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Assessment of Physicochemical Characteristics and Spatial Distribution of Heavy Metals in Hand-Dug Wells near Septic Tanks in Ojo LGA, Lagos. Nigeria

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Abstract

One of the most important environmental issues today is groundwater contamination, and between the wide diversity of contaminants affecting water resources, microbial quality and heavy metals receive particular concern considering possible outbreak of diseases. Thus, well water meant for consumption must meet the guidelines for drinking water quality to reduce possible health-risk associated with chemical hazards. In Nigeria, there is a scarcity of portable drinking water, hence many homes have wells dug around the house at a distance of about nine meters from the septic tank. The lack of drinkable water has prompted people to seek other sources of water. This study assessed the physicochemical quality and concentration of heavy metals in water samples drawn from fifteen hand-dug wells sited close to septic tanks in Ojo Local Government Area of Lagos State, Nigeria. Samples were collected in both the rainy and dry seasons, Temperature, Ph, Conductivity, Salinity, Total Dissolved Solid (TDS) were determined using standard procedures. Iron, Copper, Zinc, Manganese, Lead, Cadmium and Nitrate content of well water samples were evaluated by Atomic Absorption Spectrometer. The values of turbidity, conductivity and total dissolved solids obtained were higher than the WHO standard limit in some of the well sampled which shows that the well water may not be acceptable or recommended for human consumption due to the effect on human health such as gastro-intestinal irritation as well as fabric stains. The results also revealed that there were no heavy occurrences of Cu, Fe, Zn and Cd, in all the analysed water samples, their concentration values were below the desirable limits specified by World Health Organization while Mn concentration falls within the WHO desirable limit, lead has a concentration values (0.01 to 0.05 mg/L) higher than the permissible limit of 0.01 WHO standard in all the hand dug well water sampled. This implies that the well water in the studied location is unsuitable for drinking because of the possible poisoning effect of lead and the resulting health disorder even when consumed at a low concentration.

Keywords: Hand-Dug Wells; Well Water; Physicochemical Characteristics; Heavy Metal; Septic Tanks; Spatial Distribution

1. Introduction

Groundwater remains one of the most vital natural resources supporting human existence and public health globally. It provides approximately half of the world's drinking water and sustains agricultural, industrial, and domestic needs, particularly in low- and middle-income countries where surface water is often inadequate or contaminated [1], [2]. In

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many developing urban and peri-urban communities, groundwater is tapped primarily through hand-dug wells due to their low construction cost, simplicity, and accessibility [3], [4]. In Lagos State, Nigeria, such wells are a principal source of water for domestic use, especially in regions where piped water supply is unreliable or nonexistent. Despite their socioeconomic importance, hand-dug wells are shallow and often unlined, making them particularly susceptible to pollution from nearby anthropogenic activities such as septic tanks, refuse dumps, and surface runoff [5]. The increasing urbanization and inadequate sanitation infrastructure in densely populated settlements like Ojo Local Government Area exacerbate the vulnerability of groundwater systems to contamination by heavy metals and other pollutants [6], [7], [8]. Consequently, assessing the physicochemical characteristics and spatial distribution of heavy metals in such wells is crucial for understanding potential risks to human health and for informing sustainable groundwater management strategies in rapidly urbanizing regions.

To effectively evaluate these contamination risks, the analysis of physicochemical parameters serves as a fundamental step in determining groundwater quality and its suitability for various uses, including domestic, agricultural, and industrial purposes. Parameters such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), hardness, and alkalinity provide insights into the chemical composition and overall health of an aquifer [9]. For instance, pH indicates the acidity or alkalinity of water, while EC and TDS reflect the concentration of ions and dissolved salts that influence taste, scaling potential, and corrosion [10]. Rahman *et a*l. [11] emphasized that correlations among these parameters often indicate anthropogenic influence, a pattern also reported by Akpataku *et al*., [12], and Rahim *et al*. [13] who observed increasing physicochemical deterioration in densely populated regions. Similar trends have been observed in sub-Saharan Africa, where unregulated urbanization and inadequate sanitation practices have accelerated groundwater degradation [14]. These findings underscore the necessity of regular physicochemical monitoring to ensure that groundwater used for domestic and industrial purposes remains within the permissible limits of international standards, thereby safeguarding public health and promoting sustainable water resource management.

Among the various factors influencing groundwater quality, the occurrence of heavy metals is of great concern, as their concentration and mobility are often reflected in the physicochemical composition of water. Heavy metals constitute a critical group of contaminants that pose substantial risks to groundwater quality, human health, and ecological systems. These metals, which include lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), zinc (Zn), nickel (Ni), and manganese (Mn) enter groundwater primarily through industrial effluents, agricultural leaching, waste disposal, and corrosion of metallic infrastructure [15], [16]. The mobility and persistence of these metals enable them to infiltrate aquifers, where they often remain for extended periods due to their non-biodegradable nature. Pathways such as urban runoff, acid mine drainage, and percolation from contaminated soils or septic systems further exacerbate their accumulation [17]. Once ingested through drinking water, heavy metals bioaccumulate in vital organs, leading to adverse health outcomes including nephrotoxicity, neurodegeneration, carcinogenesis, and disruption of enzymatic processes [18], [19]. Ecologically, these contaminants can impair biodiversity by altering soil microbial activity and bioaccumulating through trophic levels, ultimately affecting human populations dependent on aquatic food sources [20]. The complexity of their pathways and toxicological impacts underscores the need for continuous groundwater monitoring, stricter waste management policies, and the development of sustainable remediation technologies to mitigate their long-term effects on public health and ecosystems.

One of the predominant pathways through which heavy metals and other pollutants infiltrate groundwater in urban and peri-urban areas is the effluent from on-site sanitation systems such as septic tanks. Septic tanks are widely employed as on-site wastewater treatment systems in both urban and peri-urban areas of Lagos and other parts of Nigeria, where centralized sewage systems are lacking [21]. These systems typically consist of two compartments—a concrete septic tank and a soak away pit—that facilitate the separation of solid and liquid waste, allowing partially treated effluent to percolate into the subsurface soil. However, due to high groundwater tables, permeable sandy soils, and improper siting, effluents from these septic tanks can infiltrate aquifers, leading to the contamination of nearby groundwater sources [22]. Empirical studies have demonstrated that septic effluents carry elevated levels of organic matter, nutrients, pathogens, and heavy metals, which degrade groundwater quality when located in close proximity to wells and boreholes [23], [24]. Omowumi [25] further revealed that septic plumes can migrate up to 10 meters below the surface, influencing the physicochemical and microbiological quality of hand-dug wells depending on the direction of groundwater flow. A recent systematic review by Gyimah *et al*. [26] identified nitrates, phosphates, Escherichia coli, and trace metals as recurrent contaminants from septic effluents globally, emphasizing the role of soil type, septic density, and maintenance practices in determining contamination levels. These findings underscore the potential of septic systems to serve as diffuse and persistent sources of groundwater pollution, posing serious public health risks in densely populated regions such as Ojo Local Government Area of Lagos State.

Ojo Local Government Area (LGA) is a rapidly urbanizing region located in the western part of Lagos State, Nigeria, characterized by dense residential settlements, commercial activities, and institutional zones such as Lagos State

University. The area experiences a humid tropical climate and is underlain by coastal alluvial deposits, which make groundwater the primary source of domestic and institutional water supply [27]. Due to inadequate municipal water infrastructure, most residents rely on hand-dug wells and boreholes, while domestic wastewater disposal is largely through on-site systems such as septic tanks and soak away pits. This reliance on shallow groundwater and informal sanitation infrastructure exposes the aquifers to contamination from anthropogenic activities, including leakage from septic systems and improper waste disposal. Studies conducted within Ojo and its environs have raised concerns over declining groundwater quality, with elevated levels of nitrate, iron, and magnesium, as well as heavy metals such as lead, nickel, and manganese exceeding permissible limits [28], [29]. Olaiwola *et al*., [27] also reported spatial variability in groundwater quality across Lagos State University, Ojo, linking the exceedance of physicochemical parameters to agricultural runoff and effluent infiltration. Similarly, regional studies across Lagos metropolis have documented comparable trends of heavy metal pollution in groundwater near dumpsites and high-density residential areas, indicating a broader pattern of groundwater vulnerability [30], [31]. These findings collectively highlight the pressing need for systematic assessment and monitoring of groundwater in Ojo LGA, particularly given the increasing dependence on hand-dug wells situated near septic tank systems. While investigations have identified elevated levels of nitrate, lead, and iron in groundwater within urban and peri-urban areas, there remains limited understanding of how these contaminants interact under varying hydrogeological and environmental conditions typical of densely populated regions like Ojo. Furthermore, few studies have employed spatially explicit mapping and geostatistical analyses to illustrate contamination gradients or identify hotspots of groundwater pollution around septic tank systems. This gap constrains the ability to accurately predict exposure risks and to design evidence-based mitigation strategies for communities that rely heavily on hand-dug wells for domestic water supply.

This study is therefore justified by the urgent need to evaluate the physicochemical characteristics and spatial distribution of heavy metals in hand-dug wells located near septic tanks in Ojo LGA, Lagos. Assessing the spatial distribution of contaminants provides an evidence-based approach to identifying pollution hotspots and guiding targeted interventions for groundwater protection. The findings from this study will contribute significantly to environmental management by providing localized data essential for policy formulation and regulation of on-site sanitation systems. Moreover, the research will support public health protection by revealing the extent of human exposure to heavy metals and other pollutants, while promoting the sustainable use of groundwater resources in rapidly urbanizing communities.

2. Materials and methods

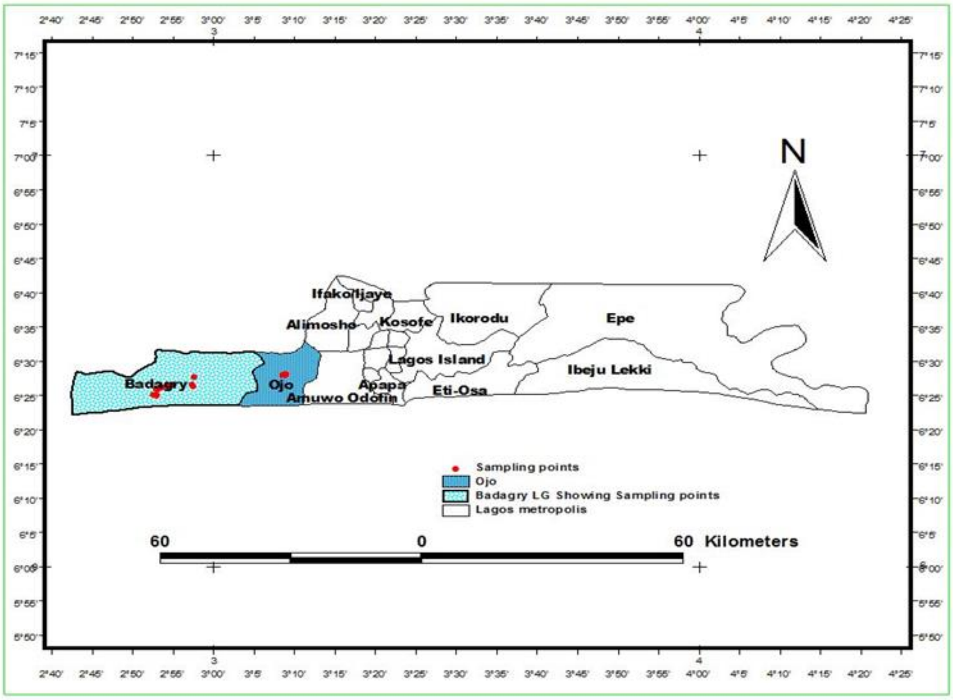

Figure 1 Map of Ojo showing selected wells for sample collection

Ojo is a local government area and town in the southwestern part of Lagos State, known for its diverse population and vibrant commercial activities. It lies between latitudes 6° 27' 0" North and longitudes 3° 13' 0" East, covering a total area of 158 km^2 (Figure 1).

Table 1 Coordinates of each well sampled in Ojo, Lagos state

Well code	Location/ sampling site	Cordinates
WW 1	12, Taiwo Adefuye Street, Iyalode Bus Stop, Ilogbo Elegba	N06.46665, E003.14722
WW2	11, Taiwo Adefuye Street, Iyalode Bus/Stop, Ilogbo Elegba	N06.46662, E003.14811
WW 3	10, Hassan Close, Ilogbo Elegba	N06.46590, E003.14695
WW 4	No. 1 Taiwo Adefuye Street, Ilogbo-Elegba	N06.46752, E003.14445
WW 5	No. 79, Adele Ekun Compound, Alatewo Street, Ilogbo-Elegba	N06.46617, E003.14951
WW 6	No. 39, Mosudo Street, , Iyalode, Bus Stop, Ajangbadi Road	N06.46602, E003.15000
WW 7	230, Iyalode Bus Stop, Ilogbo-Elegba, Ajangbadi Road	N06.46550, E003.14830
WW 8	No. 157, Iyalode Bus/Stop, Ajangbadi Road	N06.46524, E003.14813
WW 9	238, Oloriebi Bus/Stop, Ilogbo-Elegba, Ajangbadi Road	N06.46545, E003.14757
WW 10	35, Babalola Street, Babalola Roundabout, Ajangbadi Road.	N06.46578, E003.14533
WW 11	No. 40, Ilogbo Elegba Road, Ajangbadi Road	N06.46565, E003.14436
WW 12	No. 21, Oke Agbo Street, Ilogbo-Elegba, Ajangbadi Road	N06.46515, E003.14328
WW 13	No. 27, Oke-Agbo Street, Ilogbo-Elegba, Ajangbadi Road	N06.46521, E003.14276
WW 14	No. 5 Kajola Street, Ilogbo Round About, Ajangbadi	N06.46662, E003.14424
WW 15	No. 17 Kajola Chief Akogun off Ilogbo-Elegba	N06.46663, E003.14436

2.1. GIS Mapping

A handheld global positioning system (GPS) receiver (Garmin GP12 Personal Navigator) was used to generate the coordinates of sampled well water locations. An Arc View 329 program (Environmental System Research Institute [ESRI], Inc, Redland) served as the primary GIS software [32] for the creation of spatial distribution maps of heavy metals in water samples from the study area. The results are shown in (Table 1)

2.2. Samples Collection

Over a period of twelve (12) months, water samples were collected from fifteen hand-dug wells located within the study area during the rainy and dry seasons. The selection of the sampling sites was based on their closeness to an obvious source of septic tank pollution.

For sample collection, brand-new one-liter plastic bottles with screw-caps made of hard plastic were utilized. Prior to use, the sampling containers were thoroughly cleaned [33]. After carefully cleaning the containers with 1:1 $HNO3$, they were rinsed multiple times with distilled water and with the water that would be used for the sample. The different fetching buckets used by the different household were used for the actual samplings. Typically, this is a rubber container constructed from a vehicle or motorcycle wheel tube that is fastened to a long chord or an empty, used 4-liter paint plastic container fastened to a long rope.

2.3. Field parameters

The distance of well to septic tank, pH, temperature, conductivity, total dissolve solids (TDS) Oxygen Reduction Potential (ORD), salinity, and turbidity were determined on site for accuracy.

2.3.1. Physicochemical Parameters

Temperature (°C), pH, conductivity (µS/cm), salinity (mg/L), total dissolved solids (TDS-mg/L), and ORP (mV) of the samples were measured using a handheld Oyster pH meter (Model 341350A) that ran on a battery and was standardized with pH buffer solutions (4, 7, and 10 before use). The digital recorder was used to record the values.

The turbidity of the samples was measured using a portable battery-operated HI 93703 Portable Microprocessor Turbidity Meter standardized with HI 93703-0 and HI93703-10 FTV/NTU standard solutions and the values read from the digital recorder. The nephelometric turbidity units (NTU) were used to express the results.

2.4. Heavy Metals Determination (Iron, Manganese, Zinc, Copper, Cadmium and Lead) in the fifteen sampled wells in Ojo LGA, Lagos

A Buck 210 VGP Atomic Absorption Spectrophotometer (AAS system) was used to analysed the concentrations of heavy metals (Fe, Cu, Mn, Cd, Pb, and Zn) at their respective wavelengths in the water samples.

2.5. Sample pretreatment for total heavy metal analysis

The samples were prepared for analysis by carefully mixing 250ml of raw water with 5ml of concentrated nitric acid (HNO_3) in a beaker. After the mixture was reduced to roughly 50 ml by heating it on a hot plate, it was let to cool. To ensure that all the metal ions were dissolved, another 5ml of concentrated HNO_3 was added, and the mixture was then heated for 2 to 5 minutes. Following cooling, the solution was transferred into a volumetric flask and diluted with distilled water to reach a final volume of 50 ml. Following preparation, the Buck 210 VGP Atomic Absorption Spectrophotometer was used to determine the heavy metal concentrations in the prepared solution.

3. Results

3.1. Assessment of physical characteristics of the sampled wells

Fifteen (15) wells in Ojo local government areas in Lagos state, Nigeria, were sampled. It was discovered that every well analysed had a septic tank (ST) sewage system near it and were all hand dug (HD). Of the 15 wells, the surroundings of 12 (80%) were uncemented and unclean, whereas the surroundings of wells 1, 4, and 13 were clean and cemented. All other wells were left uncovered, with the exception of well 1. Well no. 13 had borehole pipe inserted into it and the pumping machine fixed outside. The wells range in depth from 3.04 to 5.56 meters. The distance between the well and septic tank ranged from 1.5 to 80 meters. Around the well locations, sandy soil was the most common type of soil. Every well had a casing, and the number of rings varied from four to six. (Table 2).

Table 2 Physical characteristics of the sampled hand dug (HD) wells

Well code	Characteristics of hand dug wells	Type of sewage system	Distance from septic tank(m)	Well depth (m)	No of casing	Soil type
WWI	Covered with metal + cemented clean environment.	Septic tank	80	5.56	6	Sand
WW2	Not covered + not cemented and dirty environment.	Septic tank	3.00	4.40	5	Sand
WW3	Not covered + not cemented dirty environment.	Septic tank	1.50	5.55	6	Sand
WW4	Not covered + cemented clean environment.	Septic tank	3.50	3.50	4	Sand
WW5	Not covered + not cemented dirty environment.	Septic tank	80.00	3.85	5	Sand
WW6	Not covered + not cemented dirty environment.	Septic tank	8.00	4.30	5	Sand
WW 7	Not covered + not cemented + dirty environment.	Septic tank	8.00	4.48	6	Sand
WW 8	Not covered + not cemented dirty environment	Septic tank	3.00	3.04	4	Sand
WW 9	Not covered + not cemented dirty environment.	Septic tank	2.00	4.45	5	Sand
WW 10	Not covered + not cemented dirty environment.	Septic tank	4.55	4.82	5	Sand

WW 11	Not covered + not cemented dirty	Septic tank	80	4.00	5	Sand
WW 12	Not covered + not cemented dirty environment.	Septic tank	100	3.85	6	Sand
WW 13	Not covered + borehole pipe + cemented clean environment	Septic tank	100	5.05	5	Sand
WW 14	Not covered + not cemented + dirty environment.	Septic tank	80	4.65	5	Sand
WW 15	Not covered + not cemented + dirty environment.	Septic tank	16.60	4.17	5	Sand

3.2. Physicochemical Parameters

The average pH of the well water sampled ranged from 4.78 ± 0.07 to 6.57 ± 0.12. Eleven of the fifteen wells sampled had pH values below the acceptable limits (6.5 - 8.5) suitable for portable water. The turbidity of the well water ranged from 0.00 to 18.13 ± 7.12 NTU, acceptable turbidity for drinking water is < 5, while conductivity ranged from 168.55 ± 4.35 to 1622.50 ± 36.50 µS/cm. The total dissolved solids (TDS), salinity and ORD values ranged from 112.80 ± 3.00 to 1089.00 ± 25.00 mg/L; 84.15 ± 2.25 to 811.50 ± 17.50 mg/L and 40.00 ±3.00 to 137.00 ± 2.00 mV respectively during rainy season. While in dry season, fifteen wells sampled had the pH values ranged from 4.79 ± 0.02 to 6.12 ± 0.17 which is below WHO acceptable limit. Turbidity ranged from 0.00 to 24.38 ± 17.07 NTU. For conductivity, the values obtained ranged from 181.95 ± 6.35 to 1693 ± 13.00 µS/cm, while the TDS ranged from 122.05 ±3.95 to 1135.00 ± 9.00 mg/L and ORD ranged from 61.50 ± 9.50 to 136.50 ± 0.50 (Tables 3 and 4).

3.2.1. Concentration of Heavy Metals in Sampled Wells during rainy and dry seasons

The heavy metal analysis results for the well water samples are presented in Tables 5 and 6. The elements lead (Pb), zinc (Zn), cadmium (Cd), manganese (Mn), copper (Cu), and iron (Fe) were examined in both the rainy and dry seasons. The results were compared to drinking water requirements set by the World Health Organization (WHO). Iron (Fe) concentrations in wells range from 0.01 mg/L to 0.09 mg/L during the rainy and dry seasons, which is significantly lower than the World Health Organization's (WHO) recommended limit of 0.3 mg/l. The obtained values for copper (Cu) fell below the maximum permissible limit of 1.3 mg/L, ranging from 0.000 mg/L to 0.004mg/L. The range of manganese (Mn) concentrations was 0.00 to 0.16 mgL-1. Only one well out of the fifteen wells sampled had manganese (Mn) concentrations marginally higher than the WHO's recommended acceptable level of 0.2 mg/L. When employed in cooking, manganese causes precipitation in food, stains clothing and metal components, gives water a bitter taste, and encourages the growth of algae in reservoirs. The concentration of cadmium (Cd) falls between 0.001 to 0.005 mgL-1, which is under the WHO-recommended threshold of 0.005 mgL-1. Lead concentrations in all areas under study during the rainy and dry seasons range from 0.00 mgL-1 to 0.05 mgL-1, above the WHO limit of 0.01 mg/l. Lead is a very hazardous metal that builds up in both human and animal skeletons. The water samples zinc (Zn) contents ranged from 0.01 to 0.03 mgL-1, which is below the WHO's maximum permissible limit of 3.0 mgL-1 for drinking water. Because the measured water has a low quantity of zinc, it may not taste caustic and can be utilized for household purposes. The nitrate values in all the water samples ranged from 17.12 to 41.09 mgL-1both in rainy and dry season

Table 3 Physicochemical parameters of the well water sampled in Rainy season

Well code	**ORD (mV)**			**Salinity(mg/L)**			**Conductivity (µS/cm)**			**TDS (mg/L)**			**Turbidity (NTU)**			**pH values**			**Temp(^{0}C)**		
	mean		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**
Well 1	84.00	±	1.00	84.15	±	2.25	168.55		4.35	112.80	±	3.00	0.00	±	0.00	5.75	±	0.05	27.35	±	0.25
Well 2	120.50	±	.50	224.50	±	9.50	449.50	±	19.50	301.00	±	13.00	0.06	±	0.06	5.05	±	0.01	27.85	±	0.25
Well 3	84.00	±	9.00	721.00	±	34.00	1443.00	±	68.00	966.00	±	46.00	18.13	±	7.12	5.75	±	0.14	26.75	±	0.25
Well 4	40.00	±	3.00	493.50	±	31.50	987.00	±	63.00	661.50	±	42.50	5.58	±	5.38	6.57	±	0.12	25.90	±	0.20
Well 5	48.00	±	1.00	527.00	±	14.00	1054.00	±	28.00	705.50	±	18.50	2.64	±	1.75	6.35	±	0.00	28.00	±	0.30
Well 6	110.50	±	1.50	230.50	±	14.50	461.00	±	29.00	308.00	±	19.00	0.54	±	0.54	5.25	±	0.03	28.00	±	0.30
Well 7	64.00	±	2.00	329.50	±	11.50	654.50	±	17.50	441.00	±	15.00	0.35	±	0.35	6.05	±	0.01	28.25	±	0.35
Well 8	112.00	±	5.00	505.50	±	35.50	1011.00	±	71.00	677.00	±	47.00	11.30	±	10.46	5.24	±	0.11	27.30	±	0.50
Well 9	137.00	±	2.00	398.00	±	12.00	797.50	±	23.50	536.00	±	13.00	0.71	±	0.71	4.78	±	0.07	28.70	±	0.50
Well 10	97.00	±	17.00	401.50	±	8.50	803.00	±	17.00	538.50	±	11.50	1.54	±	0.56	5.46	±	0.30	27.85	±	0.85
Well 11	81.00	±	6.00	811.50	±	17.50	1622.50	±	36.50	1089.00	±	25.00	4.76	±	1.58	5.76	±	0.12	28.10	±	0.50
Well 12	53.50	±	1.50	379.00	±	54.00	758.00	±	107.00	508.50	±	72.50	1.01	±	0.69	6.25	±	0.02	27.65	±	0.45
Well 13	112.00	±	20.00	282.50	±	43.50	565.00	±	87.00	378.50	±	58.50	0.00	±	0.00	5.22	±	0.39	28.05	±	0.25
Well 14	116.50	±	1.50	547.50	±	14.50	1096.50	±	28.50	734.00	±	20.00	1.02	±	0.21	5.18	±	0.09	28.85	±	0.15
Well 15	98.00	±	31.00	343.50	±	29.50	687.50	±	58.50	460.00	±	39.00	10.70	±	8.29	5.46	±	0.56	28.55	±	0.55
P Value	0.000			0.000			0.000			0.000			0.029			0.000			0.134		
WHO Std	NO			NO			1000			500			5			6.5-8.5			25.1		

Table 4 Physicochemical parameters of the well water sampled in dry season

Well code	ORD (mV)			Salinity(mg/L)			Conductivity (µS/cm)			TDS (mg/L)			Turbidity (NTU)			pH values			Temp(^{0}C)		
	mean		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**	**mean**		**SD**
Well 1	90.00	±	1.00	90.90	±	3.20	181.95	±	6.35	122.05	±	3.95	0.00	±	0.00	5.77	±	0.07	28.20	±	0.70
Well 2	118.00	±	4.00	487.00	±	185.00	975.00	±	370.00	653.00	±	248.00	2.75	±	1.41	5.07	±	0.26	28.40	±	0.70
Well 3	85.50	±	15.50	694.50	±	13.50	1378.50	±	38.50	931.00	±	18.00	24.38	±	17.07	5.67	±	0.29	28.55	±	1.75
Well 4	84.50	±	56.50	408.50	±	154.50	818.00	±	310.00	548.00	±	207.00	1.80	±	0.51	5.73	±	0.94	28.05	±	0.95
Well 5	61.50	±	9.50	556.00	±	16.00	1114.00	±	31.00	745.00	±	22.00	3.82	±	1.82	6.12	±	0.17	28.60	±	0.60
Well 6	119.00	±	14.00	240.00	±	19.00	479.00	±	39.00	321.50	±	25.50	5.00	±	2.34	5.20	±	0.21	28.85	±	0.75
Well 7	76.50	±	9.50	337.00	±	27.00	668.00	±	60.00	451.50	±	36.50	0.00	±	0.00	5.87	±	0.15	29.25	±	0.75
Well 8	134.00	±	15.00	528.00	±	38.00	1057.00	±	76.00	708.00	±	51.00	3.19	±	0.68	4.87	±	0.28	28.60	±	0.80
Well 9	136.50	±	0.50	424.00	±	14.00	840.50	±	24.50	568.50	±	18.50	0.96	±	0.96	4.79	±	0.02	29.10	±	0.60
Well 10	95.00	±	10.00	408.00	±	14.00	814.50	±	26.50	546.00	±	19.00	1.48	±	0.11	5.55	±	0.19	29.25	±	1.25
Well 11	94.00	±	6.00	846.50	±	6.50	1693.00	±	13.00	1135.00	±	9.00	8.75	±	0.36	5.04	±	0.60	28.70	±	0.60
Well 12	88.50	±	1.50	369.00	±	45.00	737.50	±	90.50	495.00	±	61.00	3.74	±	0.34	5.63	±	0.03	28.45	±	0.55
Well 13	122.50	±	10.50	270.50	±	7.50	541.50	±	14.50	651.00	±	298.00	0.04	±	0.04	5.05	±	0.19	28.70	±	0.40
Well 14	123.00	±	1.00	537.50	±	7.50	1073.50	±	17.50	720.50	±	10.50	0.48	±	0.12	5.04	±	0.02	29.85	±	0.45
Well 15	106.00	±	37.00	368.50	±	21.50	737.00	±	44.00	493.50	±	29.50	3.34	±	1.97	5.35	±	0.65	28.90	±	0.80
P Value	0.000			0.000			0.000			0.000			0.013			0.000			0.982		
WHO Std	NO			NO			1000			500			5			6.5-8.5			25.1		

Note: ORD: Oxygen Reduction TDS: Total Dissolved Solids; NO: No standard; P < 0.001 Significant

Table 5 Mean Concentrations of heavy metals in Ojo sampled wells (Rainy Season)

Sample Number	Co-ordinates	Heavy metal ion concentration in mg/l						
		Fe	Cu	Mn	Cd	Pb	Zn	NO
Well 1	N06.46665, E003.14722	0.04	0.001	0.04	0.001	0.02	0.01	19.94
Well 2	N06.46662, E003.14811	0.02	0.001	0.05	0.002	0.01	0.01	39.14
Well 3	N06.46590, E003.14695	0.05	0.001	0.04	0.004	0.02	0.03	40.57
Well 4	N06.46752, E003.14445	0.06	0.001	0.02	0.003	0.02	0.02	40.25
Well 5	N06.46617, E003.14951	0.05	0.001	0.01	0.003	0.02	0.01	40.57
Well 6	N06.46602, E003.15000	0.05	0.001	0.02	0.004	0.02	0.01	33.27
Well 7	N06.46550, E003.14830	0.04	0.001	0.03	0.003	0.02	0.02	40.57
Well 8	N06.46524, E003.14813	0.07	0.001	0.05	0.003	0.02	0.02	39.41
Well 9	N06.46545, E003.14757	0.06	0.011	0.05	0.003	0.02	0.02	37.98
Well 10	N06.46578, E003.14533	0.05	0.000	0.02	0.002	0.01	0.01	37.09
Well 11	N06.46565, E003.14436	0.07	0.002	0.05	0.004	0.03	0.04	41.09
Well 12	N06.46515, E003.14328	0.05	0.001	0.06	0.003	0.02	0.02	37.40
Well 13	N06.46521, E003.14276	0.07	0.001	0.06	0.002	0.03	0.01	16.93
Well 14	N06.46662, E003.14424	0.06	0.001	0.08	0.003	0.01	0.03	40.57
Well 15	N06.46663, E003.14436	0.09	0.001	0.16	0.001	0.02	0.03	39.37
P value		1.000	.591	.000	.386	.683	.005	.000
WHO STD		0.3	1.3	0.2	0.005	0.01	3	50

Table 6 Mean Concentrations of heavy metals in Ojo sampled wells (Dry Season)

Sample Number	Co-ordinates	Heavy metal ion concentration in mg/l						
		Fe	Cu	Mn	Cd	Pb	Zn	NO
Well 1	N06.46665, E003.14722	0.03	0.001	0.00	0.001	0.04	0.02	17.12
Well 2	N06.46662, E003.14811	0.03	0.003	0.03	0.002	0.02	0.03	33.18
Well 3	N06.46590, E003.14695	0.04	0.002	0.04	0.004	0.02	0.02	31.34
Well 4	N06.46752, E003.14445	0.04	0.002	0.02	0.002	0.02	0.02	27.87
Well 5	N06.46617, E003.14951	0.05	0.001	0.02	0.002	0.03	0.01	28.81
Well 6	N06.46602, E003.15000	0.05	0.003	0.02	0.003	0.02	0.02	23.49
Well 7	N06.46550, E003.14830	0.05	0.004	0.02	0.001	0.01	0.02	26.93
Well 8	N06.46524, E003.14813	0.06	0.004	0.01	0.001	0.02	0.02	30.25
Well 9	N06.46545, E003.14757	0.05	0.003	0.02	0.003	0.05	0.02	28.47
Well 10	N06.46578, E003.14533	0.04	0.001	0.02	0.004	001	0.02	28.43
Well 11	N06.46565, E003.14436	0.08	0.001	0.03	0.005	0.01	0.04	43.69
Well 12	N06.46515, E003.14328	0.07	0.001	0.01	0.003	0.01	0.02	28.44
Well 13	N06.46521, E003.14276	0.07	0.001	0.02	0.003	0.01	0.01	37.17

Well 14	N06.46662, E003.14424	0.07	0.000	0.02	0.004	0.002	0.02	36.03
Well 15	N06.46663, E003.14436	0.10	0.002	0.02	0.002	0.01	.06	33.36
P value		0.98	0.092	0.835	.001	0.308	0.001	0.014
WHO STD		0.3	1.3	0.2	0.005	0.01	3	50

P < 0.001 Significant; P < 0.001 Significant

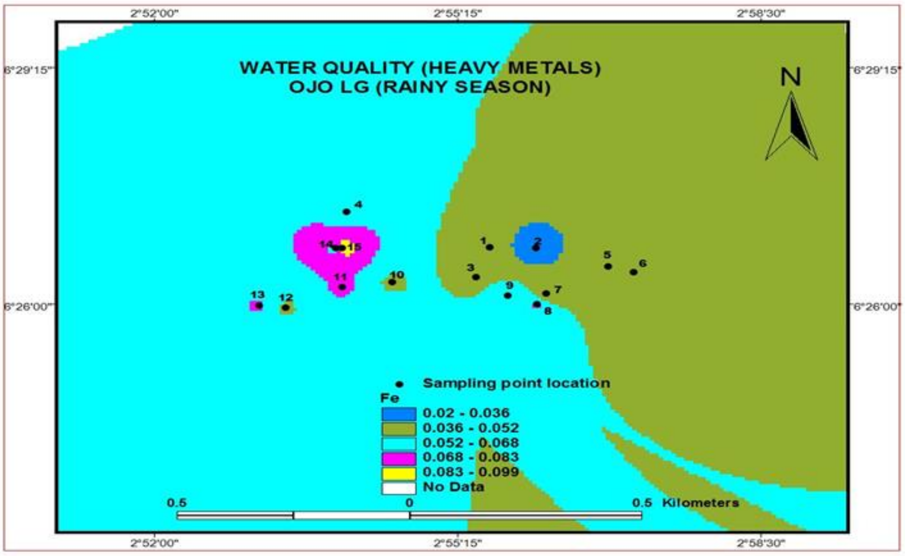

Figure 2 Spatial distribution of Iron (Fe) in well water in Ojo LG, Lagos

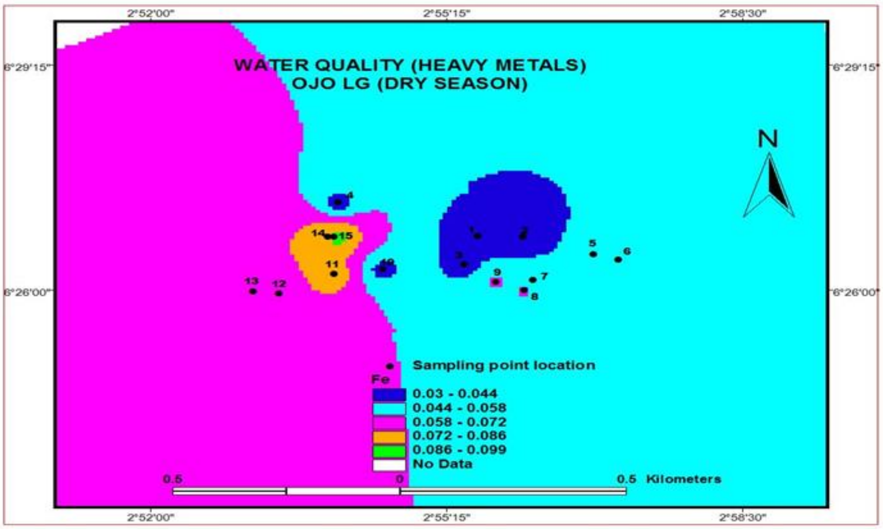

Figure 3 Spatial distribution of Iron (Fe) in well water in Ojo LG, Lagos

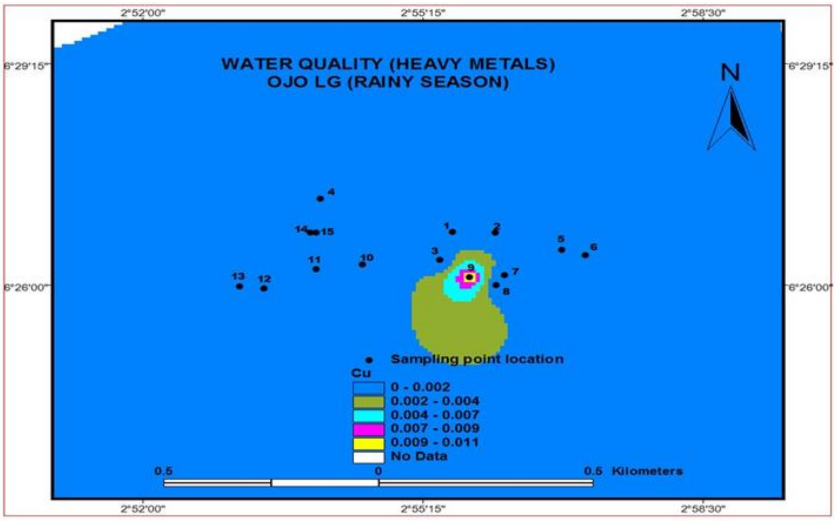

Figure 4 Spatial distribution of Copper (Cu) in well water in Ojo LG, Lagos

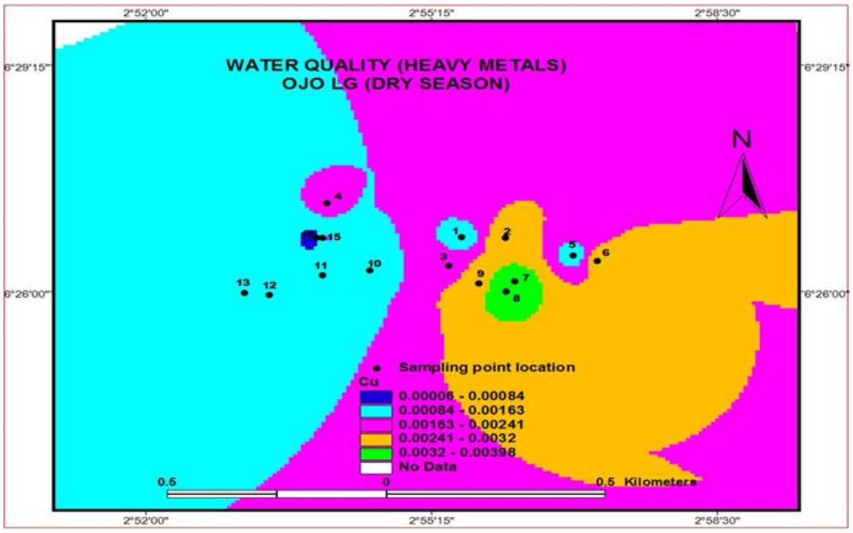

Figure 5 Spatial distribution of Copper (Cu) in well water in Ojo LG, Lagos

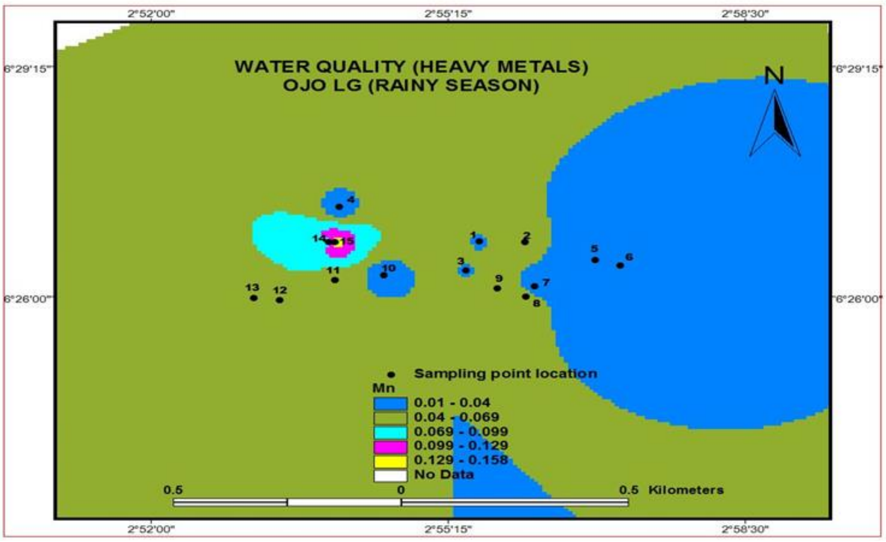

Figure 6 Spatial distribution of Manganese (Mn) in well water in Ojo LG, Lagos

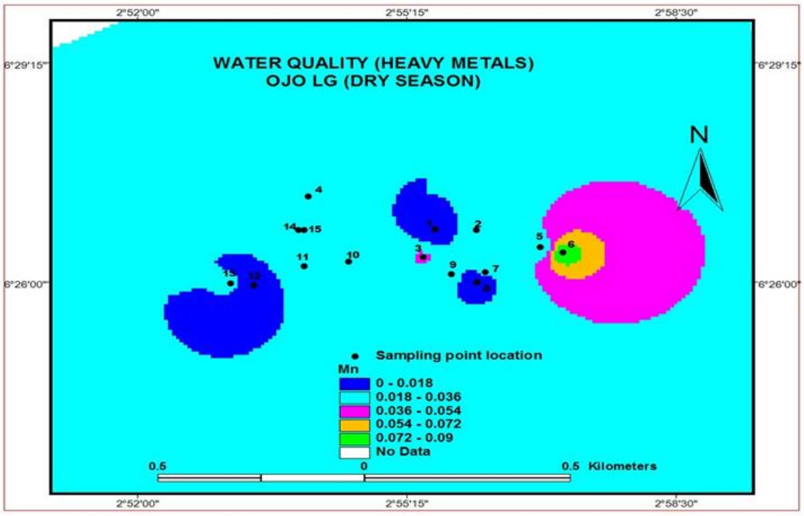

Figure 7 Spatial distribution of Manganese (Mn) in well water in Ojo LG, Lagos

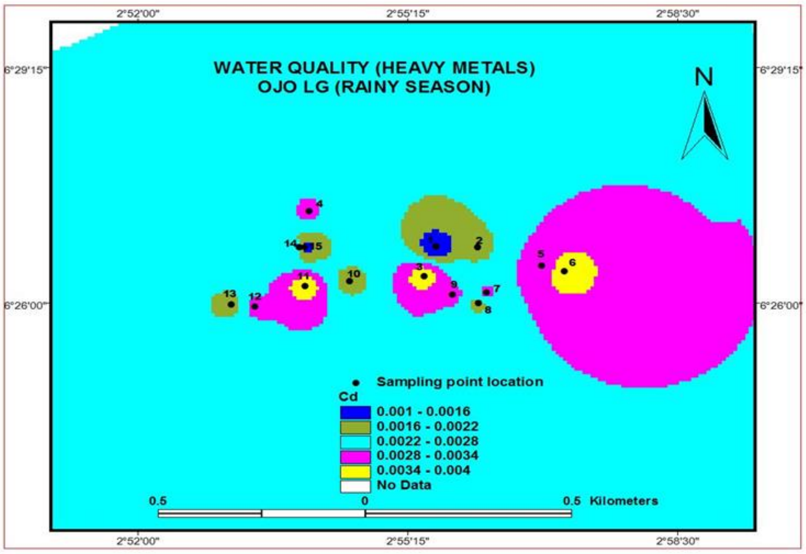

Figure 8 Spatial distribution of Cadmium (Cd) in well water in Ojo LG, Lagos

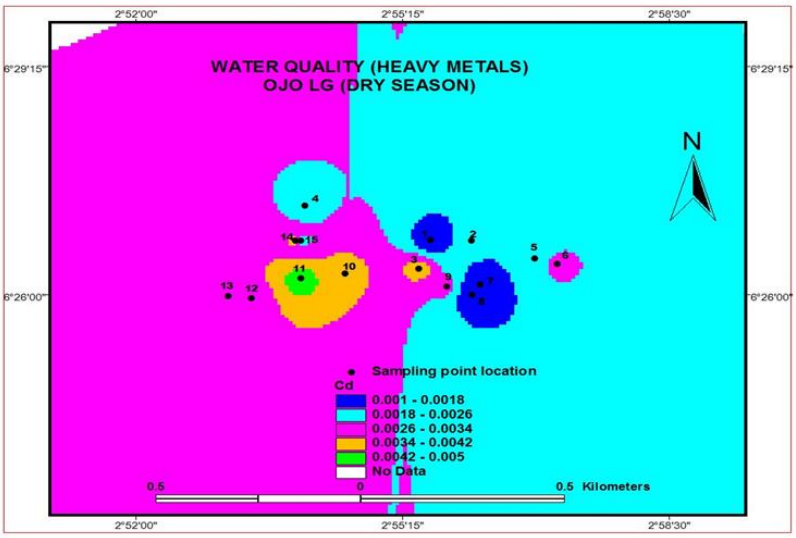

Figure 9 Spatial distribution of Cadmium (Cd) in well water in Ojo LG, Lagos

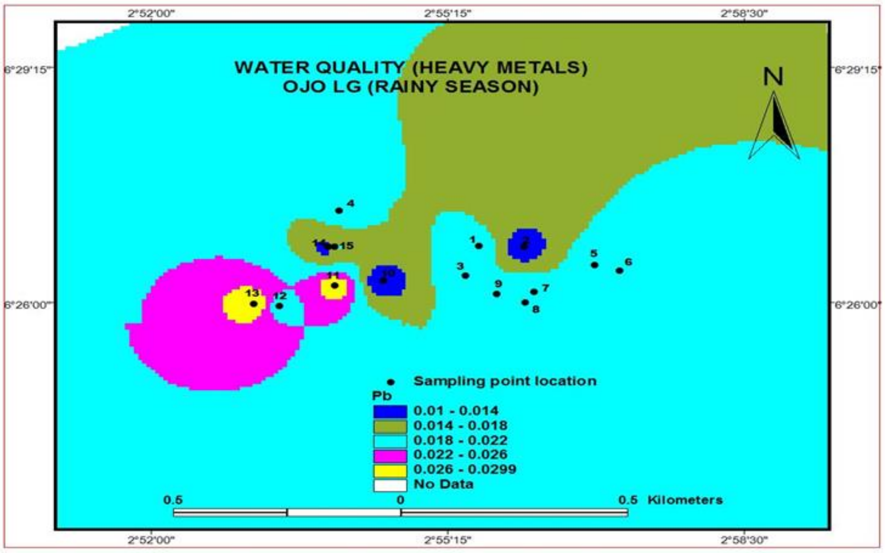

Figure 10 Spatial distribution of Lead (Pb) in well water in Ojo LG, Lagos

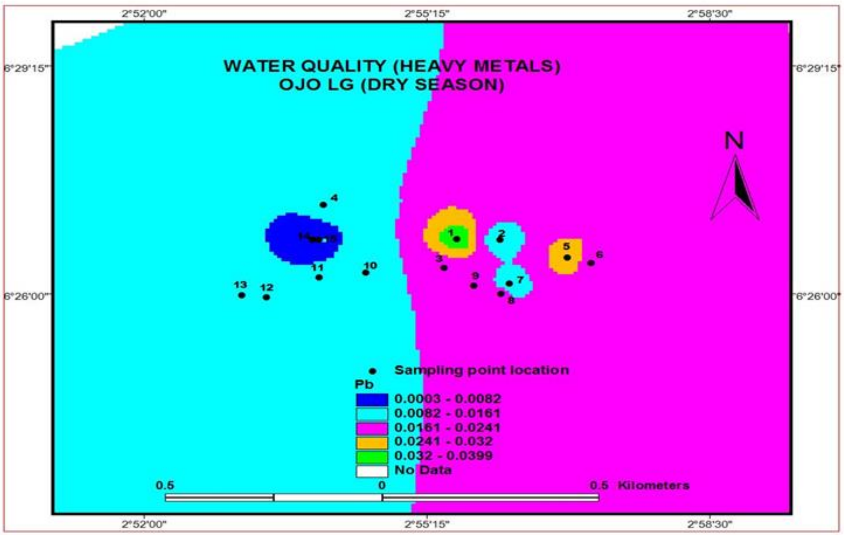

Figure 11 Spatial distribution of Lead (Pb) in well water in Ojo LG, Lagos

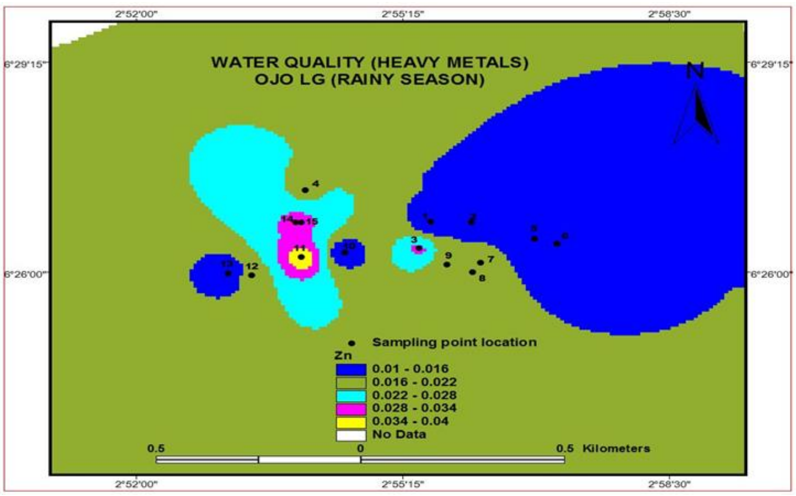

Figure 12 Spatial distribution of Zinc (Zn) in well water in Ojo LG, Lagos

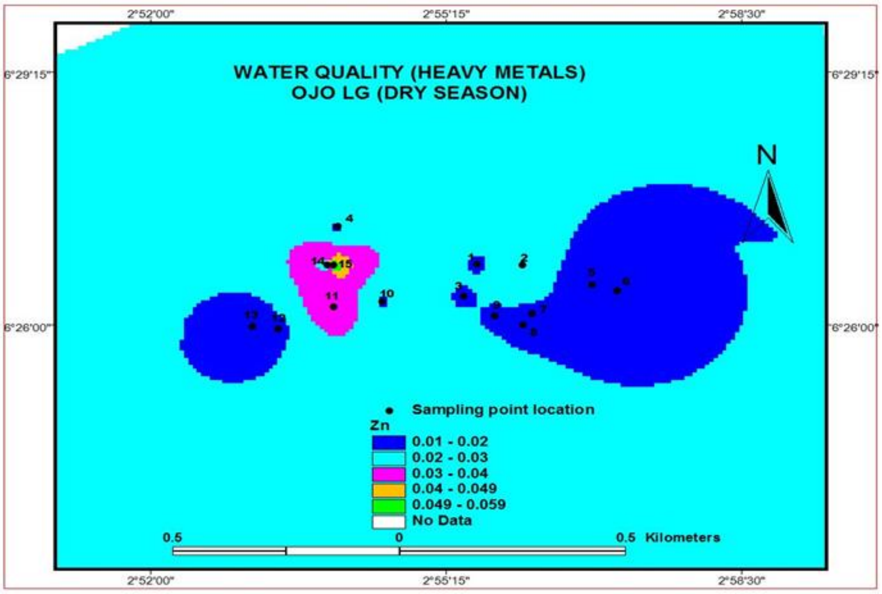

Figure 13 Spatial distribution of Zinc (Zn) in well water in Ojo LG, Lagos

4. Discussion

Water quality assessment has become a big issue today because of the potential hazards associated with the use of contaminated water supplies. It has a great potential of transmitting a wide variety of diseases and illnesses among millions of people that do not have access to safe water supply. Many semi- urban areas in Nigeria such as Ojo do not have access to clean drinking water. Inhabitants of such areas depend on unreliable water sources such as wells, rivers and streams for water supply while few have access to bore-hole water or water from a treated source.

The fifteen (15) wells sampled in the study area are all hand dug wells, sited close to septic tanks. Most of the well's surroundings were not cemented and are dirty. Seven of the wells sampled had a distance from septic tank above the USEPA standard distance of 15.24 meters, while the other eight wells were situated at a proximal distance below the USEPA standard which may promote infiltration of heavy metal and other pollutants into the wells as observed by [22], [24]. The well depth ranged between 3.04 to 5.56 meters, these shallow depths exposed the well water to contamination from anthropogenic activities, including leakage from septic systems and improper waste disposal thereby degrading the quality of the well water. The main soil type in all sampling sites was sandy (Table 2). The Poor casing, shallow depths, proximity to septic tanks, high groundwater tables and the high permeability of sandy soils collectively increase the risk of contamination.

The pH of sampled wells in Ojo was carried out to determine whether it is acidic or alkaline in nature. The values obtained from the sampled wells ranged from 4.78 to 6.57 in both rainy and seasons. Most of the sampled wells had pH values below the WHO acceptable limits (6.5 - 8.5) suitable for portable water, these values indicated that the well water samples are slightly acidic. The acidic nature of the water could be attributed to the presence of acidic metabolites and or the presence of tiny shale intercalations in the aquiferous coastal plain sand. Continuous consumption of acidic water over time is known to have some detrimental effect on human health such as eroding of tooth enamel, leading to dental problems like tooth decay and sensitivity, it also causes stomach upset, nausea, indigestion in some individual. Five of the sampled wells were turbid and had values beyond WHO standard limit of 5 NTU. This may be due to refuse dump and surface run-off into the well water. Turbidity is a measure of light-emitting properties of water and is used to indicate the quality of waste discharged with respect to colloidal matter, the greater the turbidity of water sample the higher the risk of microbial contamination hence the possibility of prevalence of gastrointestinal diseases among the users of the water sample. The high values of conductivity recorded in four of the well sampled in rainy and dry seasons indicates a high level of dissolved solids and impurities in the water, which can render the water unfit for drinking. Eleven (73.3%) of the well water samples had total dissolved solids (TDS) values above the WHO standard limit which shows that the well water is unacceptable and not recommended for human consumption due to the effect on human health such as gastro-intestinal irritation as well as fabric stains.

Heavy metals are among the most harmful environmental contaminants. They are harmful due to their toxicity, persistence, and bioaccumulation. The presence of these elements in water results from both natural and artificial sources, such as land dumping of waste products, usage of agricultural inputs, industrial effluents, sewage, and sludge from diesel generators. [34], [35]. The metals generated from these activities tend to percolate through soil into the water table, thus polluting the underground water. The concentration of some heavy metals (Zn, Fe, Cu, Mn, Cd and Pb) in wells was determined in this study. The concentrations of zinc, iron, copper, manganese and cadmium in both rainy and dry session were far below the desirable limit set by World Health Organization (WHO) for drinking water. However, their presence is of public health concerns due to the potential long-term impacts of continuous exposure. For instance, zinc, which is considered as one of the important non- toxic trace elements that plays a significant role in the physiological and metabolic process of many organisms when in excess may cause system dysfunction resulting in growth impairment and reproduction with clinical symptoms such as vomiting, diarrhea, hematuria, liver and kidney failure, and anaemia [18], [36]. Iron is the fourth most abundant element by mass in the earth's crust. In water, it occurs mainly in ferrous or ferric state [37]. It is an essential and non - conservative trace element found in significant concentration in drinking water because of its abundance in the earth's crust. Usually, iron occurs in groundwater in the form of ferric hydroxide [38]. Though the iron concentration were below the WHO limit for domestic use, the shortage of iron causes disease called "anaemia" and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called haemosiderosis, gene mutation leading to heamochromatosis with symptoms such as fatigue, weight loss, joint pains, as well as heart disease and diabetes. Also, excess iron in water can result in severe allergic reaction with rash and itching, difficulty in breathing, tightness in chest, swelling of mouth, lip sand faces, black tarry stools and severe blood or streaks of blood in the stool. Manganese impacts a bitter taste to water, stains cloths and metal parts and precipitate in foods when used for cooking, it also promotes the growth of algae in reservoirs and excessive manganese intake may cause hypertension in patients older than 40years old as well as symptoms of toxicity mimic those of Parkinson's disease i.e. tremors, stiff muscles. The low concentration of Manganese implies that water from the sampled wells would not promote the growth of algae in reservoirs or collection tanks. Cadmium concentrations across all sampled wells were within the WHO guideline value of 0.005 mg/L. However, cadmium remains a significant threat because of its carcinogenic properties and long biological half-life, which allows it to accumulate in organs such as the liver and kidneys. Chronic exposure can cause kidney damage, while acute exposure to high concentrations may trigger immediate health effects. The concentration of lead in most of the sampled wells were above the WHO permissible limit for drinking water. This high value is of great concern as lead has been recognized for centuries as a cumulative general metabolic poison. It is a neurotoxin and is responsible for the most common type of human metal toxicosis [39]. Also, studies have linked lead exposures even at low concentration with an increase in blood pressure and reduced intelligence quotient in children and attention disorder. Some of the important reasons for the slightly high lead concentration in the sampled water might be as a result of vibrant commercial activities such as increased in traffic flow, industrialization, emissions from automobile exhausts contaminants from these activities can leach through the soil, contaminating groundwater thereby contributing to high lead levels.

The spatial and seasonal variations in the concentrations of the six heavy metals (Fe, Cu, Mn, Cd, Pb, and Zn) under investigation are shown in Figures 2–13. Every element was divided into three categories: harmful or extremely poisonous, above permissible, and permissible. The concentrations of all other elements stayed below WHO permitted range, with the exception of lead, which continuously surpassed the allowable threshold.

5. Conclusion

Well water has been a significant substitute home water supply for many years. The amounts of heavy metals, such as copper, zinc, cadmium, lead, manganese, and iron, were measured in this study using water samples from hand-dug wells. Only lead, with concentrations ranging from 0.01 to 0.05 mg/L, was found to be above the World Health Organization's (WHO) acceptable limit of 0.01 mg/L. This result shows that the research area's wells are contaminated with lead, making the water unfit for human consumption. Lead offers serious health concerns, including poisoning and other chronic illnesses, even at low concentrations. The observed spatial and seasonal fluctuations in metal contents indicate that the hand-dug wells are probably contaminated by point sources. Routine well monitoring and assessment are critical for protecting water quality, particularly to prevent chemical contaminants from infiltrating the system. Several measures are recommended: Existing wells should be well maintained, with open wells outfitted with long-lasting covers and constructed in accordance with local requirements and best practices. Communities should prioritize sanitation by encouraging residents to install and use modern toilet facilities while also implementing better sewage disposal procedures. Furthermore, strict compliance to the WHO requirement that wells be located at least 50-100 feet away from septic tanks is required to maintain a safe and sustainable water supply for the community.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by, Tayo Modupe Kayode-Isola, Olusoji Olusegun Adebisi, Olukayode Oluwole Isola, Sunday Awe, Kehinde Imisi Temitope Eniola and Abass Adebayo Olalekan. The first draft of the manuscript was written by Tayo Modupe Kayode-Isola and, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The data sets generated during and/or analysed during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to privacy or ethical restrictions.

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