Ground Water Quality Assessment and Health Risk in a Semi-Urban Nigerian Community

A Case Study of Ifetedo L.G.A.

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Publication Date: 2026/09/09

Abstract: This study accessed the Geospatial Analysis of Water Quality for Domestic use in Ifetedo, Ife South L.G.A., Osun State. The study described the distribution of water resources for drinking purposes, and the physico-chemical properties and quality of the water samples were modeled using geospatial methods. Data were primarily collected from selected households with the aim of assessing the bacteriological and physico-chemical properties. The water samples were collected using 2 L polyethylene bottles and sterilized 100 ml glass bottles by using 281 nested groups placed over the study area, from which thirty-two grids were purposively selected. The coordinates of sample locations were also collected using GPS. The water samples were taken to the laboratory for the determination of selected ions (Pb, Fe, Cd, As, Ca2+, Mg2+, K+) and total coliform (TC) count. Water quality was assessed in reference to the recommended limits of the World Health Organization. The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method, and correlation statistics were used to examine the relationship between water quality parameters among groundwater sources and surface water sources during both wet and dry seasons using Stata software. The results revealed that hand dug well was the major source of water supply for domestic use (70%), followed by stream water (18%), borehole (8%), and mono pump (4%) in common. The results of the physico-chemical properties analysis of water samples showed high variation in the properties of water from different sources examined. When the water quality index was compared with that of the World Health Organization, the findings showed that the water in the study area was mostly fit for irrigation and industrial use. The study concluded that there is a variation in the physical and chemical properties of water in the study area. Groundwater sources are the most common source of water in the area, and the use of groundwater is influenced by geology, seasons, man's activities (anthropogenic factors), and topography. The study established that the majority of water sources sampled were not fit for domestic purposes, as most ranked with high concentrations of chemical elements. Keywords: Geospatial Analysis, Water Quality Index, Physico-chemical Properties, Bacteriological Properties, Total Coliform Count.

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How to Cite: Omorodion Ellen O.; Eludoyin Adebayo O.; Adeleke Oluwafemi A.; Orungbeja Emmanuel O.; Sani Iliya U.; Renner Adeolu M.; Akeredolu Oladayo E. (2026) Ground Water Quality Assessment and Health Risk in a Semi-Urban Nigerian Community. *International Journal of Innovative Science and Research Technology*, 11(8), 3187-3212. https://doi.org/10.38124/ijisrt/26aug1259

I. INTRODUCTION

Water quality plays a vital role in drinking and various domestic uses, directly impacting human and environmental health within a nation (Hall et al., 2014). As the population continues to grow, the strain on water resources intensifies, making careful management essential (Arnell et al., 1999). The Sustainable Development Goals (SDGs), particularly Goal 6, emphasize the importance of safe water and sanitation for human well-being, environmental sustainability, and economic progress. In order to make informed decisions, it is crucial to have comprehensive information and understanding of water quality. Understanding water quality empowers policymakers in the realm of politics to develop effective regulations, legislation, and governance frameworks. By considering the effects of water quality on human health,

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

ecosystems, and societal well-being, policymakers can prioritize sustainable water management and protect communities' interests. Economically, water quality directly affects key sectors such as agriculture, industry, and tourism. A nuanced understanding of water quality's implications in these sectors allows for the formulation of robust economic plans that optimize resource allocation, promote efficiency, and foster sustainable growth. Recognizing the economic value of clean and accessible water enables decision-makers to harness its potential for innovation, job creation, and overall prosperity (SDG 6; Kanu *et al.*, 2011).

At the social level, access to safe and clean water significantly impacts public health and quality of life. Informed decisions regarding water quality ensure that communities have access to drinkable water, reducing the risks of waterborne diseases and enhancing overall well-being. Furthermore, understanding the social implications of water quality can address equity concerns, ensuring that marginalized populations are not disproportionately affected by inadequate water resources or contaminated supplies (Boadi et al., 2005). The environmental dimension of water quality should not be underestimated. A holistic understanding of water quality enables effective conservation and management of ecosystems, safeguarding biodiversity and ecological balance. By incorporating environmental considerations into decision-making processes, pollution can be mitigated, water habitats can be preserved, and sustainable water use can be promoted for the benefit of future generations (Ritchie *et al*., 2003). Recognizing the interdependence of water quality with various aspects of our society allows us to ensure the sustainable management of this invaluable resource and work towards a future where clean and accessible water is universally available (Howard et al., 2003; Umali et al., 1993). The quality of domestic water is crucial for maintaining human health, and protecting distribution systems is essential to ensure the availability of high-quality water for household use. Therefore, it becomes imperative to monitor water quality, quantity, and distribution to achieve access to safe drinking water (Lee et al., 2005). Domestic water quality is a significant public health concern as it is primarily intended for consumption, drinking, and body contact (Asano et al., 2002). Contaminated water can carry microorganisms, biotoxins, toxic contaminants, and various pathogens, leading to diseases such as cholera, dysentery, cryptosporidiosis, hepatitis A, and giardia (Zielinski et al., 2009; Ashbolt et al., 2004). In developing countries, a large proportion of illnesses can be directly or indirectly attributed to unsafe drinking water, inadequate hygiene practices, and open defecation (Rajgire et al., 2013). Water quality assessment provides baseline information on water safety, and continuous monitoring is crucial due to potential changes in water quality over time. While the World Health Organization (WHO) guidelines provide values for 96 substances out of the initially reviewed 128 chemicals, testing for all parameters can be expensive, time-consuming, difficult, and often unnecessary. The selection of parameters for water assessment and monitoring programs should consider local conditions (Mahmud et al., 2007). Despite Nigeria's participation as a signatory to the International Water Decade (1981-1990), the country still faces significant challenges in terms of water supply. It ranks among the countries with the lowest global water supply levels, with low coverage in both urban and rural areas (Adepoju et al., 2009). This situation may be attributed to factors such as weak political commitment, a lack of operational and maintenance culture for existing facilities, and poor workmanship by contractors. In rural areas of southwest Nigeria, the main sources of domestic water include boreholes, hand-dug wells, streams, and other sources (Nnamdi et al., 2010). In conclusion, consuming water contaminated with pathogens or toxic chemicals, as well as using inadequate amounts of water leading to poor hygiene, poses serious health risks. Therefore, water quality assessment and continuous monitoring are crucial. Neglected water-related infectious diseases disproportionately affect disadvantaged populations in developing nations, highlighting the need for increased attention and effective interventions (Sivakumar et al., 2011). Managing water quality from source to tap is essential to ensure access to safe drinking water, prevent disease outbreaks, and maximize the health benefits of clean water (Howard et al., 2003). A comprehensive understanding of water quality encompasses its physical, chemical, biological, and aesthetic characteristics, enabling effective evaluation (Kanu *et al*., 2011; DeZuane *et al*., 1997). Recognizing the economic, social, and environmental dimensions of water quality empowers us to make informed decisions, protect public health, promote sustainability, and strive for equitable access to clean water for all.

➢ *Aim and Objectives of the Study:*

- *Aim*

The study aims at assessing the spatial distribution and quality of drinking water resources with the view to providing decision-support information for domestic water management in line with the Sustainable Development Goal 6, in the study area.

- *Objectives*

The specific objectives are as follows:

✓ Identify the water supply sources in the study area;
✓ Assess the biological and physico-chemical quality of water samples from the water resources in the area; and
✓ Model the spatial and temporal distribution of selected physical and chemical variables over the study area.

➢ *The Study Area*

- Location and Extent: Ifetedo lies within Latitudes 7°10'21'' N and 7°11'14'' N and Longitudes 04°41'25'' E and 04°42'50'' E. The inhabitants are predominantly Yoruba speaking people of the Southwest with a mixture of people from different ethnic groups in Nigeria. It is the administrative capital of Ife South LGA, it has several government offices (Omotola et al., 2019). There are six government primary schools in Ifetedo. None of the schools had a water supply. Among the households in Ifetedo, the two major sources of water supply are streams and wells. Methods of faecal disposal in the primary

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

schools includes pit latrine and open defecation (Omotola et al., 2017).

- Climate: In Osun state and Nigeria as a whole, there are two distinct seasons: the wet season and the dry season. The wet season typically begins in April and extends until October, while the dry season lasts from November to March (Adekunle et al., 2018). The dry season commences with the Harmattan, a dry and chilly period that persists until February, accompanied by dusty conditions caused by northeast winds blowing from the Arabian Peninsula across the hot Sahara Desert. The latter half of the dry season, specifically February to March, experiences the highest temperatures, reaching up to 38 degrees Celsius. The average annual rainfall in the region is approximately 1800mm. During the wet season, the relative humidity in the Ifetedo area is around 75-80% in the morning, leading to early morning precipitation, and decreases to about 68% in the afternoon, resulting in heat and slight physical discomfort (Ogundiran et al., 2020). Rainfall typically commences in February and March, while it ceases around November. The lowest recorded rainfall occurs in January and December, with an average of about 14mm, whereas the highest rainfall is observed in June, averaging 287mm (Gagiano et al., 2012). The mean maximum ambient temperature ranges from 33.84°C in February to 28.8°C in August, while the mean minimum temperatures range from 25.18°C in March to 23.0°C in August 10 (Adekunle et al., 2018). Higher temperatures are recorded during the peak of the dry season, from November to May, whereas lower temperatures are experienced in the rainy season. The mean annual wind speed fluctuates within a narrow range of 4.0 to 6.2m/s. Wind speeds are higher in July and August, known as the period of "August break" (Weyand et al., 2000). Conversely, during the peak of the rainy season in September and October, wind speeds are at their lowest, measuring between 4.1 and 4.2m/s. Over the past ten years, the prevailing wind direction has been south-westerly, with this direction dominating the wetter period of the year, while north-easterlies dominate the drier season (Floyd et al., 1969; Adekunle et al., 2018). Relative humidity tends to be above 70%, especially during the peak of the wet season. The highest relative humidity values, reaching 78%, occur from June to October, while the lowest value of 57% was recorded in February. Atmospheric pressure is highest around November, with a value of 58.36hpa, and lowest in August, measuring 51.83hpa.

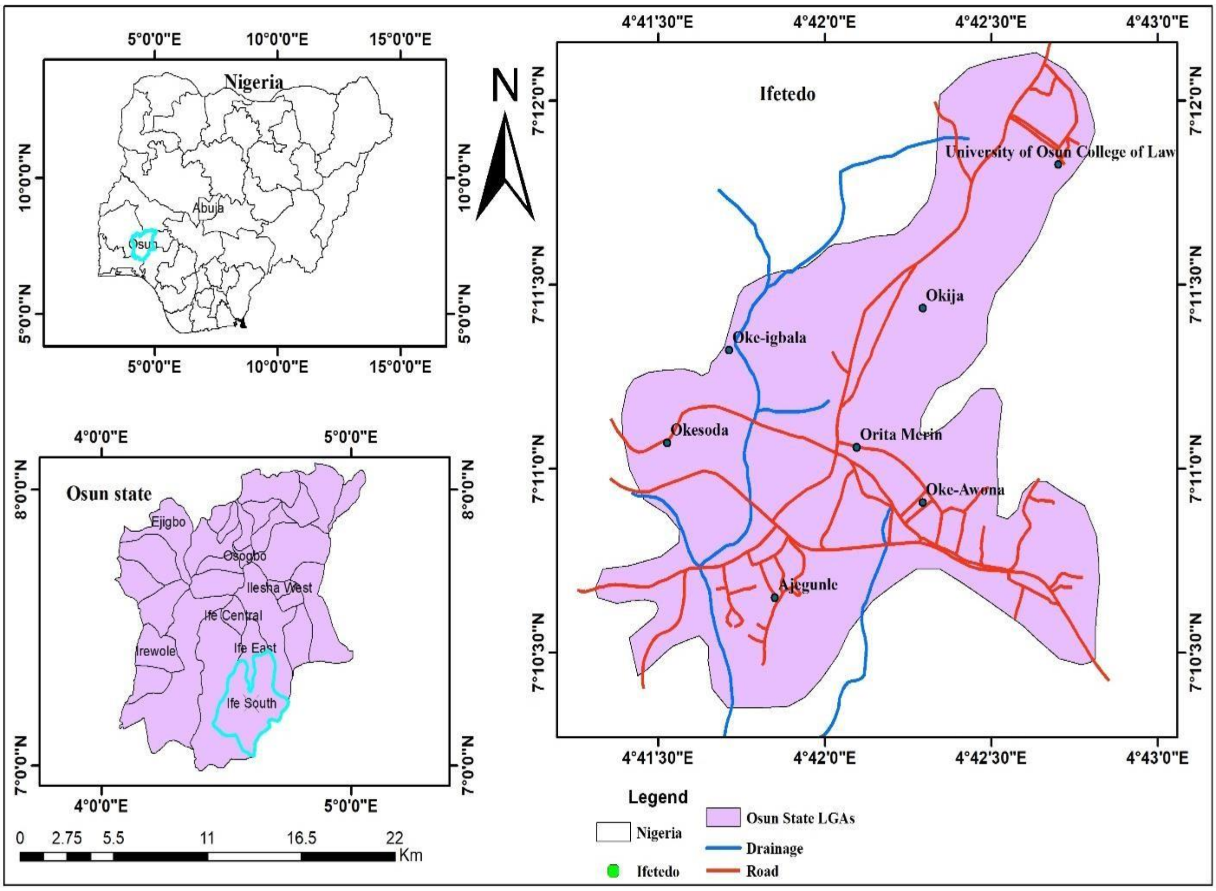

Fig 1 Map of Study Area

- Geology and Soil: The soil is of the highly ferruginous tropical red soils typology, which is associated with basement complex rocks (Fookes et al., 1997; Adekunle et al., 2018). As a result of the dense humid forest cover in the area, the soils are generally deep and of two types, namely, deep clayey soils formed on low smooth hill crests and upper slopes; and the sandier hill wash soils on the lower slopes. The well-drained clay soils of the hillcrest and slopes are very important because they provide the best soils for cocoa and coffee cultivation in

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

the state (Sofoluwe et al., 2012; Dotterweich et al., 2013). The lighter loams are more suitable for cultivation of the local food crops, such as yam, cassava, and maize. Soil degradation and soil erosion are generally not serious in the state, but considerable hill wash is recorded along the slopes of the hills.

- Land Use/ Land Cover: There are various identifiable land use types in Ifetedo, the study area. The land use ranges from dense vegetation in the periphery of the settlement to sparse vegetation and agricultural land use around the settlement. Also, within the settlement there is built-up (residential land use), roads, etc. Although report suggests that there has been reduction and rapid change in the dense vegetation cover of the study area between the periods of 1986 and 2017.
- Vegetation: The planning area consists of heavy forest blended with light forest zones. Some parts are of the Savannah (orchard bush) zone mixed with shrubs. The vegetation of the area falls under tropical rainforest belt characterized by multiple canopies and lianas. Farming practice on the floodplains of some major rivers in Ile-Ife is characterized by small holdings with cultivation of field crops such as maize, cocoyam and vegetables.
- Topography: Ifetedo has an elevation of about 213m above the sea level. The topography within 3.2km of Ifetedo contains significant variations in elevation, with a maximum elevation change of 181.1 meters and an average elevation above sea level of 225m. Within 16 km contains significant variations in elevation (331.8m). Within 80.6 km miles contains very significant variations in elevation (900.1 meters). The area within 3.2 km of Ifetedo is covered by cropland (39%), trees (35%), and grassland (16%), within 16.1 km by cropland (42%) and trees (37%), and within 50.5 km by cropland (40%) and trees (34%).

II. METHODOLOGY

➢ *Data Types and Sources:*

The data for this study were obtained from both secondary and primary sources.

➢ *Primary Data:*

Primary data were collected from the study site, consisting of water samples obtained from selected households within each topological stratum (Fig 3.4). The purpose of this data collection was to assess the physical, bacteriological, and chemical properties of the water. The samples were collected using 2L polyethylene bottles and sterilized 100 ml glass bottles. Additionally, data were primarily collected using Global Positioning Systems (GPS) readings to determine the coordinates and altitude of the sample sites, along with key informant interviews.

➢ *Secondary Data:*

Were sourced from Shuttle Radar Topographic Mission (SRTM) which was used to generate the Digital Elevation Model (DEM) for the area (Fig 5).

➢ *Sampling:*

The coordinates (X, Y, Z) of the locations of sampling points were determined with a handheld Global Positioning System (GPS). The physical, bacteriological and chemical parameters were Acidity (pH), Electrical Conductivity (EC), Total Dissolved Solids (T.D.S), Temperature, Total Coliform Count, Lead, Arsenic, Cadmium and Manganese and the Cations such as Sodium, Potassium, Calcium, and Manganese content. Electrical conductivity (EC) was measured in micro Siemens per cm (µScm-1). The water samples were taken for a wide range of analysis including chemical and bacteriological parameters. The primary data collection involved the use of 2L polyethylene bottles and sterilized 100 ml glass bottles to collect water samples at thirtytwo purposively selected locations across the built-up areas and the different elevation categories in the study area. For water sample collection, a total number of 281 nested grids measuring 26,060.67 sq. meter each was overlaid on the map of the study area. Consequent upon this, a total number of Thirtytwo grids were purposively selected based on availability and accessibility of a functioning water source for domestic purposes: 27 groundwater sources and 5 surface water sources (Figure 3.1). Water samples were collected using adequate aesthetic techniques and determined for pH, conductivity, total dissolved solids (TDS) and water temperature using pH/Conductivity and TDS/water temperature meters on the field. The water samples were taken to the laboratory for the determination of selected ions (Pb, Fe, Cd, As, Ca 2+, Mg2+, K+) and total coliform(TC) count. Water quality were assessed in reference to the recommended limits of the World Health Organisation (2017); Water Quality Index (WQI) using Weighed Arithmetic Index method (Brown et al,1972; US EPA, 2009) and correlation coefficients to examine differences in the Water Quality Parameters (WQPs) between ground water sources and surface water sources during both wet and dry seasons using STATA Software. Key informants in the sampled points were interviewed using the questionnaire as a guide across the sample sites and water samples were collected from each respondent. The imagery of Ifetedo, Ife South Local Government Area was downloaded from Shuttle Radar Topography Mission (SRTM) which was used to generate the Digital Elevation Model (DEM) for the area. From the SRTM, the highest elevation value was 248.5m and the lowest was 119m The elevation difference was calculated to be 129.5m. The contour interval of the digital elevation model was 10m. This was used to enhance visibility of the contour lines and ensure proper delineation into three different categories of elevation, low, medium and high (Figure 3.2). There were three Number of classes of elevation obtained from this delineation and samples were collected across the three distinct topographical strata based on the characteristics and accessibility of the area.

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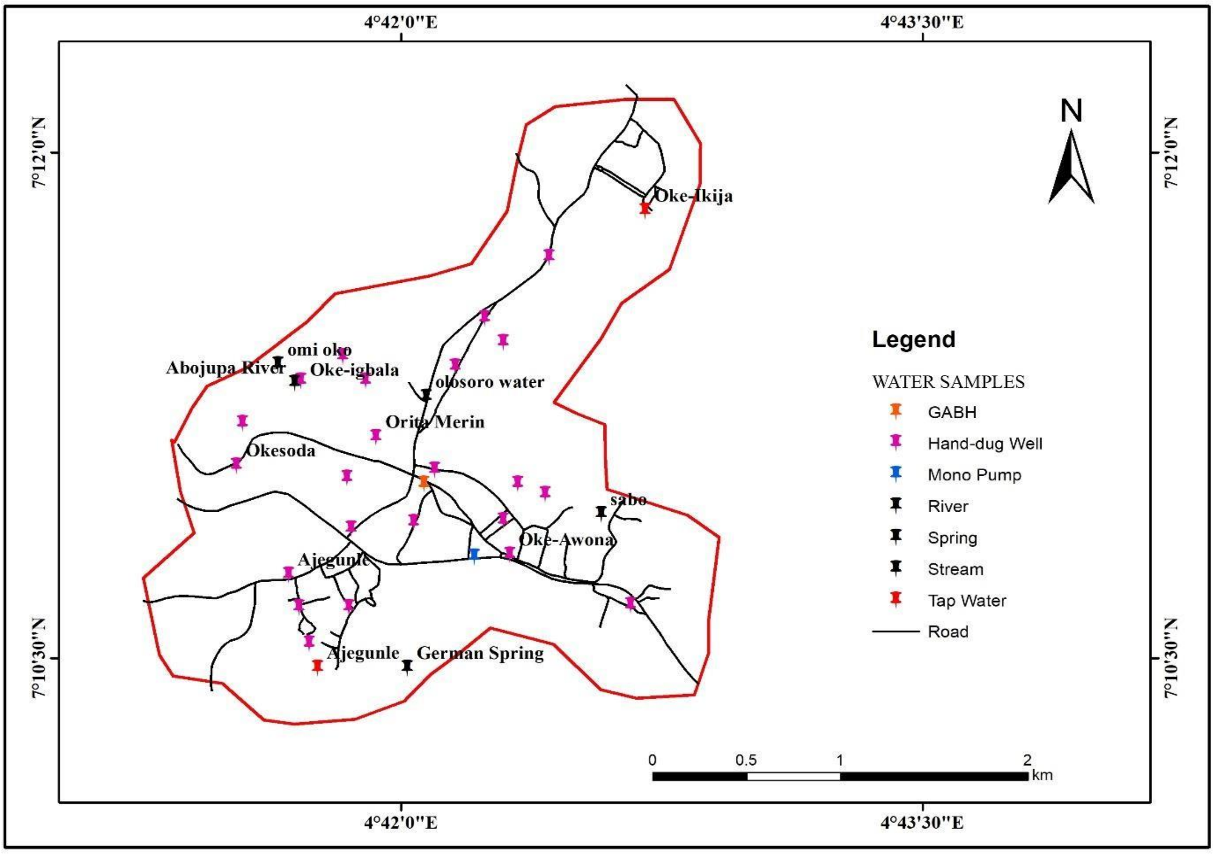

Fig 2 Map of the Study Area Showing the Sample Points

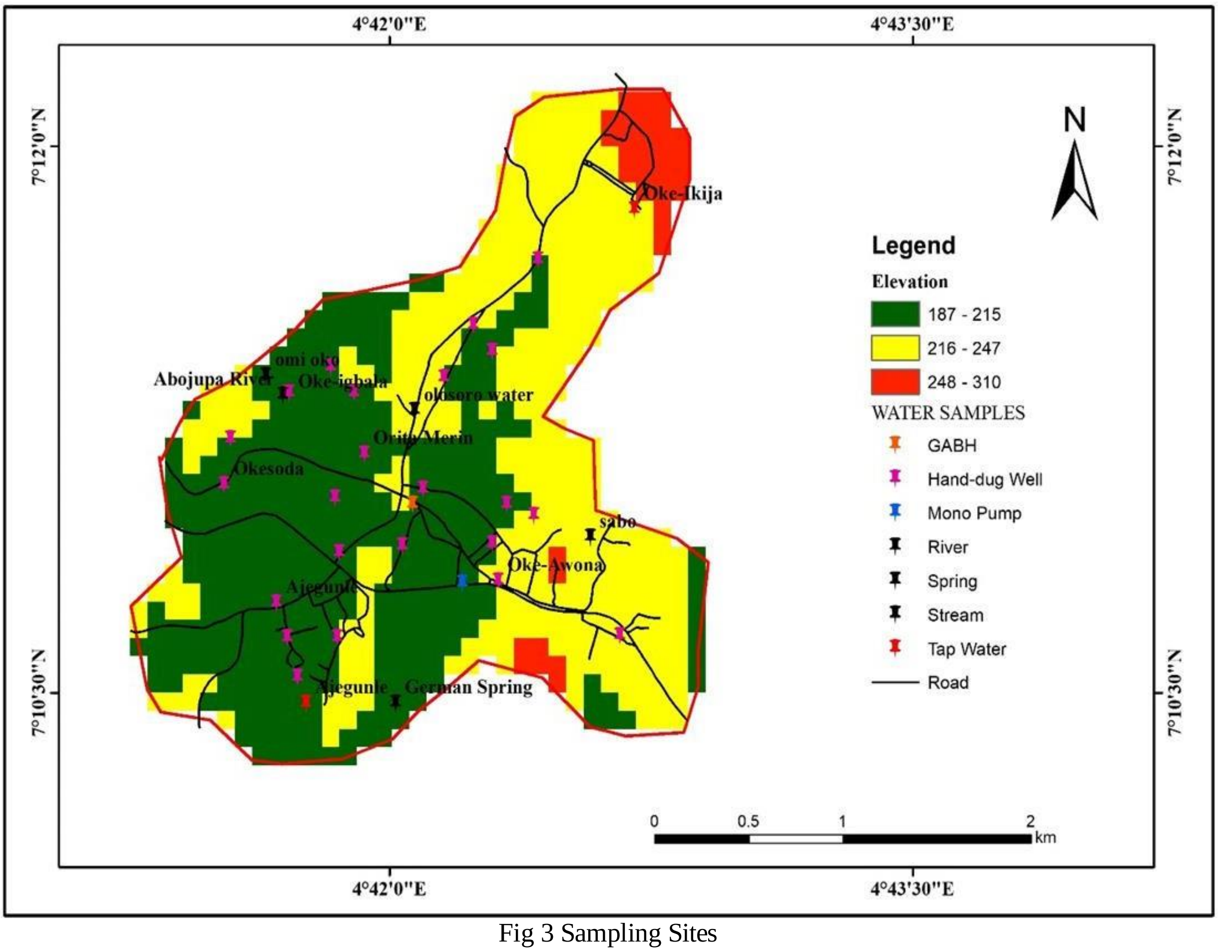

Fig 3 Sampling Sites

➢ *Sampling Frame:*

The sampling frame is the entire households in Ifetedo, where sources of water for domestic purposes are accessible. Though some regions lacked groundwater sources.

➢ *Sample Population:*

The sample population were divided into users of individual (private), communal and public water sources. For the individual/private stratum, a total number of 281 nested grid was cropped from a total of 400 nested grid over the sample site measuring 26,060.67 sq meter was overlaid on the map of the study area, and this makes a total of 27 groundwater sources. Thirty-two grids were purposely selected based on availability and accessibility of a functioning water source for domestic purposes. The grids also contain households that collect water from five surface water bodies (streams/springs/rivers) and three public water sources were also purposely selected. Consequently, 32 key informants, representing 27 households and 5 others from the surface water sources was interviewed for information on water use, quality, among others.

➢ *Sampling Technique:*

The Multistage Sampling technique was employed, where the thirty-two sites were randomly selected from different grids based on the availability of water resources. It should be noted that there was a scarcity of water in some wells as certain sources within the sampling frame had dried up or were not accessible. During the dry season, initial visits were made to four wells, and water samples were collected from these wells. However, it was observed that during the wet season, these wells did not have any water. Respondents confirmed that these wells usually dry up during the wet season but were unable to provide specific information regarding the month or reason for such dryness. Importantly, considering the number of selected households, 32 copies of a set of questionnaires were administered to the chosen key informants. The administration of the questionnaire was accompanied by in-depth interviews to gather comprehensive information.

➢ *Microbiological Analysis of Water Samples:*

The microbial analysis was conducted by a postgraduate student from the Department of Microbiology. The student utilized various tools and equipment for the analysis, including cotton wool, petri dishes, test tubes, an incubator, nutrient agar, distilled water, and an autoclave. The autoclave was used to sterilize the test tubes and other instruments required for the microbial analysis, as well as the 100mL bottles before they were taken to the field. These measures were taken to ensure the samples were free from contaminants and to determine the presence of microbes in the collected water samples.

➢ *Plate Count:*

One ml from each sample were introduced into test tubes containing 9 mL sterile distilled water respectively and then mixed thoroughly for even dispersion of the sample. Serial dilution was done for each sample from 10-1 to 10-3 . This was done by adding 1ml from the first tube to the 9mL of sterile distilled water in the second tube and finally to the third tube. One mL of the diluent from the first tube and the third tubes were transferred into Petri-plates for each water samples. Sterile molten nutrient agar (NA) was aseptically poured into plates containing 10-1 to 10-3 dilution. The plate was as well swirled on the bench to dispense and mix the inoculum with the media and allowed to solidify, inverted and incubated at 37°C for 24 hours.

Table 1 Sample Points/Locations

Sample Points	AREA	STREET	GROUNDWATER SOURCE	TYPE
1	Ajegunle	INEC Area	Hand-dug Well	Covered with rings
2	Ajegunle	Ajegunle Street	Hand-dug Well	covered with no rings
3	Ajegunle	Love Bread Bakery	Hand-dug Well	Covered with rings
4	Ajegunle	Power Line	Tap Water	Storage not Covered
5	Ajegunle	Power Line	Hand-dug Well	covered, with ring
6	Oke-Awona	Ifetedo High Court	Mono Pump	Mono Pump
7	Oke-Awona	Local Government Area	Hand-dug Well	covered with rings
8	Oke-Awona	Oke-Awona Street	Hand-dug Well	not covered
9	Oke-Awona	Sasa Road	Hand-dug Well	No ring
10	Oke-Awona	Sasa Road	Hand-dug Well	covered with rings
11	Oke-Ikija	Baba Akodi Street	Hand-dug Well	covered with no ring
12	Okija	University of Osun College of Law	Tap Water	Tap water
13	Okija	Ifetedo Middle School Area	Hand-dug Well	covered with rings
14	Okija	Moree Street	Hand-dug Well	Not covered and no rings
15	Okija	Otutu Street	Hand-dug Well	Partially covered with no rings
16	Okesoda	Okesoda	Hand-dug Well	covered with rings
17	Okesoda	Ayanbeku	Hand-dug Well	covered and rings
18	Oke-igbala	Oluwalose	Hand-dug Well	covered and rings
19	Oke-igbala	New Hope School area	Hand-dug Well	partially covered and no rings
20	Oke-igbala	Jagi Lagbo	Hand-dug Well	partially covered and no rings
21	Orita Merin	Ayesan	Hand-dug Well	partially covered and no rings
22	Orita Merin	Ayesan	Hand-dug Well	partially covered and no rings
23	Orita Merin	Orita-Merin	Hand-dug Well	partially covered and no rings
24	Orita Merin	Oke-Alafia	Hand-dug Well	Covered with rings
25	Orita Merin	Ayetoro Ogban Area	Hand-dug Well	Not covered and no rings
26	Sabo	Sabo	Hand-dug Well	Covered with rings
27	Sabo	Sabo	GABH	GABH
28	Sabo	Sabo	Spring	Spring
29	Olosoro Water	Sabo	Spring	Spring
30	German Spring	Ikija	Stream	Stream
31	Omi Oko	Oke Igbala	Stream	Stream
32	Abojupa River	Oke Igbala	River	River

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

➢ *Basic Principle:*

The Atomic absorption spectrometric technique makes use of the flames as the atomizers. The sample solutions are aspirated into the flames, and the sample elements are converted into atomic vapors, resulting in the flames containing atoms of the elements. Some atoms are thermally excited by the flames, but most remain in the ground state where they can absorb radiations given off by special 'sources' made from those elements. The wavelengths of radiation given off by the sources are the same as those absorbed by the atoms in the flames. This absorption follows Beer-Lambert's law, which states that the absorbance is directly proportional to the path lengths in the flames and to the concentrations of atomic vapors in the flames. Both of these variables are difficult to determine, but the path lengths can be held constant, and the concentrations of atomic vapors in the flames are directly proportional to the concentrations of the analytes in the solutions being aspirated into the flames. This procedure is used to prepare calibration curves of concentration in the solutions versus absorbance. The basic principles of atomic absorption spectrometry are illustrated in Figure 4, which clearly shows the schematic representations of the basic components of simple AAS instruments.

➢ *Analysis and Calibration:*

Curve Preparation The samples were analyzed with PG990 AASs of the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria, for the metals in the samples by flame atomization. The analyses utilized air-acetylene flames and single-element hollow cathode lamps, following the equipment procedures. In the preparation of the calibration curves for the metals analysis, various concentrations of each metal were prepared from the stock solution 52 (1000 ppm) for each cation. These different concentrations were used to create linear curves for each metal, ensuring that the curves passed through zero.

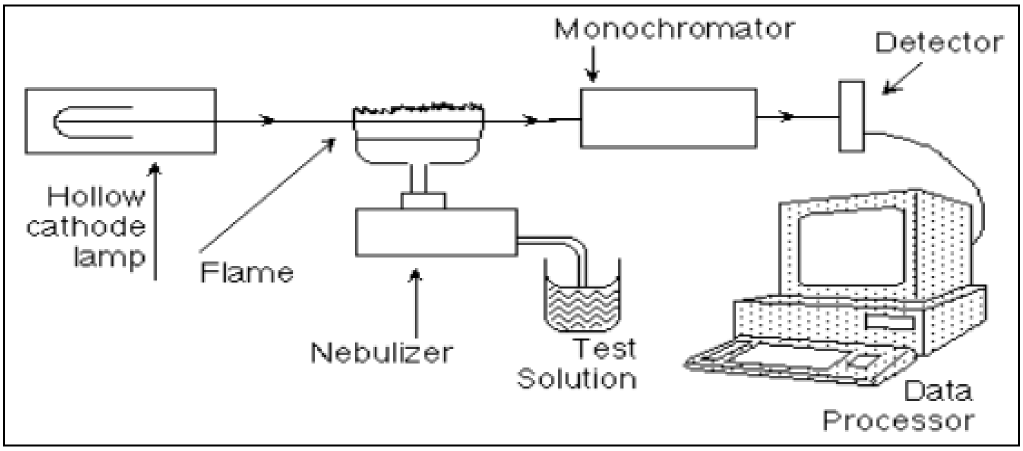

Fig 4 Schematic Diagram of Atomic Absorption Spectrophotometer (AAS)

➢ *Data Analysis:*

Field data was analyzed using descriptive statistics (graphs and charts) and inferential statistics.

➢ *To Describe the Distribution of Water Resources for Drinking Purpose:*

This was achieved by running a frequency test in the EXCEL environment, and plot a graph of X, Y, coordinates and a nearest neighbor analysis in the PAST environment on the water sources for domestic use for domestic purposes.

➢ *Assessment of the Physio-Chemical Quality of Water:*

The laboratory analysis results were transferred to an Excel environment for further analysis. Measures of central tendency were used to determine the domain (overall) minimum and maximum values of the water characteristics for the study area. These measures provide insights into the typical or average values as well as the range of variation for the different water parameters assessed in the study.

➢ *Model the Spatial and Temporal Distribution of Selected Physio-Chemical and Bacterial Variables over the Study Area:*

This was achieved by running Spatial Interpolation (Inverse distance weighted) in the ARCGIS environment on the results of the physicochemical analysis on the quality of domestic water sources in both wet and dry season.

➢ *Relationship Between Ground Water and Surface Water:*

Properties in Dry and Wet Season Correlation and regression statistics were used to establish the relationship between the parameters tested and the water quality index. Pearson correlation was used to assess the relationship between the water properties. The relationship is as expressed in the equation below: $r = N \sum xy-(\sum x) \sum y) \sqrt{}[\sum x\ 2-(\sum x)2][N \sum y2-(\sum y)2]$

Where:

N is number of pairs of scores, $\sum xy$ is sum of the products of paired scores, $\sum x$ is sum of scores, $\sum y$ is sum of y scores, $\sum x\ 2$ is sum of squared x scores, $\sum y\ 2$ is sum of squared y scores, x and y are unknown relationship to be investigated.

The regression equation is: Y predicted =b0+b1x1 + b2x2 + b3x3.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

➢ *Water Quality Index (Calculation of WQI):*

The calculation of WQI was made using Weighed Arithmetic index method (Brown et al,1972) in order to assess water suitability for drinking purposes. The quality rating scale, relative weight, and overall Water Quality Index (WQI) for each parameter respectively. The Quality rating was calculated by using this expression: qi = (Ci/Si) ×100.

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. Let there be n water quality parameters and quality rating (qn) corresponding to nth parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value. qn values are given by the relationship. qn=100 (vn-vi) / (vs-vi) vs = Standard value, vn = observed value, vi = ideal value In most cases vi=0 except in certain parameters like pH, dissolved oxygen etc., exceeding the permissible limits as prescribed by Indian standards. However, the WQI values (38.3 – 42.6) calculated for the different samples indicate that the water is safe for human consumption. It can safely be considered that the values of WQI in the present investigation were reported to be less than 50, indicating that the water is suitable for human consumption. The ranges of WQI, the corresponding status of water quality and their possible use are summarized in Table 2.

Table 2 WQI and Corresponding Water Quality Status

S/N	WQI	Status	Possible Usages
1	10 – 25	Excellent Drinking	Irrigation and Industrial
2	25 – 50	Good Domestic	Irrigation and Industrial
3	51 -75	Fair	Irrigation and Industrial
4	76 101	Poor	Irrigation
5	150 – 100	Very Poor	Restricted use for Irrigation
6	Above 150	Unfit for Drinking	Proper treatment required before use.

Source: National Sanitation Foundations Water Quality Index (NSFWQI)

Fig 5 Methodology Flow Chart

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

III. RESULTS AND DISCUSSION

The study found that there were two major sources of water supply in the communities. These were underground and surface water (Fig 7). However, the technologies used to harness water across the community varied in protection and types. In Ifetedo, there were some form of water intervention programmes; The Government assisted boreholes, Spring water house, and Mono pump. The most common method of harnessing underground water was through hand dug wells used by 75%. This was followed closely by streams (18%), bore holes (10%) and mono pump (2%). (Figure 6). The analyses of water source revealed a result in line with the findings of Oluyemi et al. (2010) posited that the major source of water for Osun state in general is the hand dug wells. However, Konwea et al., (2020) revealed that there was variation in water withdrawal from these different sources of water according to seasons. This is due to failure of hand dug well especially in the dry season. This is because there were seasonal variations in water levels thus affecting the quantity of water a borehole or hand-dug well can produce at a particular time of the year. Maximum quantity of water is pumped out of a borehole or hand-dug well during the wet season because of the high recharge rate accompanying high rainfall in the wet season, while in the dry season, reverse is the case. This type of failure account for 8 % of the total borehole and hand dug well failures reported in many areas of Osun State including Ifetedo. The problem of water level fluctuation can also arise from over-pumping, resulting in dynamic water levels dropping below the pump intake, leading to seasonal failure of water.

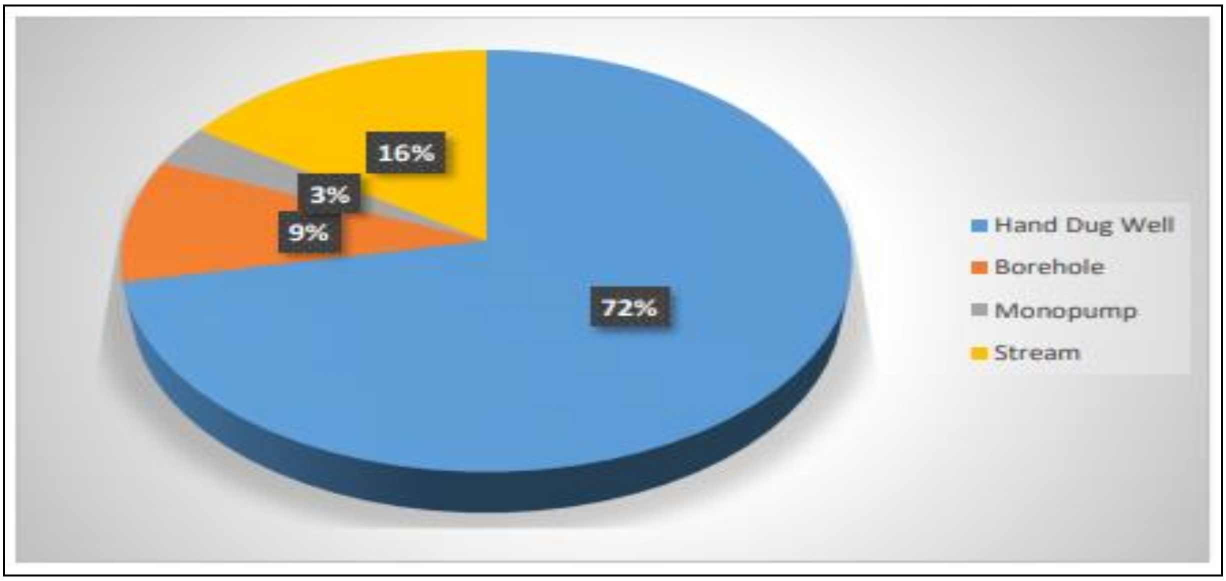

Fig 6 Percentage of Identified Water Points of Selected Water Sources in Ifetedo, Ife South LGA

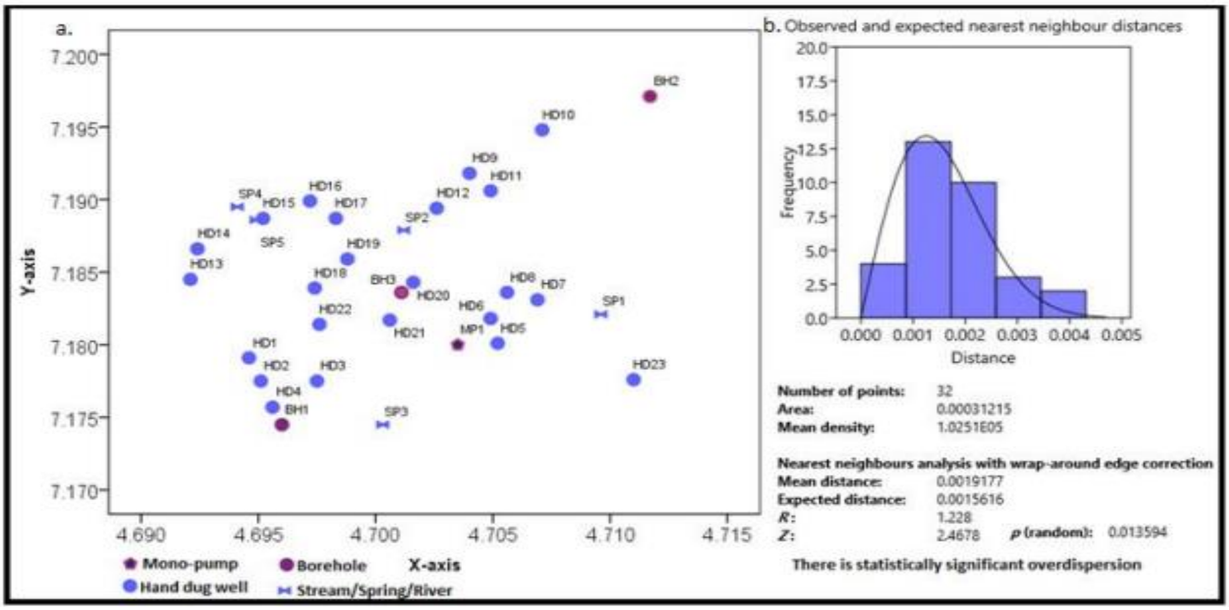

Fig 7 Distribution of Water Resources in Ifetedo, Ife-South Local Government Area, Osun State; a. Shows the Pattern Obtained from the Neighbourhood Analysis, b. is the Distribution Across Varying Distances Indicating that the Sources Significantly Dispersed (Overdispersed)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

There were a total of 32 points in this sample, arranged in 32 rows of X,Y coordinates. It was observed that the nearest neighbor mean distance was calculated as 0.0019177, and the expected mean nearest neighbor distance was calculated as 0.0015616. These two values were compared using the normal distribution for a=0.05 (2-tail), which is +/- 1.96. The calculated Z value was 2.4678, which was less than 2.58. The calculated Z value indicated that the p-value calculated for the randomly distributed pattern was less than 0.05. Therefore, it was statistically significant, showing that the observed variance was higher than the variance of the theoretical model. Over dispersion is a very common feature in applied data analysis because, in practice, populations are frequently heterogeneous (non-uniform), contrary to the assumptions implicit within widely used simple parametric models (Fig 7).

Table 3 Physical and Chemical Characteristics of Sampled Water Resources

Variables	**Boreholes**						**Hand-dug wells**			**Streams**		
	Govt. Assisted			**Privately owned**								
	Mean	SD	Min - Max	Mean	SD	Min - Max	Mean	SD	Min - Max	Mean	SD	Min - Max
Water temperature	29.33	2.1654	27-31.5	30.6	1.3856	28.7-29	28.55	3.6761	27-31.7	27.05	1.2777	25.5-28.5
pH	6.3	0.5944	5.5-6.8	6.77	0.4041	6.3-7.0	6.59	0.8901	36-657	6.95	0.7275	6.2-8.2
Conductivity	243.75	207.069	100-542	192.33	128.36	62-252	218.04	157.008	36-657	120.6	134.206	32-438
Total Dissolved Solids	121.25	104.13	47-271	96.33	63.89	31-126	109.34	79.58	14-336	65.95	77.85	16-269
Arsenic	0.0093	0.0043	0.005-0.013	0.005	0.0044	0.003-0.01	0.0066	0.0022	0.002-0.013	0.0067	0.0016	0.003-0.01
Lead	0.0075	0.0029	0.004-0.011	0.0073	0.0031	0.005-0.008	0.0072	0.0138	0.001-0.015	0.0069	0.0029	0.003-0.014
Iron	0.090	0,0238	0.042-0.1	0.05	0.005	0.045-0.055	0.069	0.0168	0.55-0.1	0.0906	0.0117	0.075-0.11
Cadmium	0.026	0.0135	0.012-0.043	0.022	0.0072	0.017-0.03	0.0255	0.0087	0.01-0.057	0.0164	0.0082	0.013-0.046
Calcium	0.0608	0.0485	0.019-0.109	0.0893	0.0525	0.03-0.132	0.0746	0.0148	0.017-0.144	0.075	0.0440	0.025-0.124
Magnesium	0.0303	0.0105	0.018-0.039	0.0237	0.0047	0.022-0.038	0.0265	0.0077	0.015-0.051	0.0285	0.0044	0.019-0.04
Sodium	0.0413	0.0218	0.023-0.072	0.055	0.0164	0.037-0.073	0.0511	0.0216	0.022-0.114	0.0608	0.0153	0.032-0.09
Potassium	0.0933	0.0205	0.07-0.118	0.067	0.025	0.04-0.09	0.0652	0.0264	0.057-0.098	0.087	0.0171	0.052-0.101

The concentration or values of selected physio-chemical variables examined in the study are presented in Table 3.

The groundwater sources are distributed into hand dug wells, wells not used for drinking purposes, commercial boreholes, privately owned boreholes and government provided hand pump wells, for clarification on their uses and quality expectations. Water temperature generally viewed as 24.6-38.80C with the warmest water being that of the commercial boreholes. pH unit in the boreholes were also more acidic than those of the hand dug wells, varying 5.26-7.8 units while the hand dug wells were 6.5-8.9 units in range. In term of conductivity, the least value occurred at a privately owned hand dug well. Aluminium ion was detected in the boreholes (0-1.8mg/L) but not in the hand dug wells while arsenic and lead mainly occurred in the hand dug wells (0-0.003, 0.003-0.001 mg/L) but were not detected in the boreholes. Temperature of water is basically important because it effects bio-chemical reactions in aquatic organisms. A rise in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the tastes and odours. The average temperature of groundwater samples of the study area was 28.88 °C and in the range of 25.5 °C to 31.7 °C. Temperature in this study was found within permissible limit of WHO (30 °C). Ezeribe et al. (2012) reports similar result (29 °C) of well water in Nigeria. In dry season the groundwater temperature ranges from 27°C to 31.5 °C where the Mono Pump had the least temperature and the Government assisted borehole with the highest Temperature. In wet season, groundwater temperature ranges from 27 °C to 30 °C where the Mono Pump maintained the least temperature and a Hand dug well the highest temperature. Unfortunately, the Government assisted borehole which had the highest temperature during the dry season was dried up upon visit during the wet season. Surface water maintained presumably temperatures below 30 °C in both seasons. Ranging from 25.5 °C to 28.5 °C in both wet season and dry season. Abojupa River had the least temperature in the dry season while Omi Oko Stream had the least temperature in the wet season. Omi Oko Stream had the highest temperature in the dry season while Olosoro Spring had the highest temperature in the wet season. The average surface water temperature in the study area was 27.05 °C.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

➢ *Temperature:*

Table 3 displays the values of water temperature for the different water sources; Boreholes, Hand-dug wells, Streams, Government-Assisted, and Privately Owned sources. The data includes the mean, standard deviation (SD) and the minimum and maximum values observed for each water source. Comparing the mean temperatures, Boreholes had an average temperature of 29.33oC, Hand-dug wells had an average temperature of 30.6 oC, Streams had an average temperature of 28.55 oC, and Government-Assisted sources had an average temperature of 27.05 oC. In relation to the World Health Organization (WHO) standards, the temperature values fall within the acceptable range for drinking water. According to the WHO guidelines, the recommended temperature for drinking water ranges from 10oC to 20oC the temperature values observed in the table are higher than the lower limit but still within permissible range. Higher water temperatures can have certain effects on human health. Firstly, elevated water temperature can promote the growth of microorganisms, including bacteria and algae, which can lead to waterborne diseases. Additionally, warm water can affect the taste and odour of drinking water, making it less pleasant to consume. Moreover, hot water may cause scalding or burns if used for direct contacts with the skin. It is important to note that although the temperatures are within their acceptable range, other water quality parameters should also be considered to ensure the safety and suitability of the water for human consumption. Regular monitoring and testing of water sources and necessary to identify any potential risk or deviations from the recommended standards.

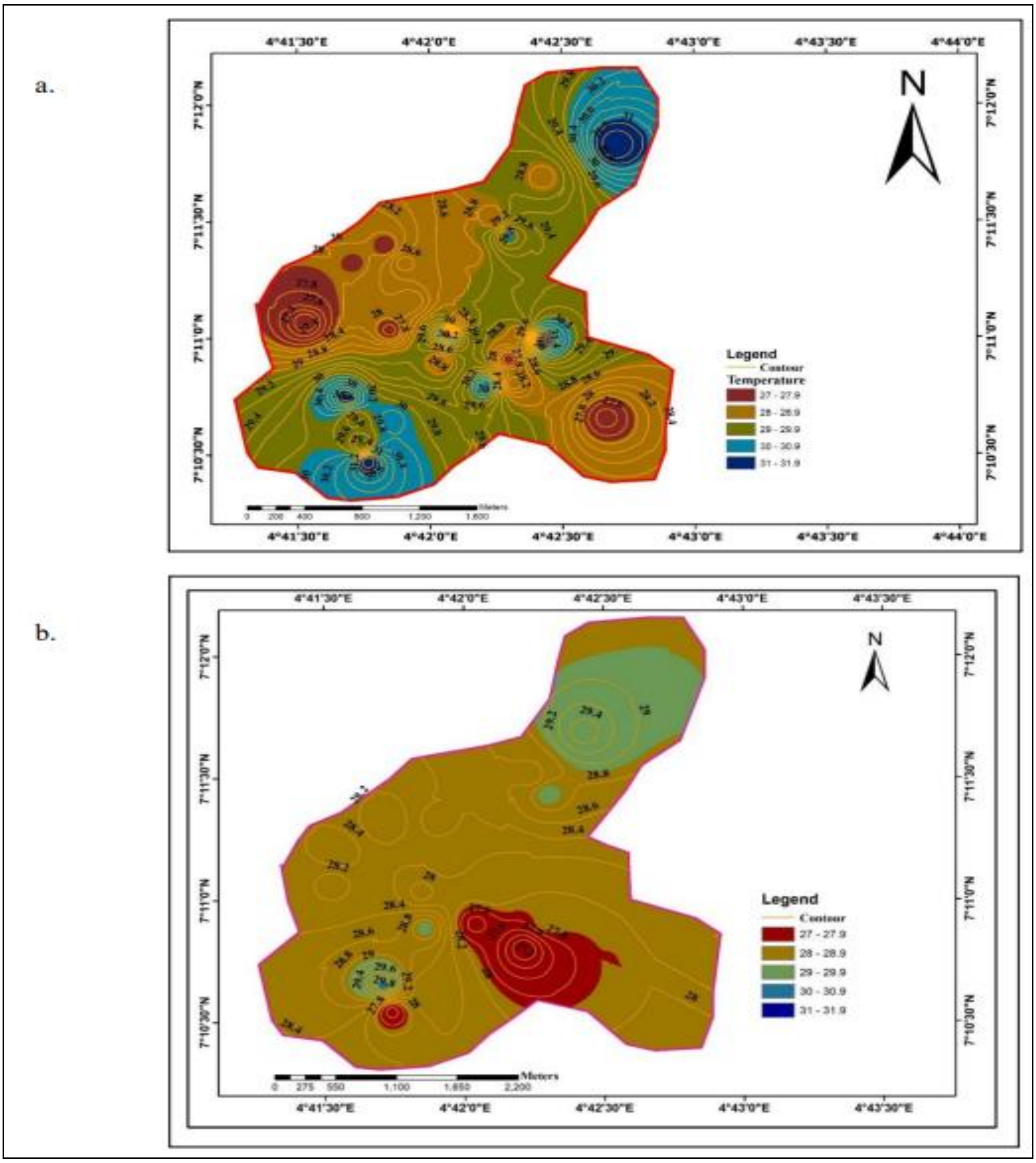

Fig 8 Spatial Variation in Temperature During a Dry and b Wet Season

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

➢ *Total Dissolved Solids (TDS):*

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produce an unwanted taste and diluted color in the appearance of water. This is the important parameter for the use of water. The water with high TDS value indicates that water is highly mineralized. The desired limit for TDS is 500 mg/l and the maximum limit is 1000 mg/l which is prescribed for drinking purposes. The concentration of TDS in present study was observed in the range of 16 ppm to 140 mg/l in wet season and 29 mg/l to 269 mg/l in dry season for surface water. For groundwater, the observed range of TDS is 27 mg/l to 197 mg/l in wet season and 23 mg/l to 336 mg/l in dry season (Fig 9). The mean total dissolved solids concentration of groundwater in Ifetedo was found to be 118.19 mg/l and for surface water was 65.9 mg/l, and it is within the limit of WHO standards. Similar value was reported by Soylak et al. (2001), drinking water of turkey. High values of TDS in groundwater are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects.

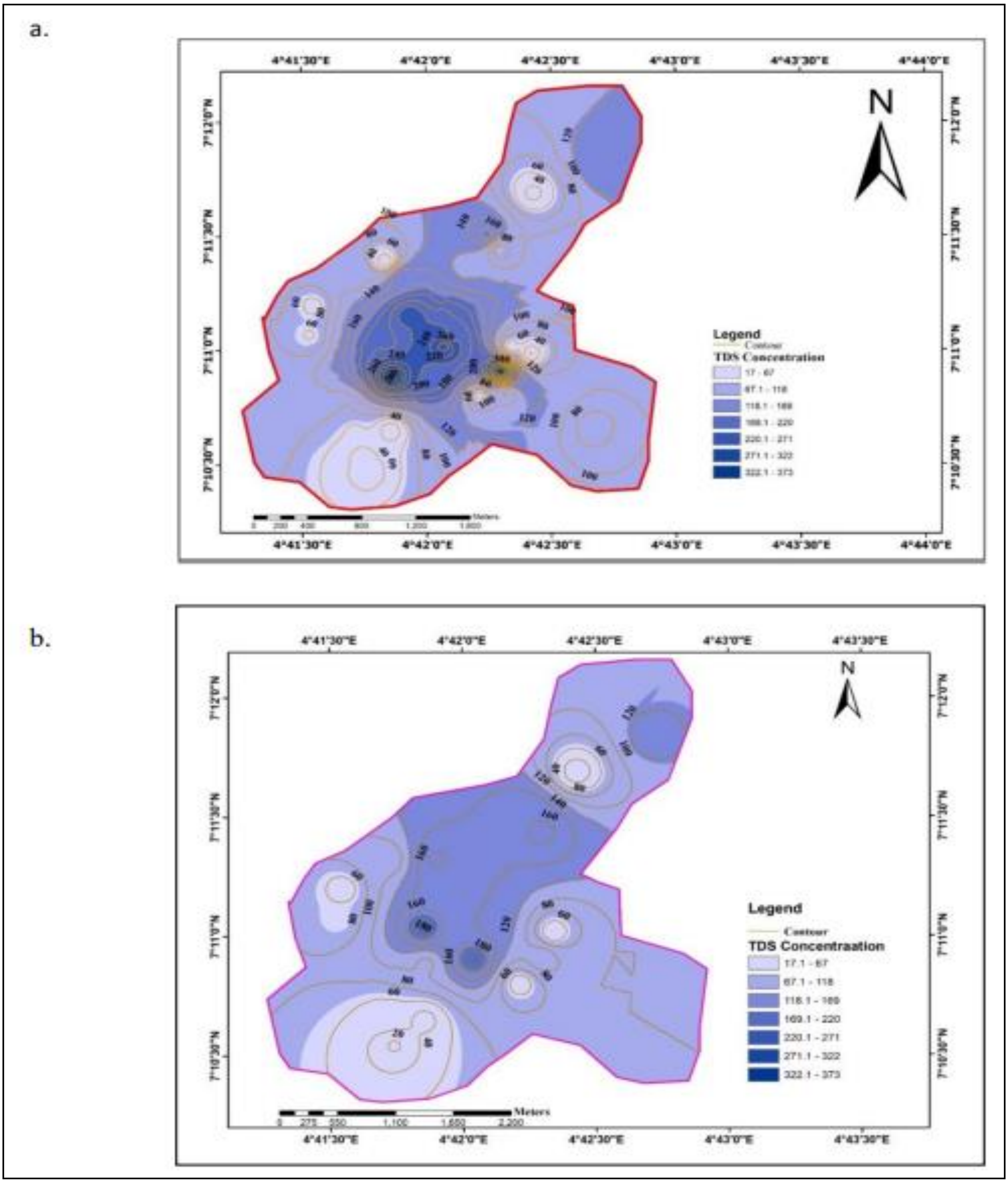

Fig 9 Spatial Variation in Total Dissolved Solids in a Dry and b Wet Season

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

➢ *PH of Water:*

PH is an important parameter in evaluating the acid–base balance of water. It is also the indicator of acidic or alkaline condition of water status. The pH value of natural water changes due to the biological activity and industrial contamination. WHO has recommended a maximum permissible limit of pH from 6.5 to 8.5. The current investigation ranges were 6.52–6.83 (Fig 10) which are in the range of WHO standards. The overall result indicates that the water sources are within the desirable and suitable range. Basically, the pH is determined by the amount of dissolved carbon dioxide (CO_2), which forms carbonic acid in water. Present investigation was similar with reports made by other researchers' study (Edimeh et al., 2011; Oko et al., 2014).

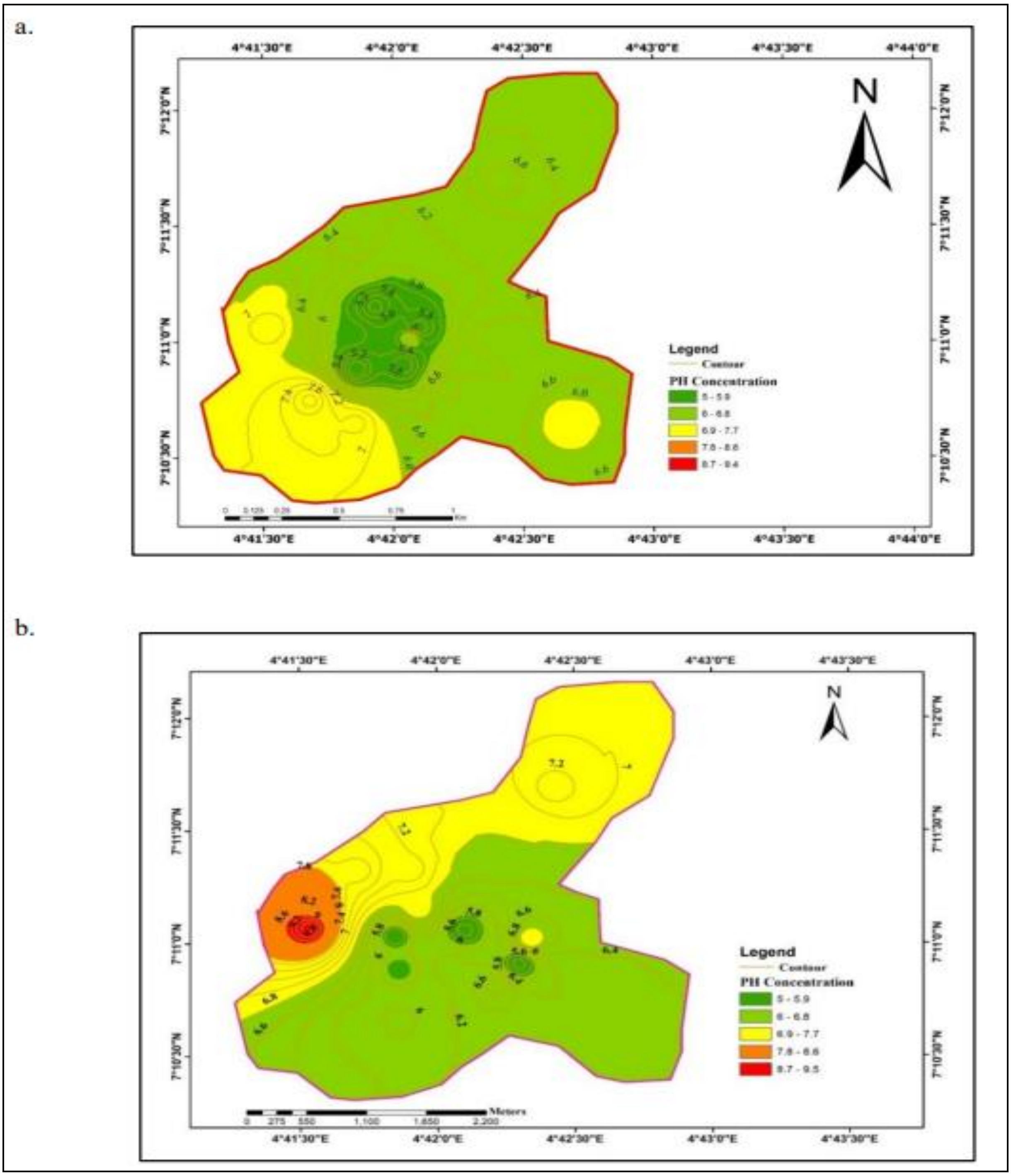

Fig 10 Spatial Variation in Concentration of pH in a Dry and b Wet Season

➢ *Arsenic in Water:*

Arsenic is one of the chemicals of great health concern in determining water quality. Its concentrations can be significantly elevated where there are sulfide mineral deposits and sedimentary deposits derived from volcanic rocks. One of the most important routes of exposure to arsenic are through food and drinking-water, including beverages that are made from drinkingwater. The recommended concentration of arsenic in drinking-water is 0.01 mg/l (10 µg/l). Nigerian Standard for water quality reports that intake of excessive

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

arsenic could pose cancer threat (NIS-554-2015). The current investigation ranges were 0.0022 – 0.013 mg/l (Fig. 11) which are in the range of WHO standards. One of the hand-dug wells slightly exceeded the permissible limit by 0.003mg/l. The Rapid Assessment of Drinking-Water Quality in the Federal Republic of Nigeria reports one hundred percent (100%) compliance with WHO guidelines or suggested value for every category of improved drinking-water quality tested. (Ince et al., 2010)

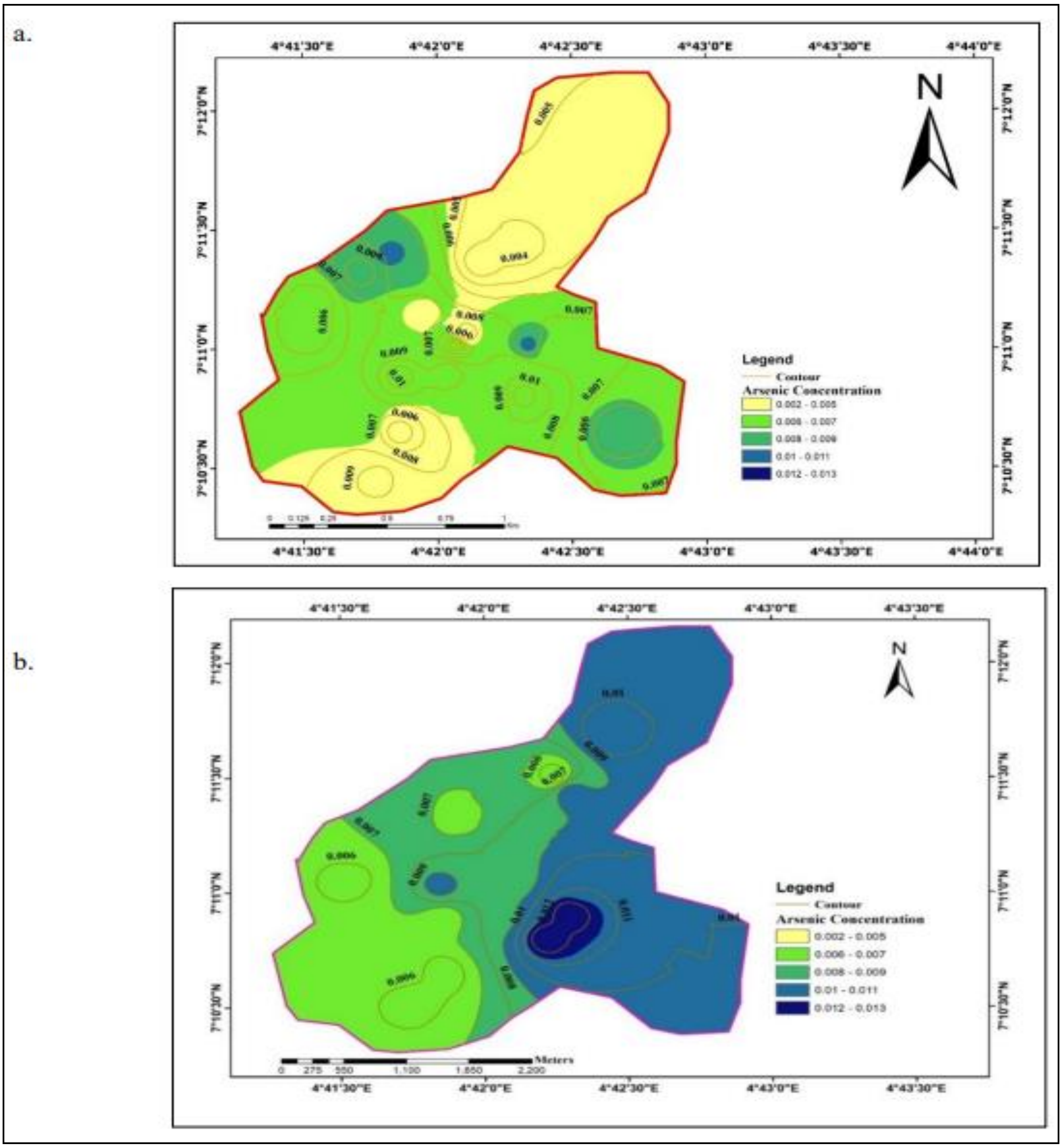

Fig 11 Spatial Distribution of Arsenic Concentration in Groundwater for a Dry and b Wet Season

- *Concentration of Calcium and Magnesium in Water:*

The mean Calcium value ranged from 0.0608 -0.0893 ppm, while the mean of magnesium concentration ranged from 0.0237 to 0.0303 ppm. Privately owned boreholes had the highest calcium concentration 0.0893, followed by hand-dug wells (0.0746), government-assisted boreholes (0.0608), and streams (0.075). Government-assisted sources had the highest magnesium concentration (0.0303), followed by streams (0.0285), hand-dug wells (0.0265) and privately-owned sources (0.0237). Both calcium and magnesium are essential minerals with positive health effects. Calcium plays a crucial role in bone health, nerve function, muscle contraction, and blood clotting. Meanwhile, magnesium is vital for energy production, muscle function, and maintaining a healthy heart rhythm. Additionally, both calcium and magnesium are important factors in determining water hardness. The levels of calcium and magnesium obtained from different areas as shown in figures 12-13. While having a moderate amount of calcium and magnesium in drinking water is generally beneficial for human health, excessively

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

high concentration can cause problems. High calcium levels lead to “hard water”, causing scaling in pipes and appliances and reducing soap and detergent effectiveness. Similarly, elevated magnesium levels contribute to water hardness and affect water taste and appearance. Maintaining a balanced and appropriate concentration of calcium and magnesium in water is crucial to ensure it is safe and beneficial for human consumption. Very low levels of these minerals in water may result in inadequate dietary intake, which can lead to health issues like osteoporosis and cardiovascular problems. The World Health Organization (WHO) has established guidelines for acceptable levels of minerals in drinking water to prevent health risks. Regular monitoring and testing of water sources essential to uphold water quality and ensure compliance with the necessary standards for human consumption. Excessive magnesium levels reaching around 400 mg/L, can cause symptoms such as nausea, muscular weakness, and paralysis. However, the sampling sites in this study demonstrated magnesium values within the w h o prescribed limit.

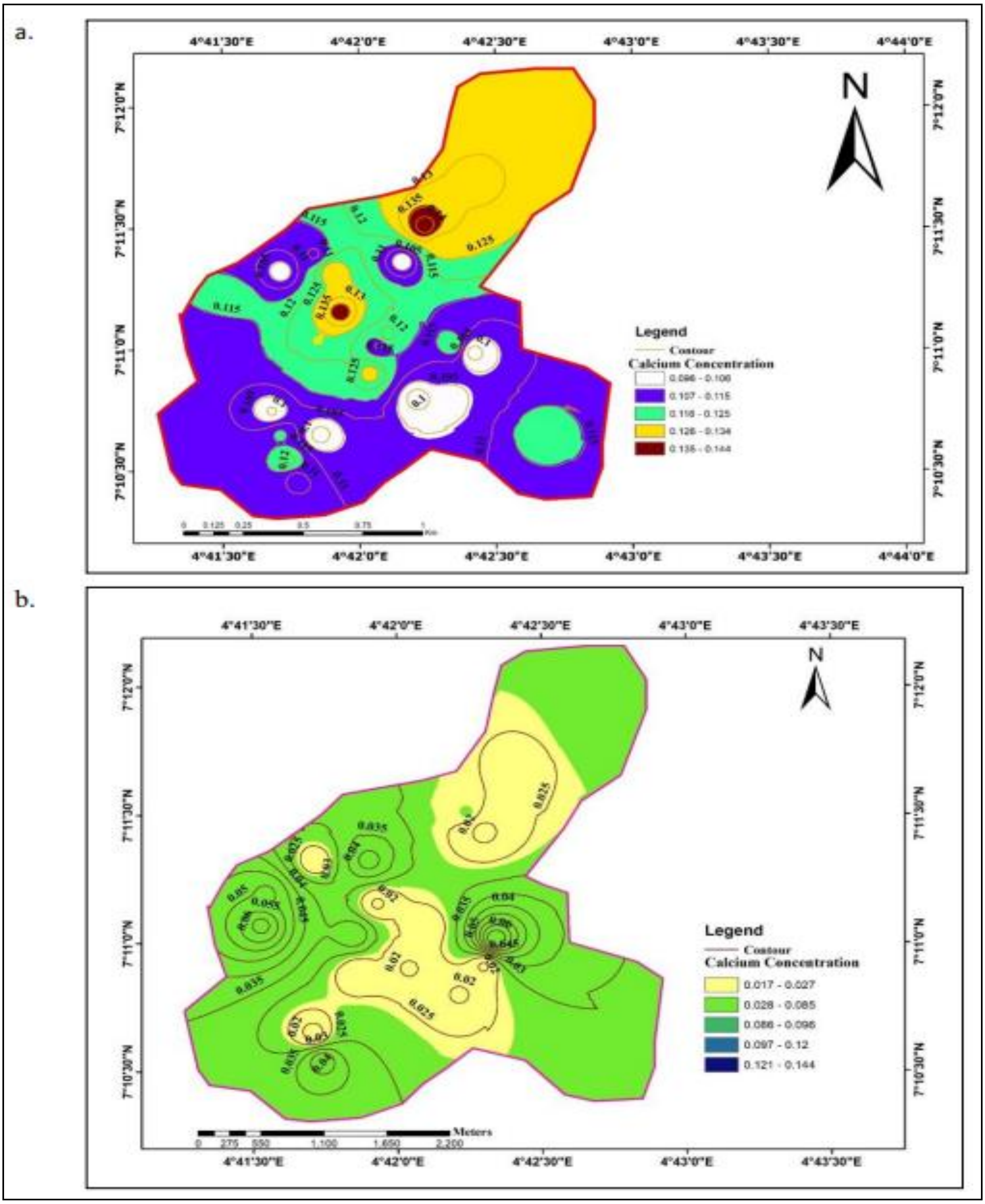

Fig 12 Spatial Variation in Concentration of Calcium in a Dry and b Wet Season

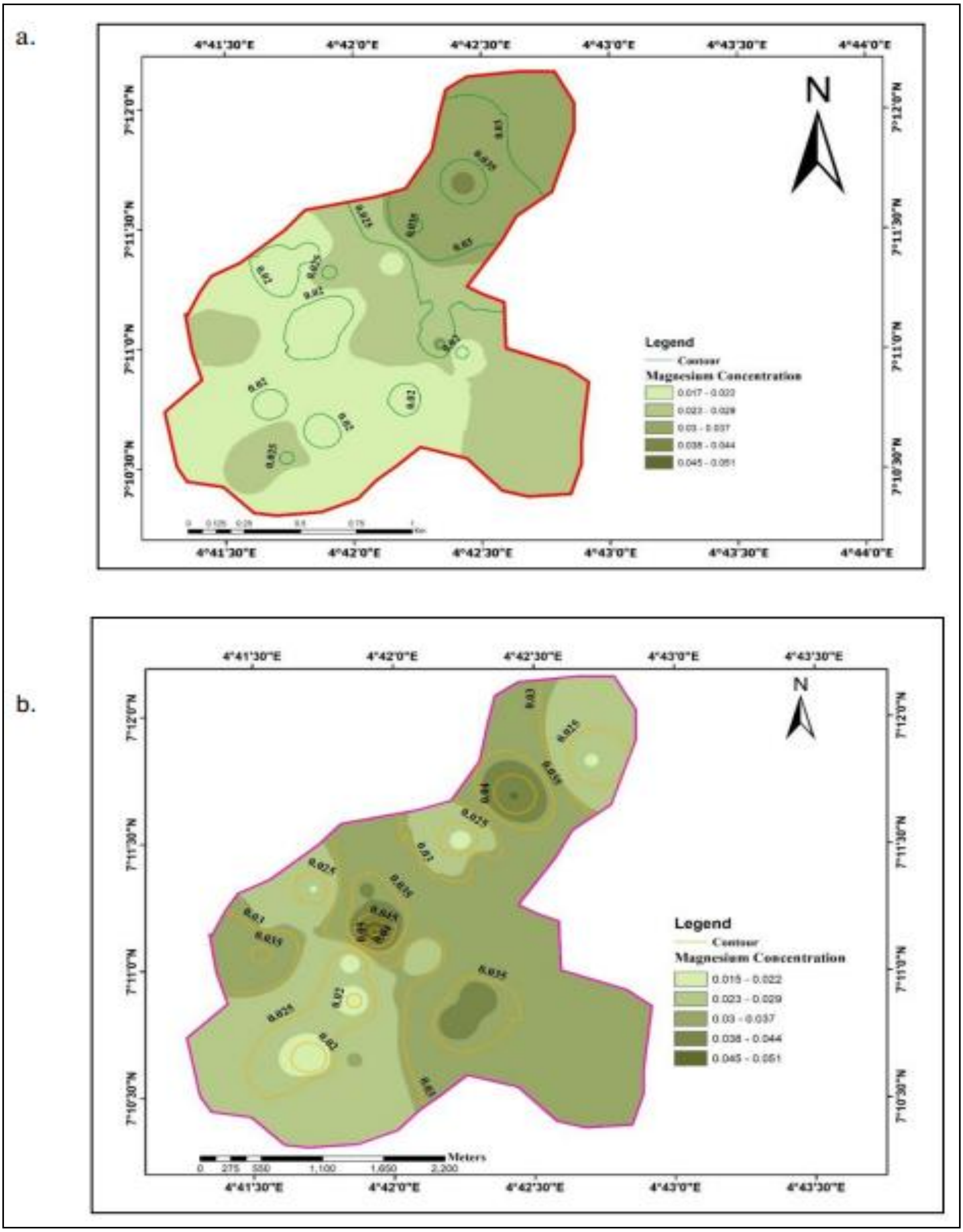

Fig 13 Spatial Variation in Concentration of Magnesium in a Dry and b Wet Season

➤ *Concentration of Cadmium in Water Source:*

The mean cadmium concentration in water samples was (0.0069 - 0.0073 ppm). The level Cadmium obtained from different water sources are shown in (Fig. 14). The current investigation ranges were 0.0069ml/l – 0.073 mg/l which shows the presence of high concentration of cadmium above the permissible limits of the WHO standards of less than or equal to 0.003 mg/l. this study been similar to result of the analysis of water samples from selected boreholes and well water in Zaria (Musa et al., 2007). Exposure to excessive Cadmium leads to poisoning and has been reported to be toxic to the kidney. Hence, the need further study in this regard to determine its health impact within the community.

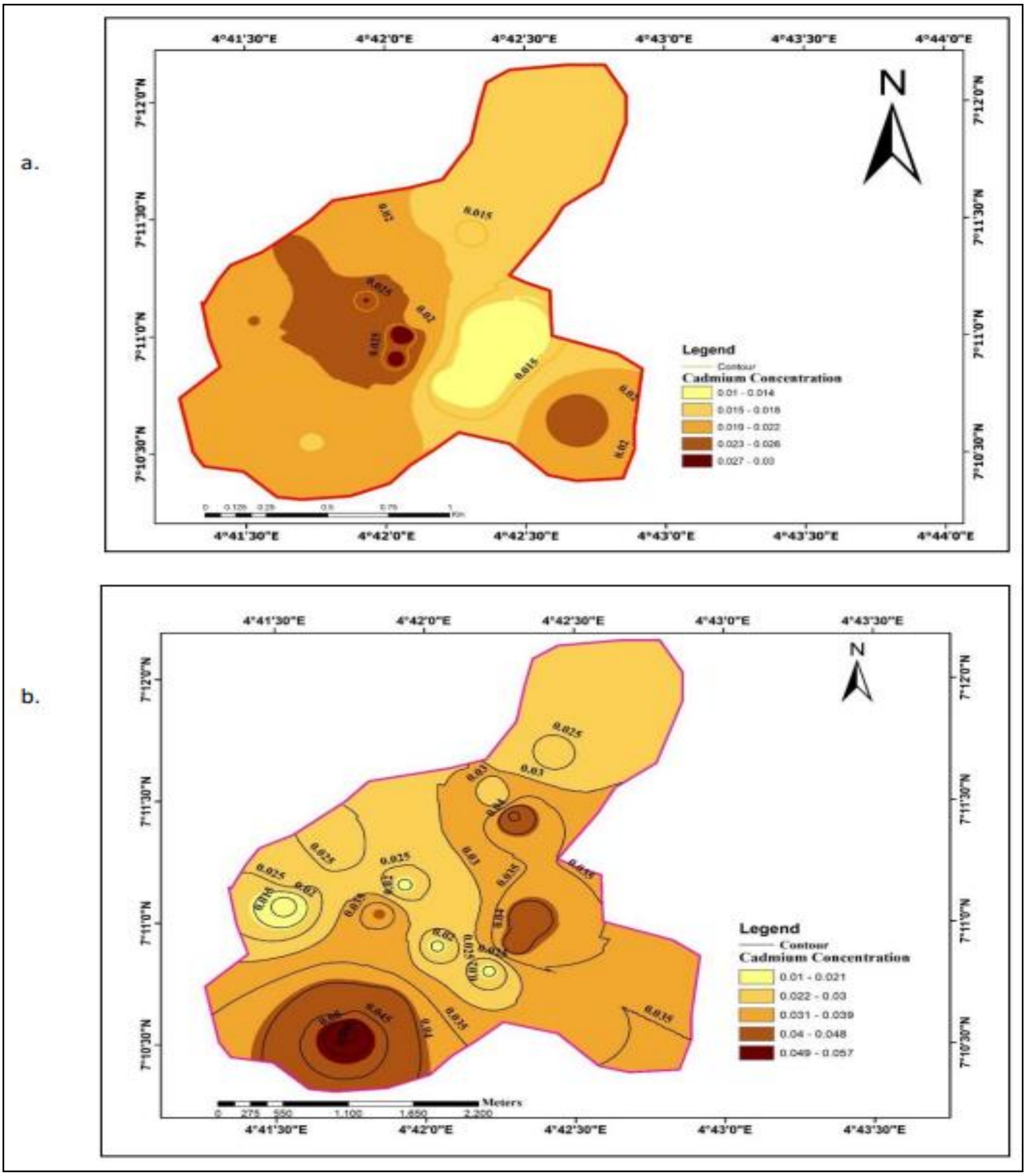

Fig 14 Spatial Variation in the Concentration of Cadmium in a Dry and b Wet Season

➢ *Concentration of Iron in Water Sample:*

The mean iron values in the studied area varied between 0.05-0.906 mg/L (Figure 15). This study reveals that the mean iron concentration in the sampled ground and surface water are above the WHO standard of 0.3 mg/l. If the value of iron is higher in water prevents the selfpurification of water and thereby produces adverse effect for aquatic lives. Although there is no recorded information as to the potential health hazard on human life recorded in the NIS-554- 2015. Water with high iron levels may taste metallic and smell bad, which makes it less tempting to drink. A surplus of iron can turn water reddish-brown, ruining clothing, pipes, and kitchenware in the process. Water that contains a lot of iron may appear hazy or turbid, which reduces its purity. Even though iron is a necessary component, ingesting too much of it can have negative health effects. These may include digestive problems like heartburn, diarrhea, and constipation. Iron-rich water encourages the development of iron bacteria and other microbes, which causes the development of slimy biofilms in plumbing systems. This can result in clogged pipes, less water flow, and more upkeep.

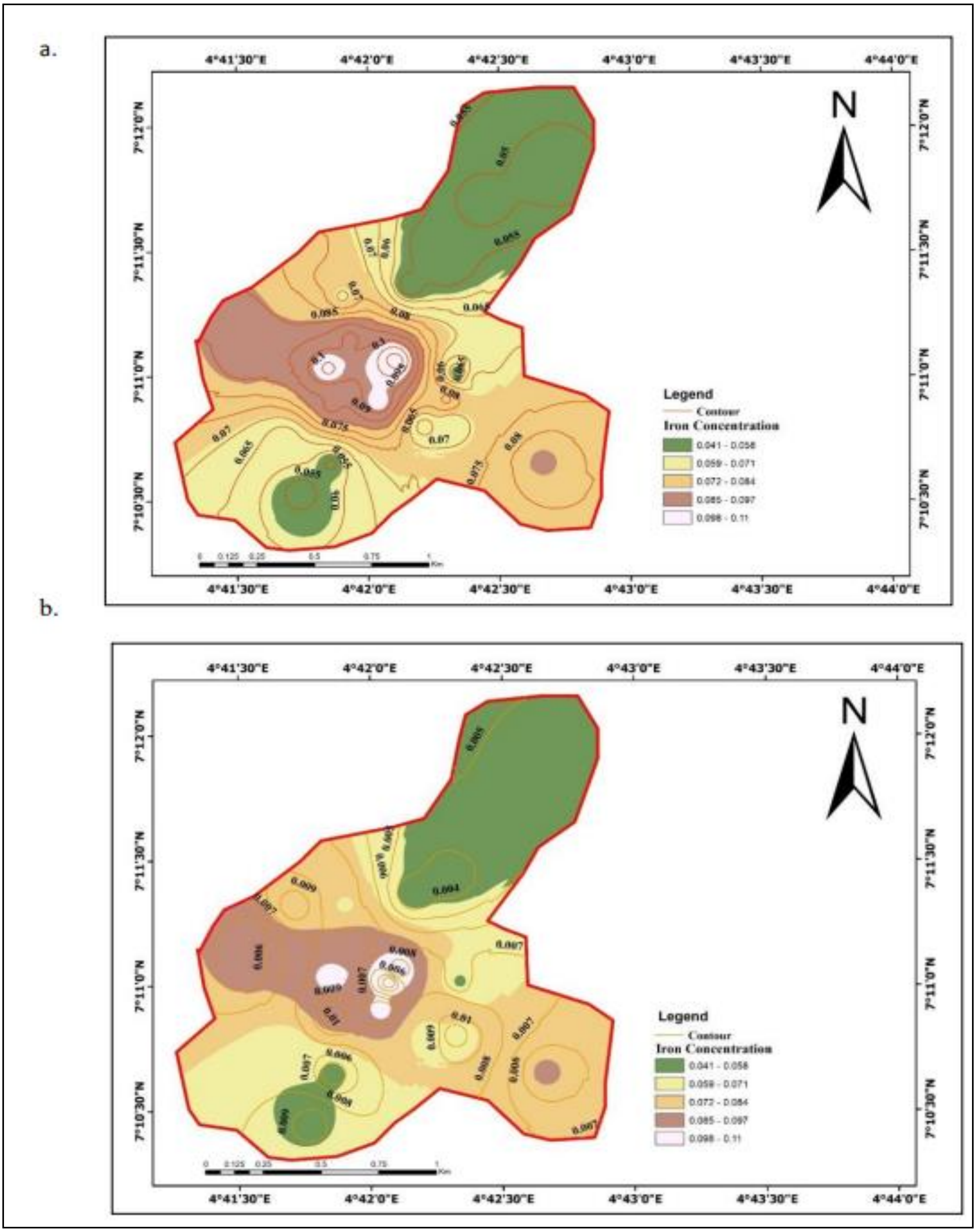

Fig 15 Spatial Variation in Concentration of Iron in a Dry and b Wet Season

➢ *Concentration of Potassium in Water Sample:*

Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. The mean potassium values in the studied area varied between 0.065-0.93 mg/L (Figure 16). Currently, there is no evidence that potassium levels in municipally treated drinking water, even water treated with potassium permanganate, are likely to pose any risk for the health of consumers. It is not considered necessary to establish a health-based guideline value for potassium in drinking-water (WHO, 2009)

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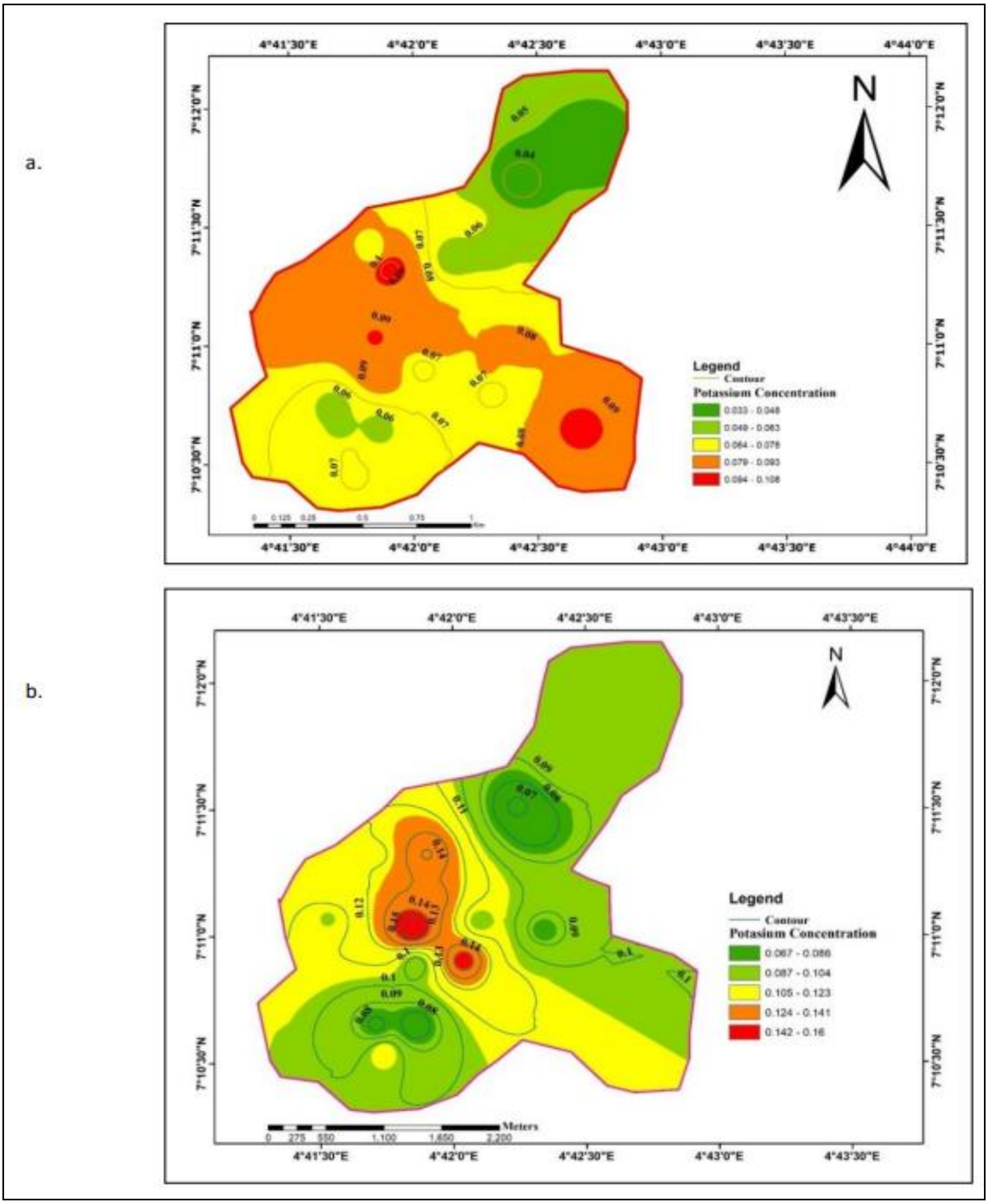

Fig 16 Spatial Variation in the Concentration of Potassium in a Dry and b Wet Season

➢ *Concentration of Sodium in Water Sample:*

The mean Sodium values in the studied area between 0.0413 -0.0608 mg/L (Figure 17). The higher the concentration of sodium can be related to cardiovascular diseases and in pregnant woman. No sampling site showed excess concentration of sodium. The permissible limit by WHO standard, been 200mg/l. High levels of iron can cause water to have a metallic taste, unpleasant odor, and a reddish-brown color. This may have an impact on the overall look and taste of the water. Iron-rich water can discolor clothing, plumbing fixtures, and kitchenware, necessitating extra cleaning work and perhaps causing damage. In water with a high iron content, iron bacteria and other microorganisms can flourish. These microorganisms have the ability to produce sticky biofilms in plumbing systems, which can block pipes, restrict water flow, and necessitate more frequent maintenance. Drinking water with too much iron in it may be harmful to your health. Although iron is a necessary nutrient, excessive amounts can cause gastrointestinal problems like diarrhea, constipation, and stomach pains.

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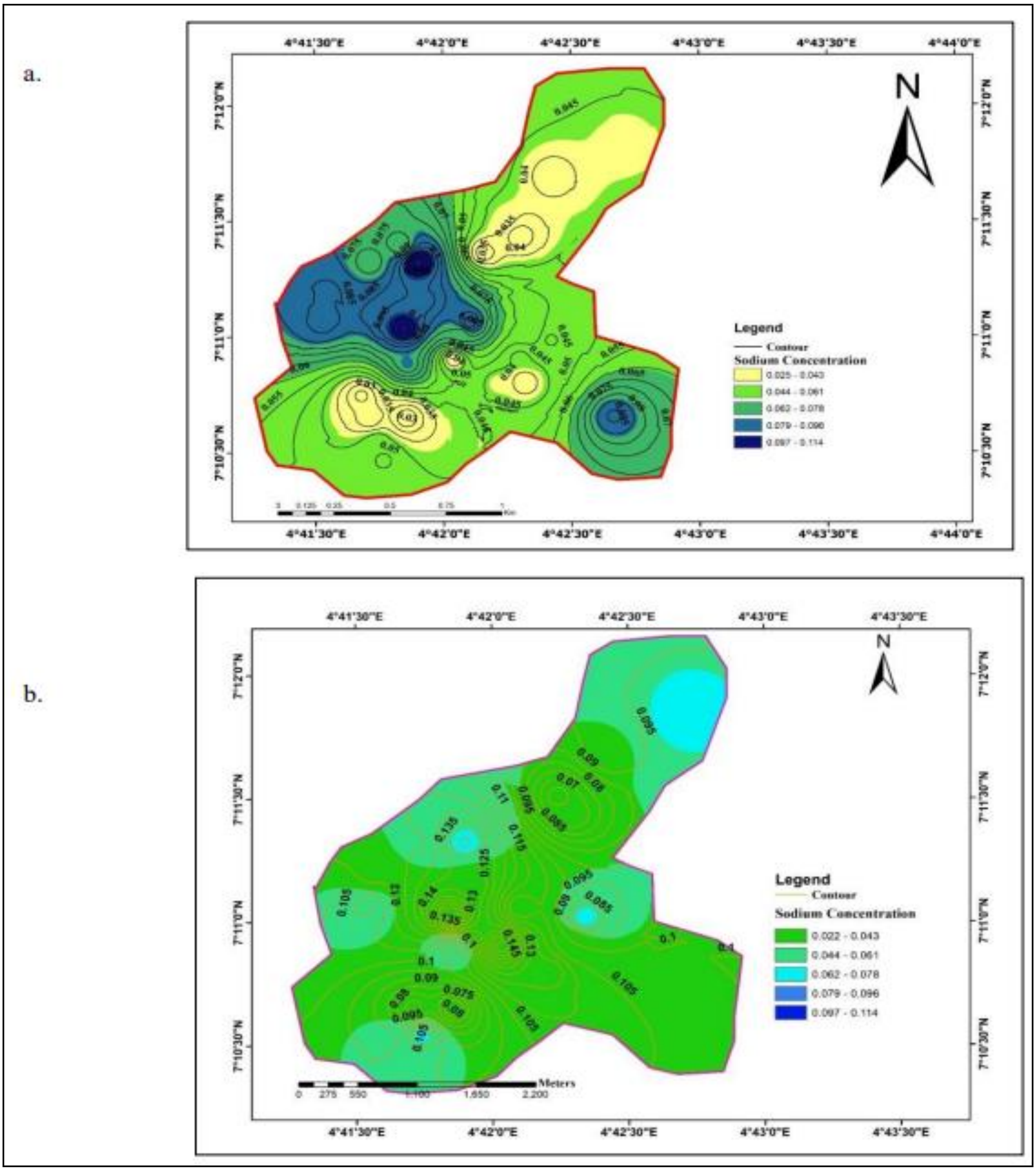

Fig 17 Spatial Variation in the Concentration of Sodium in a Dry and b Wet Season

Concentration of Lead in Water Sample Lead is the commonest of the heavy elements, accounting for 13 mg/kg of the earth's crust. (WHO, 2009). Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems in which the pipes, solder, fittings, or service connections to homes contain lead. For this study, the mean concentration of lead in the sampling site is 0.0069 – 0.0075 mg/l (Figure 18) which is within the permissible limit of 0.01 as prescribed by the World Health Organisation (WHO).

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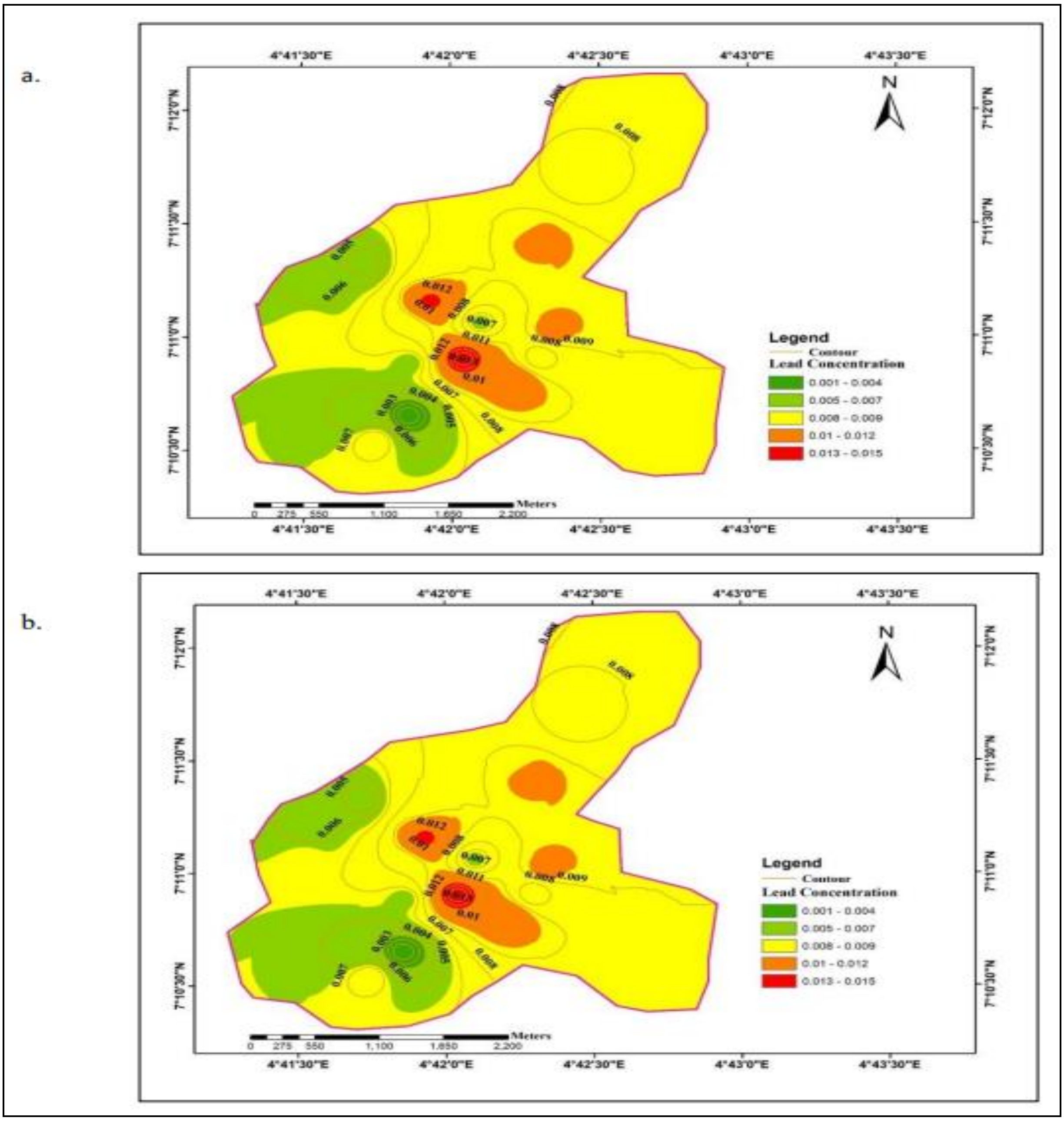

Fig 18 Spatial Variation in the Concentration of Lead in a Dry and b Wet Season

➢ *Microbial Quality of Sampled Groundwater Resources:*

Most Probable Number (MPN) is a statistical method used to estimate the concentration of microorganisms in a sample. Total coliforms are a group of bacteria that are commonly used as indicators of potential contamination in water. High coliform counts may suggest the presence of harmful pathogens and can indicate poor water quality. There were multiple samples collected from hand-dug wells. The MPN values in most of these samples are greater than 1100, except for 4 sample points. The high MPN values in the majority of hand-dug wells suggest potential fecal contamination and poor water quality. The MPN values for the Tap water samples are relatively low, with MPN of 23 and 240. These low MPN values indicate better water quality compared to hand-dug wells. Only one sample was collected from a Mono Pump and it has an MPN value of 23. As with tap water, this relatively low MPN value indicates better water quality compared to most hand-dug wells. A single sample was collected from a government-assisted borehole and it has an MPN value of 210. This MPN value suggests some level of contamination but is lower than most hand-dug wells. In summary, this indicates that hand-dug wells generally have high total coliform counts (most samples have MPN values greater than 1100), indicating potential fecal contamination and poor water quality. In contrast, tap water and the mono pump sample show lower total coliform counts, suggesting relatively better water quality. The government-assisted borehole sample falls somewhere in between with a moderate total coliform count. (Table 4)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

Table 4 Total Coliform Count of Sampled Groundwater Resources

SITE	GROUND WATER SOURCE	MPN(per 100ml)
1	Hand-dug Well	>1100
2	Hand-dug Well	460
3	Hand-dug Well	>1100
4	Tap Water	23
5	Hand-dug Well	>1100
6	Mono Pump	23
7	Hand-dug Well	>1100
8	Hand-dug Well	240
9	Hand-dug Well	>1100
10	Hand-dug Well	>1100
11	Hand-dug Well	>1100
12	Tap Water	240
13	Hand-dug Well	93
14	Hand-dug Well	>1100
15	Hand-dug Well	460
16	Hand-dug Well	150
17	Hand-dug Well	>1100
18	Hand-dug Well	>1100
19	Hand-dug Well	>1100
20	Hand-dug Well	>1100
21	Hand-dug Well	>1100
22	Hand-dug Well	>1100
23	Hand-dug Well	>1100
24	Hand-dug Well	>1100
25	Hand-dug Well	>1100
26	Hand-dug Well	>1100
27	Government assisted borehole	210

➢ *Water Quality Index:*

Table 5 presents the results of the quality assessment conducted on the sampled water. The analysis revealed that a majority of the water samples are only suitable for irrigation and industrial purposes, as compared to the Water Quality Index established by the World Health Organization (WHO). In terms of drinking water, only a small number of samples met the acceptable standards for consumption and domestic use. The Water Quality Index (WQW), as described by Tahera et al., (2016), is considered a highly effective method for evaluating water quality. Consistent consumption of poor-quality water significantly increases the risk of gastrointestinal diseases, particularly among children within the community, thereby rendering the community vulnerable. Health risks associated with water sources labeled as "Unfit for drinking" are substantial if consumed without proper treatment. Drinking contaminated water can lead to waterborne illnesses like diarrhea, cholera, typhoid, and other gastrointestinal ailments. When a considerable number of sites are categorized as having poor or very poor water quality, it indicates limited access to safe drinking water sources within the study area. This can have detrimental effects on public health, especially for communities reliant on these water sources. Individuals who depend on water sources with poor water quality are more susceptible to waterborne diseases, further exacerbating the vulnerability of the community. This susceptibility can particularly impact individuals with compromised immune systems, such as children, the elderly, and those with pre-existing health conditions. The data underscores the importance of implementing water treatment measures to enhance the quality of the water supply. Methods such as filtration, disinfection, and purification can help eliminate contaminants and ensure safer water for consumption. This emphasizes the need to raise awareness within the community regarding the risks associated with poor water quality.

Table 5 Water Quality Index for the Study Area

Site	WQI	Remark on Quality	Use
1	136	Very Poor	Restricted use for Irrigation
2	148	Very Poor	Restricted use for Irrigation
3	75	Fair	Irrigation and Industrial
4	62	Fair	Irrigation and Industrial
5	92	Poor	Irrigation
6	85	Poor	Irrigation
7	50	Good for Domestic	Irrigation and Industrial
8	194	Unfit for drinking	Proper treatment before use
9	45	Good for Domestic	Irrigation and Industrial
10	169	Unfit for drinking	Proper treatment before use
11	179	Unfit for drinking	Proper treatment before use
12	65	Fair	Irrigation and Industrial
13	62	Fair	Irrigation and Industrial
14	80	Poor	Irrigation
15	45	Fair	Irrigation and Industrial
16	54	Fair	Irrigation and Industrial
17	78	Poor	Irrigation
18	70	Fair	Irrigation and Industrial
19	73	Fair	Irrigation and Industrial
20	73	Fair	Irrigation and Industrial
21	132	Very Poor	Restricted use for Irrigation
22	74	Fair	Irrigation and Industrial
23	67	Fair	Irrigation and Industrial
24	74	Fair	Irrigation and Industrial
25	80	Poor	Irrigation
26	10	Excellent Drinking Water	Irrigation and Industrial
27	75	Fair	Irrigation and Industrial
28	92	Poor	Irrigation
29	83	Poor	Irrigation
30	78	Poor	Irrigation
31	85	Poor	Irrigation
32	53	Fair	Irrigation and Industrial

➤ *Relationship between Composition of Water from Different Sources:*

The physico-chemical properties of the water samples collected were correlated against each both in dry and rainy season. The results are as presented in Tables 6 – 9. The results revealed generally a weak relationship between the physical and chemical properties of ground water during the dry season except on few occasions. There was a strong and positively relationship recorded between Sodium and pH (r = 0.814), between Cadmium and Iron (r = 0.612), and between the electric conductivity and the total dissolved solids (r = 0.99) in the ground water during the dry season as shown in Table 6 . In the same dry season the result revealed a physico-chemical relationship between the chemical and physical properties of surface water are generally strong relationship between the Total dissolved solids (TDS) and pH (r = -0.805), between Electric conductivity and pH (r = -0.799), between electric conductivity and total dissolved solids (r = 0.999), between lead and pH (r = - 0.766), between lead and total dissolved solid (r=r0.900), lead and electric conductivity (r = 0.883), between arsenic and Water quality index (WQI) (r = 0.926), iron and pH (r = -0.709), iron and TDS (r= 0.941), iron and electric conductivity (r = 0.9431), iron and lead (r = 0.801), cadmium and WQI (r = 0.905), cadmium and arsenic (r = 0.963), Magnesium and Calcium (r = - 0.692), sodium and WQI (r = 0.809), sodium and arsenic (r = 0.948), sodium and calcium (r = 0.964), sodium and magnesium (r = -0.781), potassium and WQI (r = 0.945), potassium and arsenic (r=0.997), potassium and calcium (r=0.998), potassium and magnesium (r=0.847), and between potassium and sodium (r = 0.938) ($p<0.05$) as shown in Table.

During the wet season the physico-chemical properties of surface water revealed a strong relationship between TDS and pH (r =-0.59), Electric conductivity (EC) and TDS (r= 0.75), lead and TDS (r=0.75), lead ad EC (r=0.74), arsenic

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26aug1259

and WQI (r=0.93), Iron (Fe) and pH (r=0.749), Cadmium and WQI (r=0.8), cadmium and PH (r=0.67), cadmium and lead (r=0.53), cadmium and arsenic (r=0.78), calcium ad pH (r=0.77), calcium and TDS (r—0.65), calcium and EC (r=0.65), calcium and arsenic (r=0.51), calcium and and cadmium (r=0.78), magnesium and pH(r=-0.54), magnesium and arsenic (r=0.57), sodium and calcium (r=0.75), sodium and magnesium (r=0.63), potassium and pH (r=-0.56), potassium and TDS (r=0.83), potassium and EC (r=0.83), potassium and lead (r=0.81), potassium and magnesium (r=0.54). These results were obtained at $p<0.05$.

Importantly, the study went further to assess the differences in the physico-chemical properties of the water by using regression statistics. The result of the regression analysis is as presented in Table 4.8. From the regression statistics, Number of observation is 32; F (11,20); R-squared = 0.5273. This is an indication that the physico-chemical properties accounts for about 52% of the variation in water samples collected during the dry and the wet season. It appears that pH, As (Arsenic), Cd (Cadmium), and Ca 2+ (Calcium) concentrations may be more strongly related to the Water Quality Index compared to the other parameters.

Table 6 Correlation Between the Properties of Groundwater During the Dry Season

	WQI	pH	TDS	E.C	Pb	As	Fe	Cd	Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}
WQI	1.00											
pH	-0.017	1.00										
T.D.S	0.283	0.732	1.00									
E.C	0.275	-0.73	0.997	1.00								
Pb	0.039	- 0.314	0.233	0.222	1.000							
As	0.053	0.170	-0.130	-0.139	0.229	1.00						
Fe	-0.134	-0.48	0.582	0.577	0.374	0.308	1.00					
Cd	-0.313	-0.22	0.365	0.369	0.024	0.136	0.611	1.000				
Ca^{2+}	0.195	-0.40	0.319	0.320	-0.185	- 0.226	0.057	0.180	1.000			
Mg^{2+}	0.183	0.047	-0.080	-0.077	-0.505	- 0.203	-0.440	-0.287	0.593	1.000		
Na^{2+}	-0.188	-0.31	0.323	0.321	0.155	0.413	0.682	0.487	0.305	-0.161	1.000	
K^{+}	-0.019	-0.18	0.341	0.335	0.298	0.568	0.659	0.336	0.015	-0.334	0.8144	1.000

Table 7 Correlation Between Surface Water Properties During Dry Season

	WQI	pH	TDS	E.C	Pb	As	Fe	Cd	Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}
WQI	1.000	-0.444	0.1763	0.158	0.2885	0.9264	0.3577	-0.0285	0.9055	-0.7202	0.8093	0.9452
pH	0	1.000	-0.8054	-0.799	-0.766	-0.281	-0.7096	0.3152	-0.3924	-0.2460	-0.1542	-0.2686
T.D.S			1.0000	0.9992	0.900	0.0211	0.9411	0.1630	0.2545	0.5049	0.0660	0.0140
E.C				1.0000	0.883	0.016	- 0.9431	0.1824	0.2517	0.5128	0.0691	0.0062
Pb					1.00	0.00	0.8006	-0.0701	0.1867	0.4257	-0.0423	0.0236
As						1.000	0.2730	0.1622	0.9637	-0.8342	0.9482	0.9972
Fe							1.0000	0.4114	0.5109	0.2429	0.3708	0.2640
Cd								1.0000	0.3181	-0.1191	0.4646	0.1481
Ca^{2+}									1.0000	-0.6920	0.9640	0.9585
Mg										1.0000	-0.7818	-0.8465
Na											1.0000	0.9383
K												1.0000

Table 8 Correlation Between the Surface Water Properties During the Wet Season

	WQI	Ph	T.D.S	E.C	Pb	As	Fe	Cd	Ca^{2+}	Mg^{2+}	Na	K
WQI	1.00	0.3471	0.1703	0.159	0.492	0.9264	0.4566	0.8163	0.4250	0.4944	0.023	0.4066
pH		1.0000	-0.592	-0.596	-0.065	0.2433	0.7494	0.6702	0.7674	-0.5371	-0.378	-0.556
T.D.S			1.000	0.999	0.747	-0.035	-0.1002	-0.092	-0.6518	0.4608	0.383	0.8297
E.C				1.000	0.744	-0.046	-0.1060	-0.100	-0.6570	0.4548	0.382	0.8270
Pb					1.000	0.2609	0.0947	0.5338	0.0000	0.1156	-0.202	0.8128
As						1.0000	0.1985	0.7234	0.5121	0.5685	-0.062	0.3440
Fe							1.0000	0.4614	0.2222	-0.1395	0.2577	-0.356
Cd								1.0000	0.7829	-0.0733	-0.498	0.211 -
Ca^{2+}									1.0000	-0.3917	-0.753	0.256
Mg										1.0000	0.631	0.5397
Na											1.000	0.0014
K												1.0000

Table 9 Correlation Between the Properties of Groundwater During the Wet Season

	WQI	Ph	T.D.S	E.C	Pb	As	Fe	Cd	Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}
WQI	1.0000	-0.4276	0.2403 -	0.2432	-0.0518	0.2022	-0.1304	-0.3455	-0.3604	-0.0206	-0.095	0.2552
pH		1.0000	0.2302	-0.2320	0.0201	-0.1999	0.1581	0.5178	0.2892	0.2912	0.0030	-0.5433
T.D.S			1.0000	0.9999	0.5132	0.0563	-0.5972	-0.2958	-0.0676	-0.1699	0.3704	-0.2053
E.C				1.0000	0.5161	0.0636	-0.5938	-0.2981	-0.0674	-0.1687	0.3729	-0.2052
Pb					1.0000	0.3208	-0.2086	-0.0931	0.3894	-0.0777	0.3533	-0.2712
As						1.0000	-0.0623	-0.2399	0.3336	-0.2031	0.0854	-0.0062
Fe							1.0000	0.1563	-0.1130	0.2105	-0.3754	0.2883
Cd								1.0000	0.0521	0.5657	0.0067	0.0922
Ca^{2+}									1.0000	-0.2449	0.1567	-0.3221
Mg^{2+}										1.0000	-0.1427	0.2385
Na^{2+}											1.0000	-0.3108
K												1.0000

Table 10 Regression Results

WQI	Coef.	Std. Err	T	P>|t	[95% Conf.	Interval]
pH	33.12377	15.55175	2.13	0.046	.6833823	65.56415
T.D.S	-0.505550	.8376355	-0.60	0.553	-2.252827	1.241727
E.C	.476778	.4400003	1.08	0.291	-.4410466	1.394603
Pb	310.3206	3508.657	0.09	0.930	-7008.61	7629.251
As	7909.943	4300.957	1.84	0.081	-1061.696	16881.58
Fe^{2+}	-115.0908	716.2549	-0.16	0.874	-1609.172	1378.991
Cd	-4199.089	1835.816	-2.29	0.033	-8028.535	-369.6442
Ca^{2+}	1025.982	507.0594	2.02	0.057	-31.7253	2083.689
Mg	-912.1914	1808.15	-0.50	0.619	-4683.926	2859.543
Na	-288.8102	553.2963	-0.52	0.607	-1442.966	865.3457
K^{+}	-485.3994	875.645	-0.55	0.585	-2311.963	1341.164
Cons	-181.1228	150.5068	-1.20	0.243	-495.0745	132.829

$F(11, 20) = 2.03$; Prob > F= 0.0816; R-squared = 0.5273; Adj R-squared = 0.2673;
Root MSE = 34.91; df =11; MS = 2471.82.

IV. RECOMMENDATIONS

Potable water is vital to sustain life and a satisfactory (adequate, safe and accessible) supply should be available to all. Also, improving access to safe drinking water can give a tangible health benefits. Provision of safe and accessible domestic water by local and state governments is vital for fulfilling Sustainable Development Goal 6. Access to potable water should be between 50 to 100 liters per person daily, affordable (not exceeding 3% of household income), and of good quality. Public awareness about the necessity of water treatment is essential to ensure safety, especially as many rely on untreated groundwater. Government agencies must regularly monitor water chemistry, particularly for groundwater, and further research on groundwater in Osun State is necessary to safeguard public health and address potential disease correlations.

V. CONCLUSION

The study reveals that increased heavy metal levels in water can adversely affect human health, necessitating monitoring to assess risks of gastrointestinal diseases. It identifies varied water sources in the area, primarily groundwater, influenced by geology, seasons, anthropogenic factors, and topography. Most sampled water sources are deemed unsuitable for domestic use due to high concentrations of harmful chemicals, with surface water particularly problematic due to elevated levels of arsenic, cadmium, sodium, and lead, surpassing WHO recommendations. While groundwater from hand-dug wells shows some Arsenic and Lead richness, certain samples remain within safe limits for consumption, indicating that seasonal variations significantly influence water chemistry. Overall, the findings highlight the need for cautious management of water resources in the community, emphasizing their suitability mostly for agricultural rather than domestic uses.

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