variable is alkalinity and mineral content in water. Thus, PCA (1) may reflect the impact of factors such as land cover types (urbanization and agricultural practices). Urban areas generate sewage and wastewater which contain organic matter and nutrients that can increase alkalinity in groundwater through microbial degradation processes that cause high values of bicarbonate ions. In addition, urban infrastructure often involves the use of construction materials (concrete and cement) which contain minerals such as calcium, magnesium, and other minerals that can leach into groundwater over time (Bawa and Dwivedi, 2019). Furthermore, increased demand for groundwater for municipal water supply and industrial processes can induce the intrusion of

saline water which causes increased mineral content, especially chloride ions, in affected groundwater. Moreover, this component may reflect contamination from agricultural runoff; land management practices (irrigation and pesticide use), and natural processes such as geological characteristics and recharge rate on groundwater quality of the study area.

Component 2: This explains 17.79% of the variance which is a substantial portion of the remaining variance after Component 1. It is loaded on 5 variables. It represents aspects related to contamination and particulate matter in the water, as indicated by variables such as DO, TDS, BOD, turbidity, and sulphate. Therefore, PCA (2) captures the influence of agricultural activities on the groundwater quality of the study area. Irrigation practices and pesticide application on farmlands can lead to the accumulation of dissolved solids such as salts in soils, which can then leach into groundwater over time, and in turn, increase TDS levels and affect the taste and odour of groundwater. According to Bijay-Singh and Craswell (2021), excessive application of fertilizers can lead to nutrient runoff into surface water bodies, thereby resulting in low DO levels in water, especially in areas where surface water interacts with groundwater. This can affect groundwater quality. Runoff from agricultural fields especially during heavy rainfall contains sediments and organic matter, such as animal waste and crop residues, which increases turbidity in water BOD levels in soils, which can then leach into groundwater (McDonough, et al., 2020). A high concentration of BOD signifies water contamination which leads to oxygen depletion in water. High turbidity can reduce light penetration.

Component 3: This component contributed 13.28% explanation to the variance which are additional significant factor influencing water quality in the study area. It captures temperature variations and specific microbial contaminants, which could impact water quality. The temperature variation reflects the impact of physical characteristics or environmental and geographical influences on water quality. Hence, this component represents the influence of industrial discharge, urbanization, and agricultural practices on the groundwater quality of the study area. Urbanization processes have accelerated the use of impervious surfaces such as asphalt and concrete which absorb and retain heat, thereby raising temperature and leading to the creation of heat islands. Furthermore, urban areas usually have fewer trees and vegetation due to the conversion of forests or grasslands to croplands, and buildings among others which reduces shade and natural cooling effects. This alters surface albedo and evapotranspiration rates and, hence, affects the temperature of groundwater (Riedel, 2019). In addition, in areas where industrial discharge directly enters groundwater, high temperatures can impair the quality of groundwater by accelerating chemical reactions, increasing the solubility of certain contaminants, and promoting microbial activity. Moreover, THC levels in groundwater can be influenced using fertilizers, pesticides, and animal waste through runoff from agricultural fields which transport nutrients and organic matter into groundwater (Xu, et al., 2019). Also, the infiltration of industrial discharges containing organic pollutants can lead to increased THC levels in groundwater, indicating microbial contamination.

Components 4 and 5: These components contribute 9.04% and 7.67% respectively to the variance. These components capture parameters such as EC and sulphate as being influenced by land use such as agricultural practices, urban development, natural processes like geological formation, and recharge processes affecting water quality. The study revealed that the excessive use of fertilizers containing sulphates (ammonium sulphate, ammonium nitrate) and soluble salts (potassium chloride) can cause the accumulation of sulphates and salts in groundwater through leaching. During rainfall, these dissolved nutrients enter the soil and percolate down the groundwater table, thereby increasing the concentration of sulphate and EC values in water

respectively. In addition, the intensive practice of livestock farming increases sulphate concentration in groundwater through the infiltration of decomposed organic matter in manure. This affects the groundwater quality, especially in shallow wells. Furthermore, the improper disposal of sewages from municipal areas can increase the concentration of sulphate and EC values respectively in groundwater due to leakages from old or damaged sewage infrastructure (Chen, et al., 2018).

Conclusion and Recommendations

Groundwater resources are facing unprecedented threats due to increasing human activities on land which exerts great impact on the quality of groundwater as it causes harm to human health and the environment. This study provides insight into the complex relationship between land use and groundwater quality. Most of the physiochemical and biological parameters considered in this study were present in the water samples. Although, the concentration values obtained from different stations varies, however, many of these values are within the WHO recommended standard except for TDS, BOD, Magnesium, Calcium, total heterotrophic count, and total fungi count. Based on the findings of this study, it is recommended that intensive monitoring is required to help prioritize interventions and remediation strategies to improve water quality by focusing on the most influential factors. Furthermore, the implementation of best management practices such as vegetative buffers, controlled drainage systems, zoning regulations, and precision agriculture techniques can help mitigate the adverse effects of land use on groundwater quality. Hence, integrating land use and water quality is essential for effective decision-making and sustainable land-water management, thereby informing land use optimization and water pollution control policies to manage water resources for the current and future generations.

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