African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 8, Issue 1, 2025 (pp. 158-176)
www.abjournals.org

GROUNDWATER QUALITY ASSESSMENT IN PARTS OF ABA METROPOLIS, SOUTHEASTERN NIGERIA

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Cite this article:

Okolo, C. M., Alichi, A. U., Madu, F. M. (2025), Groundwater Quality Assessment in Parts of Aba Metropolis, Southeastern Nigeria. African Journal of Environment and Natural Science Research 8(1), 158-176. DOI: 10.52589/AJENSR-89BQTMYA

Manuscript History

Received: 23 Dec 2024

Accepted: 4 Feb 2025

Published: 12 Feb 2025

ABSTRACT: *Groundwater quality assessment was carried out in Aba Metropolis to determine the quality of the water for various domestic uses. The study area is a metropolitan city with major markets and industries in the heart of Abia State, Nigeria. A total of forty-five (45) samples were collected and were analyzed for various physicochemical parameters using standard methods. The result shows that there is an increase in the concentration of the majority of the parameters towards the city center and these variations were attributed to geogenic and anthropogenic factors. Background concentrations for drinking water were used to ascertain the level of pollution and quality of the groundwater. Except for Fe^{++} which has background concentration above the permissible standard in the entire groundwater samples, most of the water samples fall within WHO/NAFDAC limits for drinking water. It is recommended that some remediation measures/appropriate water treatment be carried out before use for drinking purposes.*

KEYWORDS: Water quality, Aba metropolis, Groundwater, Physicochemical analysis.

Article DOI: 10.52589/AJENSR-89BQTMYA
DOI URL: https://doi.org/10.52589/AJENSR-89BQTMYA

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INTRODUCTION

Groundwater is a vital renewable source for water supplies around the world. It occurs almost everywhere beneath the earth's surface in a multiple-layer aquifer (Shahab *et al.,* 2016). It is an essential natural resource that supports the nation's socio-economic development (Flörke *et al.,* 2018) and it is a significant water source for consumption, agriculture, industry, households, and the environment (Wu *et al.,* 2017). In the world, about 65% of groundwater is used for human consumption, 20% for irrigation, and 15% for industrial uses (Adimalla & Venkatayogi, 2018; Salehi *et al.,* 2018). Groundwater contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, groundwater is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute groundwater. When groundwater becomes contaminated, it is difficult and expensive to clean up.

Water quality problems are both natural and anthropogenic in nature, with emerging contaminants playing an increasing role. There has been a tremendous increase in the demand for groundwater due to rapid growth of population, accelerated pace of industrialization and urbanization (Yisa & Jimoh, 2010; Gleick, 2020; Kumar & Sharma, 2019). Naturally, groundwater is never pure because it contains dissolved mineral ions in different concentrations. Thus, the physical, chemical and bacteriological constituents of groundwater determine its usefulness for various purposes (World Health Organization, 2019; Environmental Protection Agency, 2020). The presence of these constituents can be tolerated within some permissible limits depending on the purpose; however, when any of the constituents exceeds the acceptable limit, it may constitute health hazards resulting from the consumption of the water. The water will then require some type of treatment which may be costly. Thus, the availability and quality of groundwater are badly affected at an alarming rate due to anthropogenic activities viz. overexploitation and improper waste disposal (industrial, domestic and agricultural) to groundwater reservoirs (Panda & Sinha, 1991; Kavitha *et al.,* 2019a, 2019b). This translates to the fact that the quality of groundwater depends on the intended use.

According to the World Health Organization (WHO, 2017), about 80% of all the diseases in human beings are water-borne and groundwater forms the dominant source of water supply for various uses in the research area. The study area has prolific aquifers but because of the many industries and commercial establishments such as the popular Ariaria International Market amongst others, there is need for the assessment of groundwater sources to know the extent of degradation if any. With the recent launch of a power station and constant electricity, even moribund companies may become operational and new companies start off. The result is increased migration to the city adding more pressure to the already existing infrastructure and a corresponding increase in water uses. In view of the foregoing, there is a need for assessment of groundwater in Aba which has necessitated the present research.

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Location of the Study Area

The study area is located within latitudes 5º 02'N and 5º 13'N, and longitudes 7º 17'E and 7º 28'E. Aba has major access routes from neighboring towns and many cities in Nigeria. As a commercial nerve center in the south-east, Aba is well connected by motorable routes (Fig 1). The Aba area is characterized by a fairly flat topography underlain by the Benin Formation and slopes very gently towards the Aba River. It has an elevation range of about 40 - 84m above mean sea level. The slope ranges from 0 to 3% generally towards the Aba River. The region falls within the humid tropical climate marked by abundant rainfall. The area experiences a warm and gloomy wet season, followed by a scorching and oppressive dry season (Eze & Njoku, 2018). The rainfall data of the area show average monthly rainfall of 172.34mm with a maximum of about 353.33mm recorded in September and a minimum of 5.62mm in December. The annual average rainfall is about 2217.29mm/year. The temperature rarely drops below 61ºF or rises above 91ºF. Aba has a population of approximately 1,230,000 (NPC, 2020). Aba is one of the largest cities in Nigeria and its population makes it a significant urban center in the southeastern region of Nigeria (Okoro & Nwachukwu, 2021). The city's growth is attributed to its strategic location and historical significance as a trade center. Aba is composed of many urban and rural areas including towns such as Aba-Ukwu, Eziukwu-Aba, Obuda-Aba, Umuokpoji-Aba among others.

Geology and Hydrogeology of study area

The study area falls within the Niger Delta (Short & Stauble, 1967; Arvorbo, 1978). The basin is an extensive continental margin basin situated in the Gulf of Guinea built out into the Central South Atlantic Ocean at the mouths of the Niger-Benue and Cross River systems during the Eocene (Hospers, 1971). The basin lies between latitudes 4^0 and 7^0N and longitudes 5^0 and 8^0E. It is an arcuate delta that is wave dominated and tidally influenced by sand bodies whose thickness may be influenced by growth faulting. Three lithostratigraphic units have been identified in the basin. These include in chronological succession, Akata Formation, Agbada Formation, and Benin Formation. The Akata Formation (Paleocene Age) is predominantly of marine sedimentary sequence laid down in front of an advancing delta. It is characterized by uniform medium dark gray marine shale with lenses of siltstones and sandstones. Agbada Formation consists of alternation of sandstone and shale layers. The sands are poorly sorted except where they are graded into shale. Lignite streaks and limonitic grains are common in the upper part. Benin Formation (Fig. 2) consists of a succession of massive, highly porous, fresh water bearing sands, thin clay and shale, lignite and gravel of continental upper deltaic plain (braided-stream) environment (Nwajide, 2013). The age is Miocene –Recent (Short & Stauble, 1967) (Fig.2).

Aba is located in Niger Delta hydrological province, in the sub-basin of Imo River, with Aba River basin being the smallest sub-basin. The Aba River drains into the Imo River which ultimately flows into the Atlantic Ocean (NHSA, 2020). The water bearing units are sandstones and conglomerates with shales acting as confining units. The aquifer type is confined to semi-confined. The aquifer thickness ranges from 50-200 meters, with transmissivity of 10-500m^2/day, storativity of 0.01-0.1 and hydraulic conductivity of 1-50m/day.

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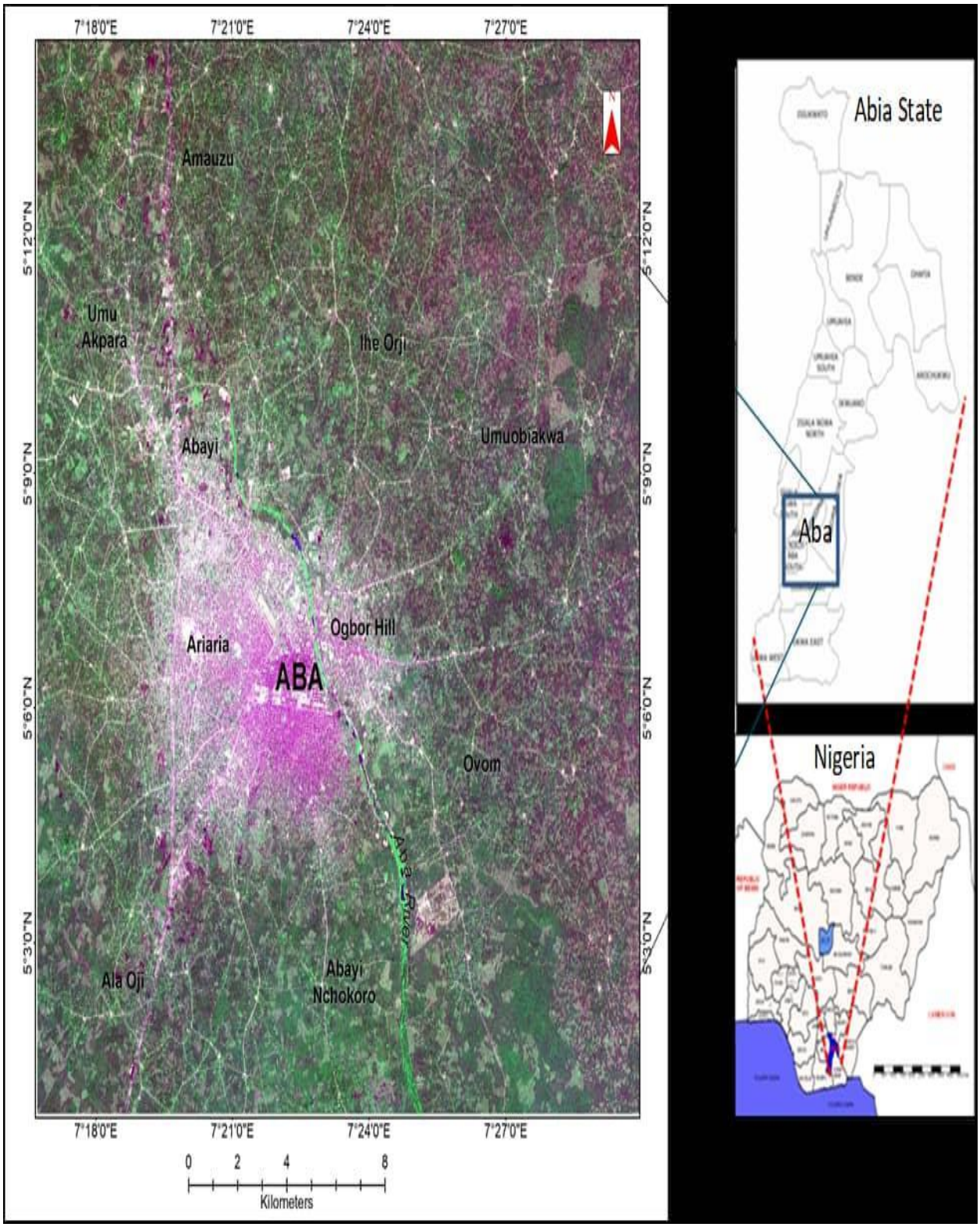

Fig. 1: Location and accessibility map of the study area

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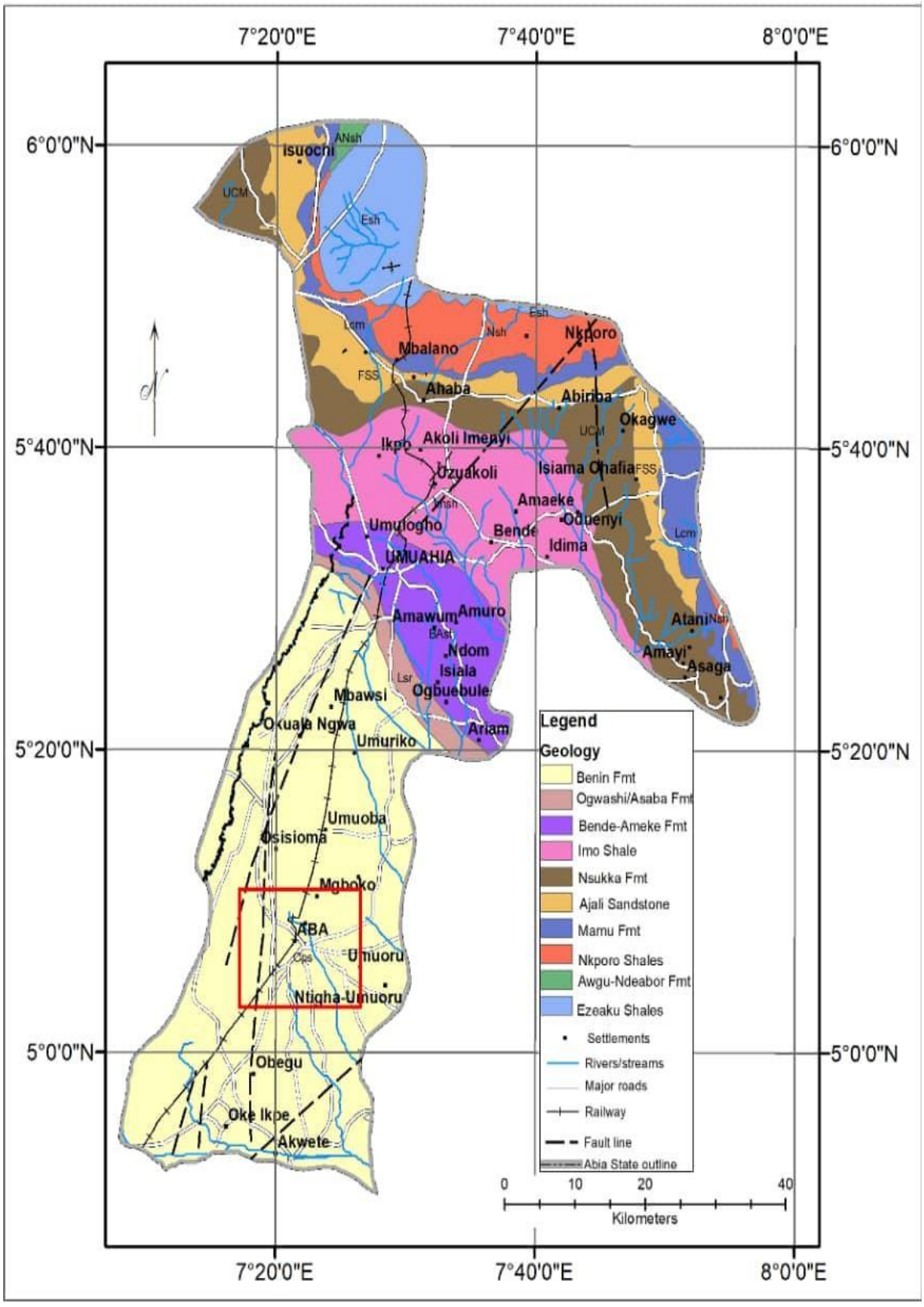

Fig. 2: Geology map of Abia State, Nigeria showing the study area in red rectangle

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METHODOLOGY

The study involved groundwater sampling in Aba town and its environs, and measuring such parameters as pH and Total Dissolved Solids (TDS) on the spot. There was no regular grid for sampling; however, sampling was done randomly following street pattern and accessibility. At each sampled borehole, two (2) samples each of 1 liter were collected in plastic containers for laboratory analysis. A total of forty-five (45) samples was collected in the study area and necessary precautions were taken to avoid exogenous contamination of the sample. The 2 sample containers were then packed in cooler boxes containing ice pellets for preservation. The containers were later transferred to a refrigerator at the Base Camp and were later taken for laboratory analysis using standard methods (APHA, 1998). One of the water samples, usually labelled A, was kept for analyses of anions, Cl^{-}, SO_4^{2-}, NO_3^{-}, HCO_3^{-}, CO_3^{-}. The second sample labelled B was acidified with 2 drops of 60% nitric acid. This was later used to analyze for cations, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and the trace metals. The environment of the sampled borehole, the density of the population around the area and private/industrial usage were all noted during the fieldwork.

RESULTS AND DISCUSSION

Result and Interpretation

Major chemical components of the water include dissolved Na^{+}, Ca^{2+}, K^{+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-} and trace elements such as PO_4^{3-} Mn, Zn and Fe^{2+}. The physical parameters include total dissolved solids (TDS), and hydrogen ion concentration (pH) (Table 2). Results and interpretations were based on acceptable standards (WHO, 2006; NAFDAC, 2006) and in comparison, to the background values of the parameters within the study area.

The background values were taken to be the threshold value of parameters measured from a relatively quiet and underdeveloped area. Metals are naturally occurring substances and as such they can always be found at natural (background) concentrations in the different environmental compartments. The natural background of a metal in the environment can be defined as the metal fraction that originates from natural geological, biogeochemical and other processes (MERAG, 2007). The following sections below describe the various physicochemical parameters of importance in the study area.

pH distribution

The pH range in the groundwater is from 3.6 – 6.7, with a mean pH value of 4.1. This implies generally that the pH of water in the area is low. This is evident all over the study area (both rural and metropolitan Aba). These ranges of pH fall below recommended values for pure water, and the minimum recommended limits for drinking water by WHO (2006) and NAFDAC (2006). This is similar to observations of Afolabi *et al.* (2018) in the study area and Ewa *et al.* (2011) in a similar study where low pH values were observed and it was attributed to be due to high carbon dioxide emissions from increased organic matter decomposition rates resulting in the formation of a weak carbonic acid, which decreases the pH of the water (Venkatesharaju *et al.*, 2010). In order to ascertain the source of the low pH of the groundwater in Aba, comparison was made with the pH of rainwater samples taken at different locations within the study area and it was observed that low pH (4.9 - 5.9) characterized the rainwater as

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well. It was concluded therefore, that the low pH could have resulted from atmospheric pollution. However, lower pH values in most cases were recorded from water samples around waste dumps and the highly busy areas and slums which introduce anthropogenic influence on the pH (Fig 3). It is worthy to note that a pH of less than 6.5 may result in increased gastrointestinal problems and bone diseases (WHO,2019). Other implications of low pH include corrosion of pipes, leaching of heavy metals (EPA, 2020), and growth of harmful bacteria (CDC, 2020).

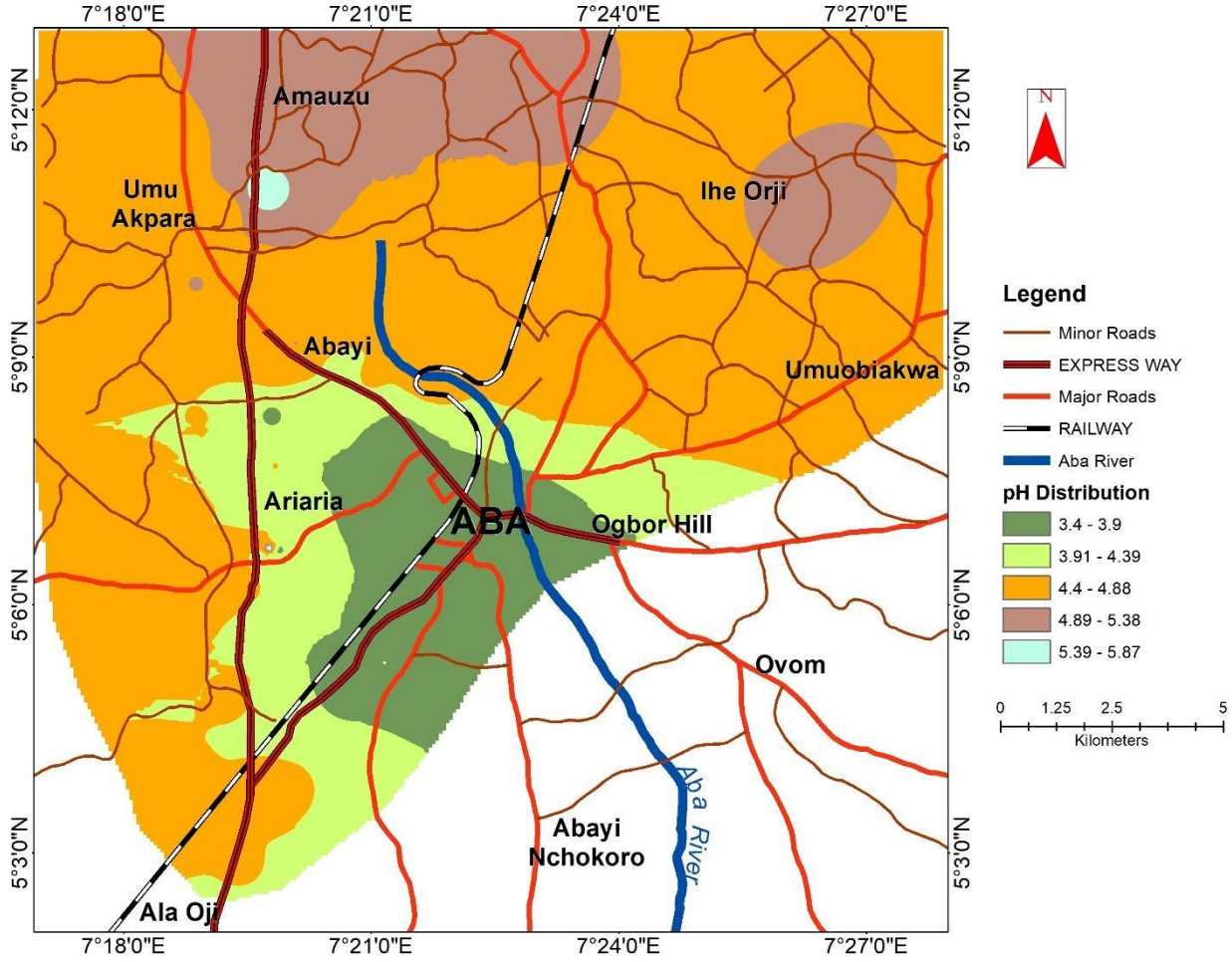

Fig. 3: pH distribution map of Aba and its environs

Table 1: Physicochemical parameters of the analyzed water samples

SAMPLE NO.	Ca^{2+}	Mg^{2+}	K^{+}	Na^{2+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3^{-}	Mn	Zn	Fe	TDS (ppm)	PH
AB-1	0.800	1.94	0.570	8.41	4.88	3.12	<0.01	5.86	0.197	0.666	0.657	10	4.9
AB-2	0.800	0.48	0.742	7.52	4.64	6.23	1.09	5.20	0.154	0.417	0.650	5	4.7
AB-3	0.800	0.48	0.546	6.47	5.37	6.23	1.85	4.70	0.189	0.384	0.650	5	5.7
AB-4	0.800	0.48	0.663	5.93	1.95	6.23	1.77	4.90	0.166	0.376	0.641	5	4.9
AB-5	0.800	0.48	0.575	8.33	2.44	6.23	2.19	5.70	0.159	0.407	2.470	5	5.0
AB-6	2.400	0.48	0.518	6.40	10.25	6.23	<0.01	4.60	0.184	0.315	0.634	10	4.7
AB-7	0.800	0.48	0.736	7.55	1.22	6.23	1.09	5.80	0.157	0.418	0.613	5	4.8

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AB-8	0.800	0.48	0.812	9.43	0.98	6.23	2.52	5.80	0.188	0.329	0.642	5	4.7
AB-9	0.800	0.48	0.614	6.38	0.98	6.23	2.86	5.60	0.174	0.314	0.642	5	4.8
AB1-0	0.800	0.48	0.515	7.59	1.71	3.12	2.52	5.60	0.149	0.528	0.643	5	4.8
AB-11	1.600	0.48	0.618	6.64	1.46	6.23	2.27	5.80	0.168	0.475	2.780	10	4.8
AB-12	0.800	0.48	0.714	8.34	1.71	6.23	2.02	4.60	0.184	0.511	0.671	5	4.8
AB-13	0.800	0.48	0.524	7.94	1.22	6.23	3.53	4.90	0.179	0.634	0.742	5	4.8
AB-14	0.800	0.48	0.663	8.26	1.46	6.23	3.03	4.60	0.153	0.538	0.861	5	5.1
AB-15	0.800	0.48	0.486	8.12	1.22	6.23	2.27	5.60	0.184	0.829	3.050	10	4.8
AB-16	2.400	0.48	0.514	7.52	1.46	6.23	3.28	4.80	0.194	0.419	0.946	5	4.7
AB-17	0.800	0.48	0.502	6.39	3.17	6.23	<0.01	4.80	0.183	0.508	14.580	5	4.6
AB-18	5.610	<0.01	0.611	8.33	24.40	6.23	3.19	5.60	0.175	0.466	3.010	5	4.7
AB-19	0.800	0.48	0.816	7.53	0.11	6.23	2.27	5.80	0.170	0.475	2.940	2	5.2
AB-20	0.800	0.48	0.519	9.46	1.22	6.23	1.18	5.60	0.164	0.424	1.050	3	4.6
AB-21	1.600	0.48	0.602	8.42	0.98	6.23	2.69	5.20	0.154	0.415	0.843	7	4.4
AB-22	0.800	0.48	0.553	10.06	1.22	6.23	1.43	5.60	0.183	0.398	0.956	5	4.7
AB-23	1.600	<0.001	0.842	5.63	2.79	3.33	6.22	0.88	0.246	0.475	0.546	5	4.9
AB-24	1.600	<0.001	0.741	4.84	2.39	3.33	5.38	0.88	0.251	0.638	0.604	10	4.6
AB-25	4.896	1.452	0.663	4.98	<0.01	6.66	4.37	0.88	0.223	0.878	0.609	4	4.6
AB-26	1.600	<0.001	0.761	5.06	<0.01	3.33	4.03	4.40	0.222	0.714	0.563	5	4.4
AB-27	3.210	<0.001	0.824	5.11	<0.01	10.00	3.78	10.10	0.228	0.604	0.594	20	3.8
AB-28	1.600	<0.001	0.719	6.41	<0.01	10.00	3.78	18.00	0.234	0.718	0.686	10	4.4
AB-29	3.210	<0.001	0.643	5.93	<0.01	3.33	3.61	3.52	0.239	0.719	0.714	10	4.6
AB-30	3.210	0.97	0.698	5.86	<0.01	3.33	0.42	18.90	0.209	0.804	0.814	60	4.1
AB-31	1.600	<0.001	0.708	5.54	<0.01	3.33	7.32	8.80	0.216	0.538	0.753	10	4.5
AB-32	3.210	<0.001	0.64	5.66	<0.01	3.33	2.35	7.92	0.290	0.241	0.687	40	4.0
AB-33	4.810	<0.001	0.598	6.04	0.99	6.66	9.41	26.40	0.214	0.542	0.541	110	4.1
AB-34	6.410	0.97	0.613	7.13	<0.01	3.33	3.78	45.80	0.223	0.511	0.633	90	3.8
AB-35	6.410	0.97	0.814	5.49	<0.01	6.66	2.94	35.60	0.196	0.638	0.786	100	3.6
AB-36	6.410	0.97	0.866	5.53	<0.01	6.66	15.38	8.36	0.209	0.549	0.742	240	4.4
AB-37	0.400	0.3	0.713	5.86	<0.01	209.90	10.08	16.06	0.218	0.743	0.842	850	6.7
AB-38	3.210	<0.001	0.728	6.15	<0.01	3.33	4.54	20.68	0.226	0.784	0.635	40	4.1
AB-39	3.210	<0.001	0.646	6.22	<0.01	3.33	3.76	16.70	0.214	0.713	0.646	30	4.2
AB-40	3.210	<0.001	0.659	5.94	1.19	6.66	2.31	0.88	0.208	0.715	0.631	5	4.5
AB-41	2.405	0.484	0.708	5.88	<0.01	6.66	4.29	0.88	0.217	0.722	0.598	5	4.6
AB-42	3.210	<0.001	0.719	6.13	<0.01	3.33	3.70	2.20	0.209	0.731	0.582	10	4.4
AB-43	1.600	<0.001	0.548	6.44	<0.01	3.33	3.45	2.64	0.224	0.694	0.713	5	4.5
AB-44	6.410	0.97	0.599	7.06	<0.01	3.33	2.52	32.60	0.215	0.708	0.696	80	3.9
AB-45	6.410	0.97	0.611	6.36	<0.01	6.66	7.98	22.00	0.209	0.719	0.677	70	3.9

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Total Dissolved Solids (TDS)

The total dissolved solids (TDS) expresses the overall amount of soluble ionic and solute content of any given water sample. The presence of these salts in water confers impurity to otherwise pure water and alters the chemical composition. Fig. 4 represents the spatial distribution of the measured TDS in the study area. TDS values range between 2 – 850 pmm in the groundwater samples and the range of TDS for sampled rainwater was about 0 and 1 ppm, which indicated that increasing TDS values in groundwater are due to geogenic and anthropogenic influences.

Background TDS values were taken as the values measured in the rural outskirt and very low-density localities within the study area, where it is assumed that anthropogenic influences are minimal. These values range between 5 - 50ppm and represent TDS values due to geogenic influences (Fig 4). Departures from the background values are thus believed to be contamination of the natural groundwater quality by anthropogenic activities. Based on this, 17.8% of the samples were observed to have TDS values above 50 ppm while 82.2% were observed to be below it. However, the level of contamination does not necessarily mean groundwater pollution, which depends on intended use and comparison with widely accepted water quality standards. This is similar to the findings of Afolabi *et al.* (2018) in the study area.

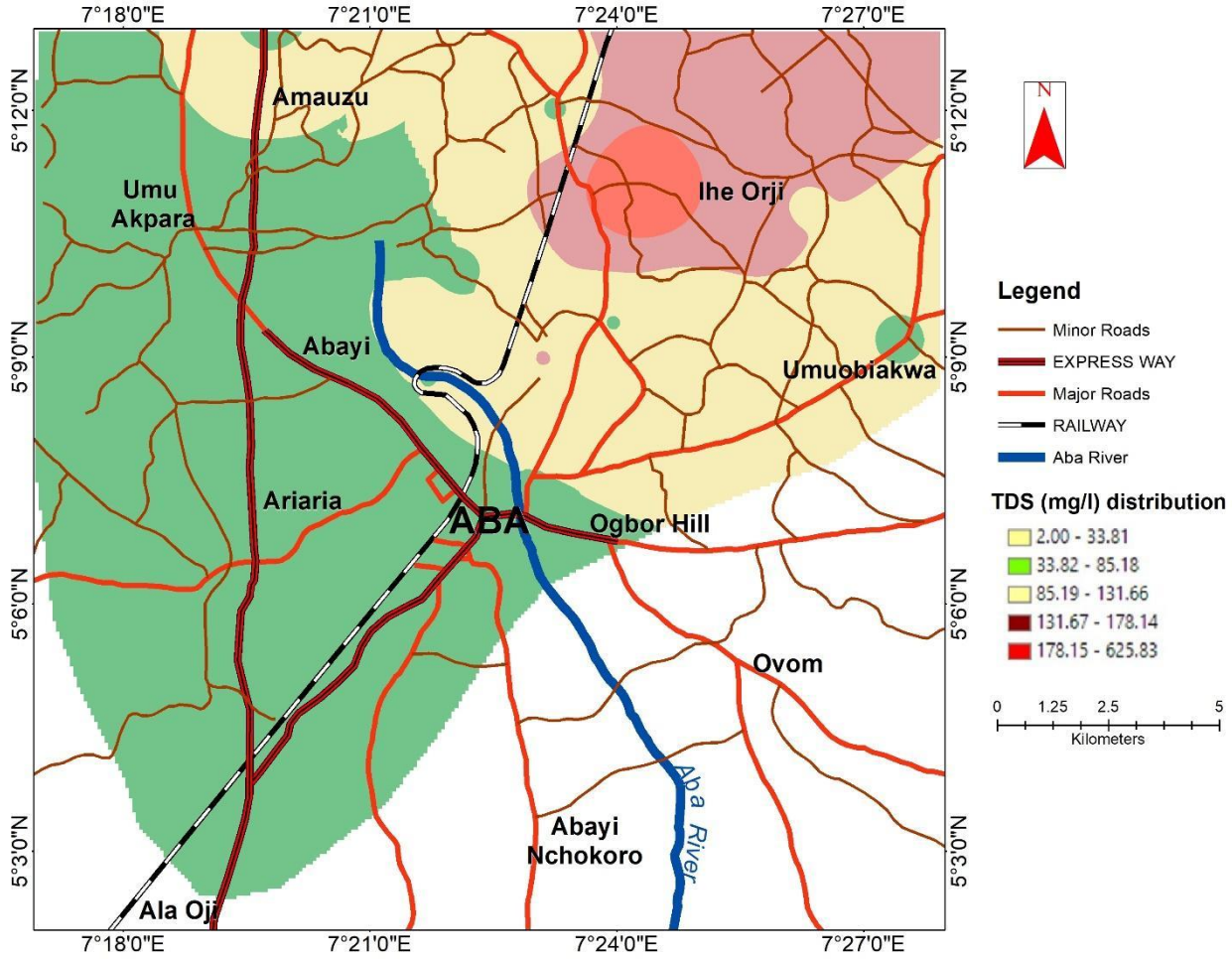

Fig. 4: TDS distribution map of study area produced from the measured field data

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Nitrate (NO_3^-)

According to Freeze and Cherry (1979), soluble forms of nitrogen are highly mobile in the subsurface environment and are easily leached through the soil zone into the underlying aquifers by infiltrating waters. Nitrates, perhaps, is the most widely spread groundwater contaminant. Nitrogen from natural sources is rarely found in groundwater concentrations greater than 3 mg/l as nitrate (Bachman, 1984). However, it can occur as soluble nitrogen in the form of nitrate. The values of nitrate concentration in the area study range from 0.88 – 45.80 mg/l. Fig 5 represents the nitrate concentration map of the area and from the map, it can be seen that higher nitrate concentrations above 3 mg/l are characteristic of the study area. This high value is indicative of non-natural nitrate contamination, but of anthropogenic influences resulting from poor sanitary conditions. Nitrates can be reduced to toxic nitrites in the human intestine, and many babies have been seriously poisoned by well water containing high levels of nitrate-nitrogen (WHO, 2019; EPA, 2020). The U.S. Public Health Service has established 10 mg/l of nitrate-nitrogen as the maximum contamination level allowed in public drinking water (New Jersey Office of State Planning, 1988). The potential sources of nitrate include agricultural runoff, sewage (EPA, 2020), industrial wastes, and poorly maintained water distribution system. Nitrate is taken to be a non-carcinogenic water pollutant (Pasupuleti *et al.*, 2022), however, ingestion can lead to a wide range of medical conditions such as: methemoglobinemia in infants' miscarriages, birth complications, increased risk of hemolytic anemia, esophageal cancer and stomach cancer, ulcerations and teratogenic effects (Ayejoto *et al.*, 2024; Isiuku *et al.*, 2020; Ji *et al.*, 2022).

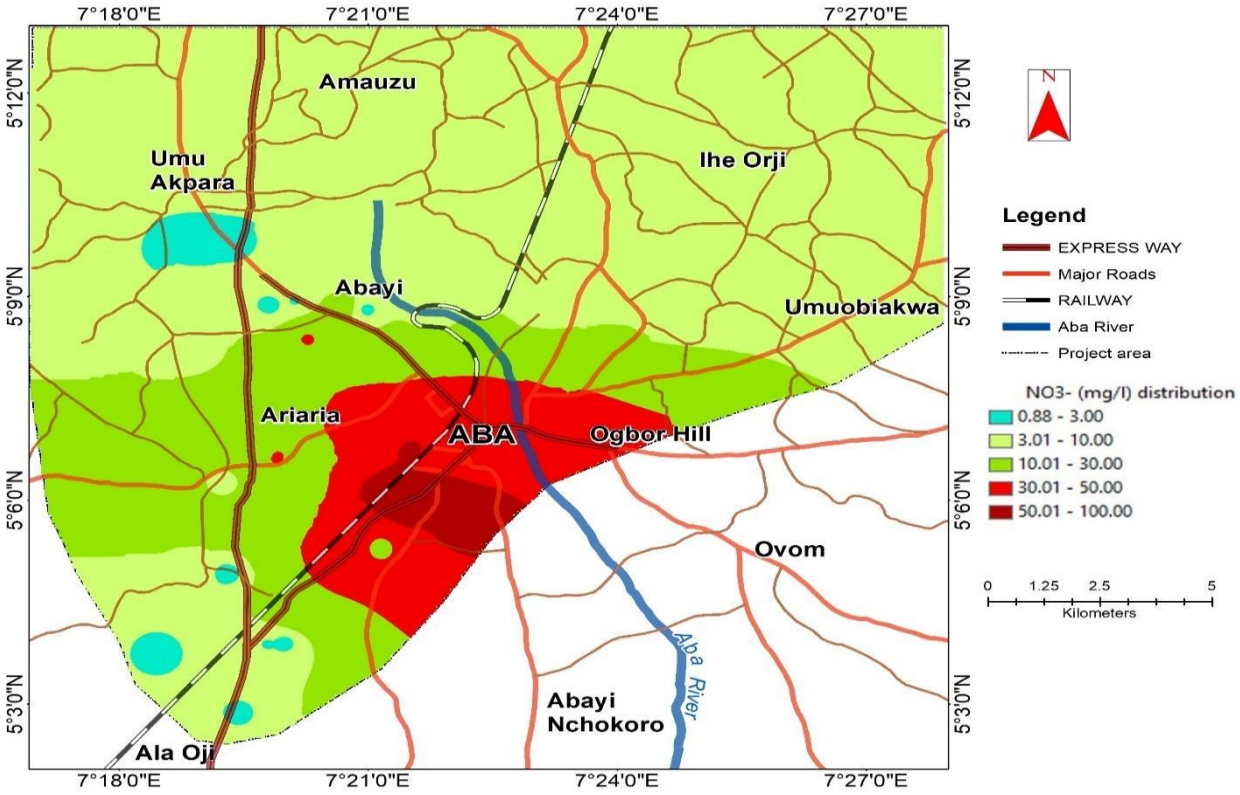

Fig. 5: NO_3^- concentration map of Aba and environs

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Sulphate SO_4^{2-} concentrations

Sulphate is a stable, highly oxidized, soluble form of sulphur (Parihar *et al.*, 2012), which is generally present in water. The obtained value of sulphate in groundwater samples in the study ranges from < 1 mg/l – 15.38 mg/l. The higher concentrations were obtained around the NNPC depot (AB 36) in the Osisioma area where there is noticeable hydrocarbon contamination of groundwater. Similarly, water samples taken from or near some petrol filling stations and areas near major automobile workshops present higher values of sulphate above background values (Fig 6). This result shows the influence of urbanization on sulphate concentration in the groundwater of Aba and its environs. However, these sulphate levels are still within the maximum recommendation of NAFDAC (2006) and WHO (2006) for drinking water and this is in agreement with the work of Onojake *et al.* (2017) in a similar study.

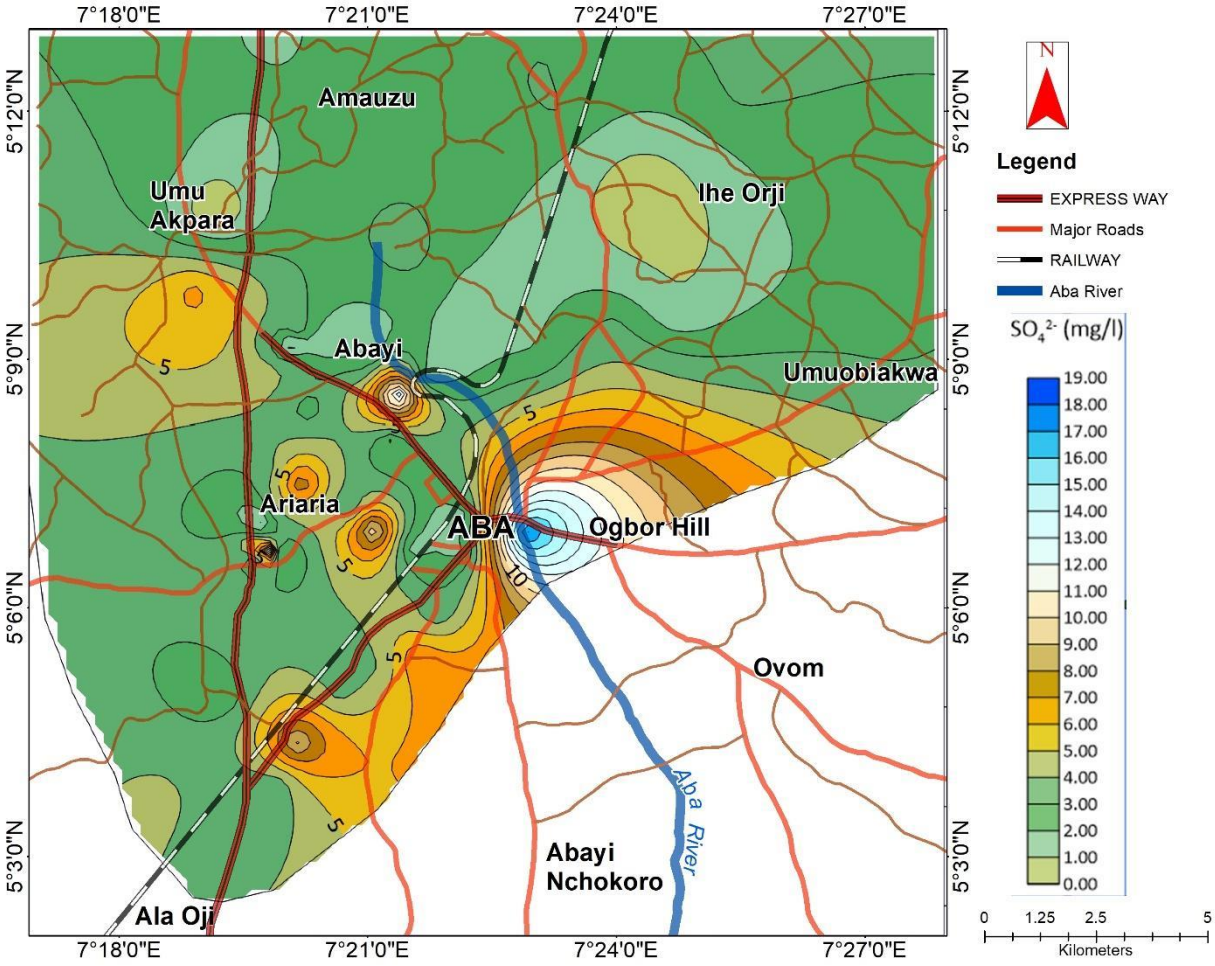

Fig 6: Sulphate (SO_4^{2-}) concentration map of study area showing areas of higher concentration

Chloride ion (Cl^-) Concentration

Chloride is present in all types of natural water in varying concentrations but excessive chloride in surface water impacts a salty taste (Ogbonna *et al.*, 2019). Fig. 7 shows the spatial representation of the concentration on map. Generally, the Cl^- concentration is within acceptable limits and the background concentration for the study area is below 5 mg/l. This

Article DOI: 10.52589/AJENSR-89BQTMYA
DOI URL: https://doi.org/10.52589/AJENSR-89BQTMYA

African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 8, Issue 1, 2025 (pp. 158-176)
www.abjournals.org

implies that the water, generally, has low salinity. Extreme case of high Cl^- concentration (209 mg/l) above the WHO and NAFDAC specifications was noticed from a sample (AB-37) near Enyimba dumpsite and this may be an indication of pollution from domestic waste and sewage (Afolabi *et al.*, 2018; Agwu *et al.*, 2013). Generally, the groundwater is within NAFDAC (2006) and WHO (2006) recommended value of 200 mg/l.

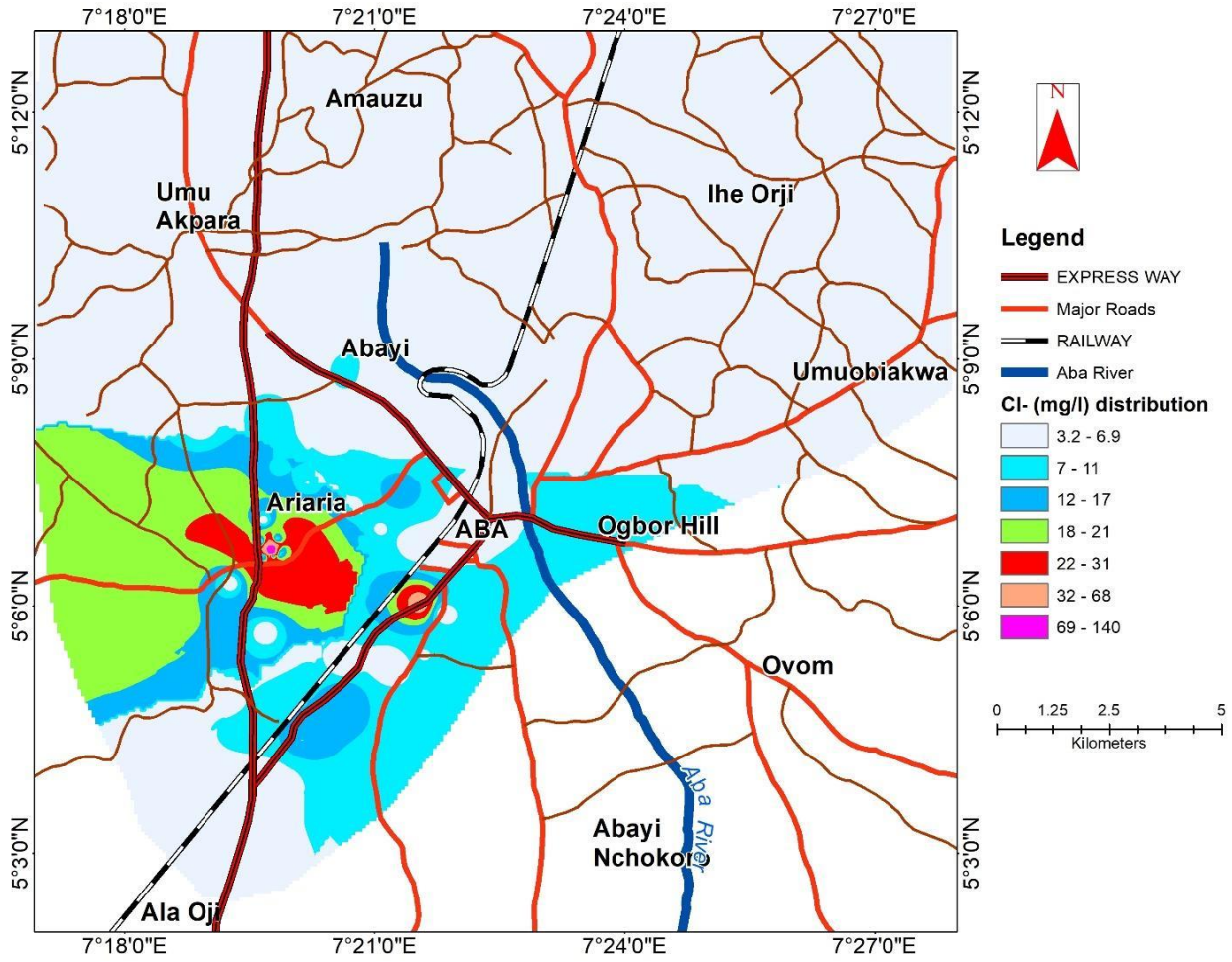

Fig 7: Chloride concentration maps of Aba

Bicarbonate (HCO_3^-)

The observed low pH concentration of Aba water is evidenced in low to very negligible HCO_3^- concentration (<0.01 – 24.40mg/l) obtained from the result of hydrochemical analysis. Decreasing concentration of bicarbonate in the groundwater coincided with areas of decreasing (negative) pH values (cf. Fig. 8 and Fig 3).

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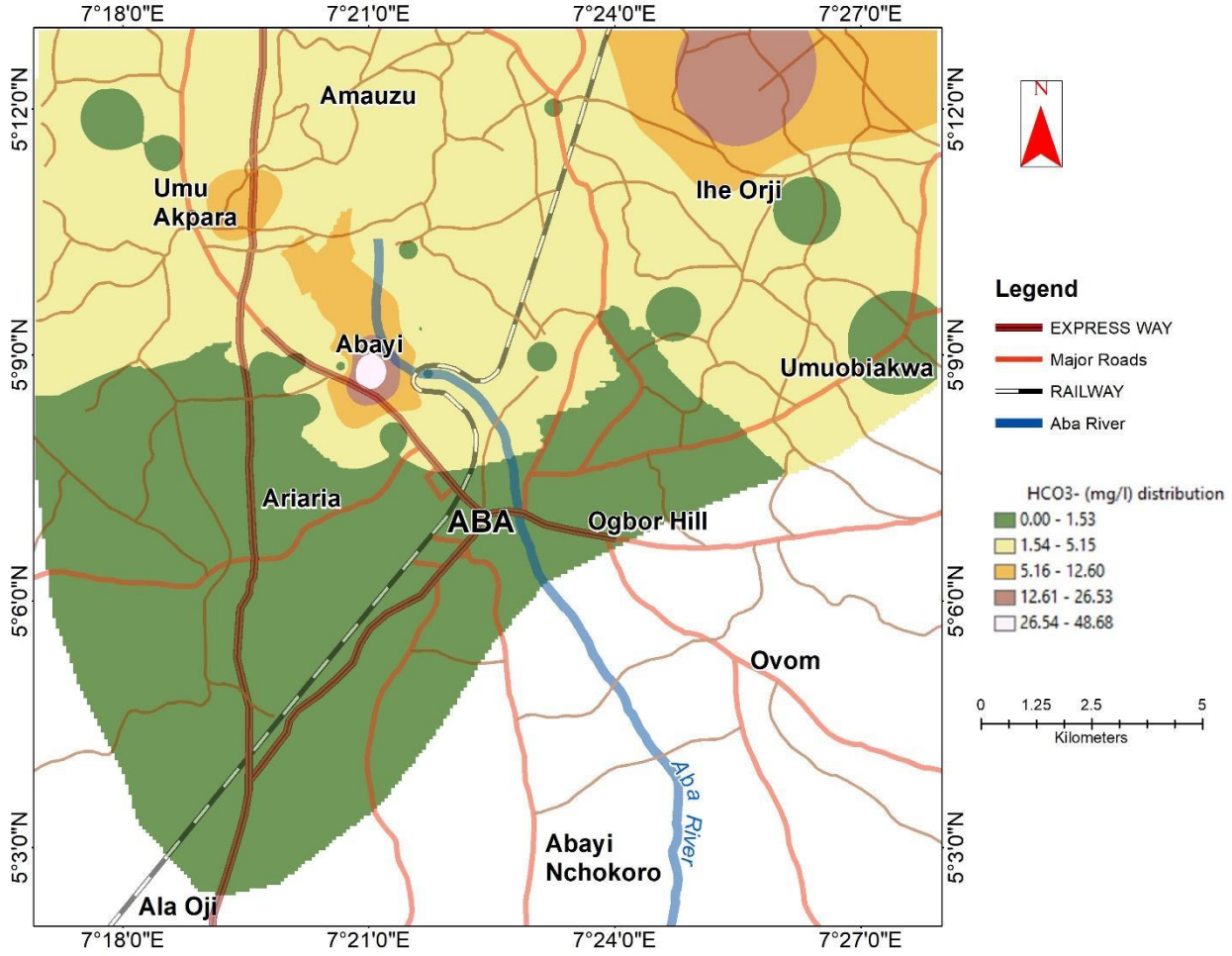

Fig. 8: Distribution of Bicarbonate HCO_3^- in groundwater of Aba and environs

Soluble iron (Fe^{2+}) Concentration

The concentration of soluble iron in the study area was generally high in the analyzed samples, although some drillers reported disturbing concentration at some places. The problem of iron in water is mainly that of aesthetics, although there is some health implication connected to it. The maximum recommended concentration for drinking water is 0.05 – 0.3mg/l (WHO, 2006). The form iron takes in water is a function of the amount of oxygen in the water and the pH value. The range of the concentration was above the recommended limits. Concentrations in the order of 1-6 mg/l occurred around Umungazi –Abayi, and Obingwa LGA (Fig 9). Extreme cases with concentration up to 14.58mg/l were obtained near Enyimba dumpsite, probably due to leachate contamination, and also at Obete village in Obingwa LGA where it is suspected to be contamination from corroded iron pipe casing of the borehole. Similar results of low Fe concentration were previously reported by Davies and Oghenetekevwe (2022) in a similar study in Apuro-Ama Creek in Rivers state.

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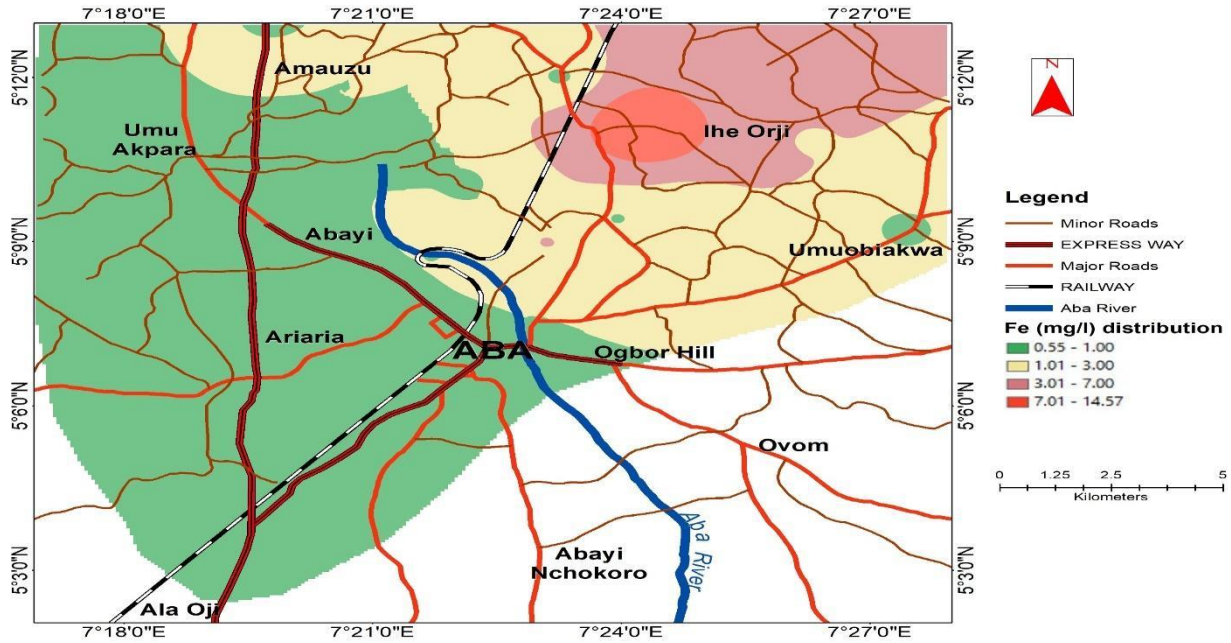

Fig. 9: Distribution of Fe^{++} in Aba groundwater

Calcium ion distribution (Ca^{++})

A clear pattern in the distribution of Ca^{++} in the groundwater is similar to that shown by the TDS, pH and the anions as seen in the study area. The distribution pattern reveals increasing concentration of the ion from the background concentration <3 mg/l to >6.41mg/l in the urban center (Fig 10). However, the level of contamination of the ion is still within the acceptable limit of the WHO (2006) specification.

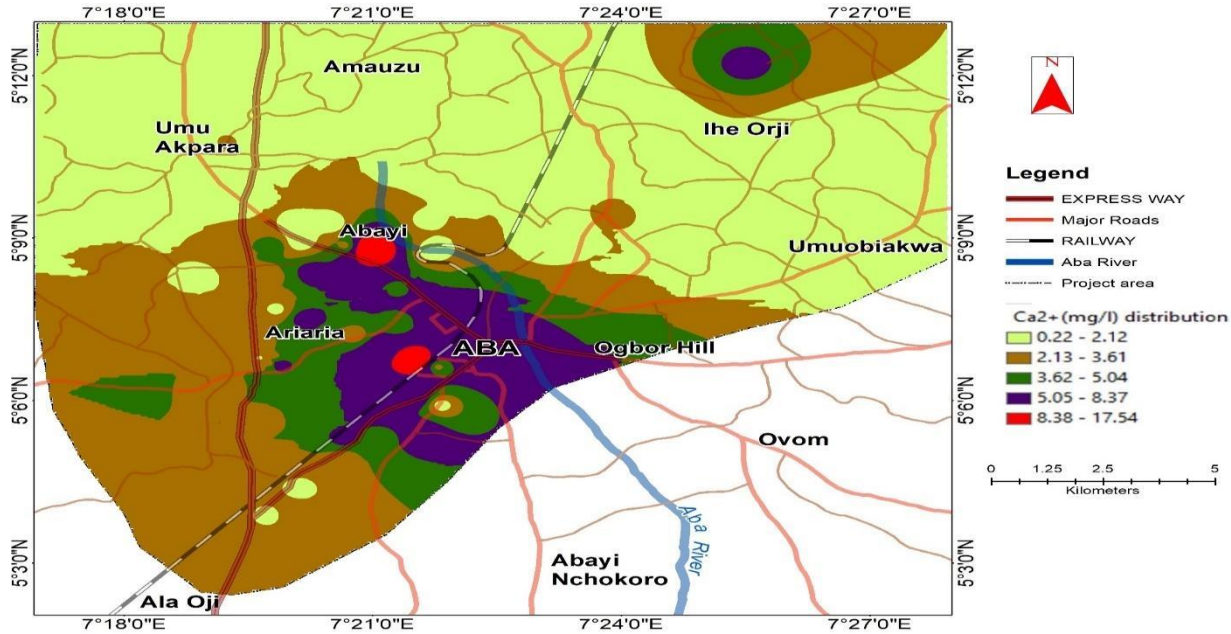

Fig 10: Distribution of Ca^{++} in Aba groundwater

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Sodium ion (Na^+) distribution

The pattern of distribution of Na^+ ions in Aba groundwater shows a trend that varies inversely as that of the Ca^{++} ion. Na^+ is observed decreasing toward the city center (cf Fig 11 and Fig 10). This phenomenon can be explained as result of cation exchange between Ca^{++} rich contaminants and Na^+ leading to enrichment of Ca^{++} ions in the groundwater since Na^+ is more reactive than Ca^{++}. The range of Na^+ in the groundwater is between 4.84mg/l and 10.06mg/l (Table 1) and is still within acceptable limits for drinking water WHO (2006) and NAFDAC (2006).

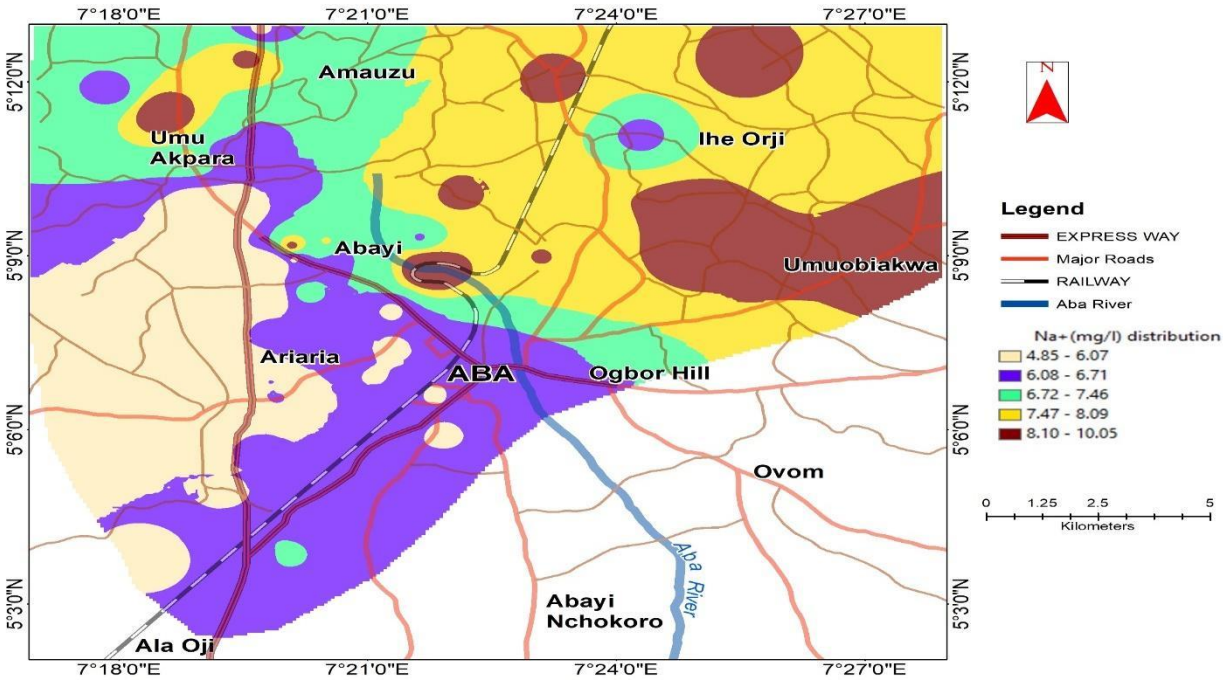

Fig 11: Distribution of Na^+ in Aba groundwater

Distribution of manganese ion (Mn^{++})

Manganese is notorious for darkening of the teeth when present in water above a certain limit (Zhoa *et al.*, 2019). In the study area, increasing concentration of manganese in the groundwater was observed from the background to the values even higher than the WHO (2006) acceptable limit (0.5 mg/l) in the urban center (Fig 12). This indicates degrading groundwater quality. Concentration ranges from background <0.2mg/l – 0.6mg/l in the urban area. The Mn values are greater than those reported in Amadi (2012), where Mn^{++} concentrations range from 0.050-0.508 mg/l. According to the WHO (2017), levels exceeding 0.1mg/l manganese will cause an undesirable taste and stains.

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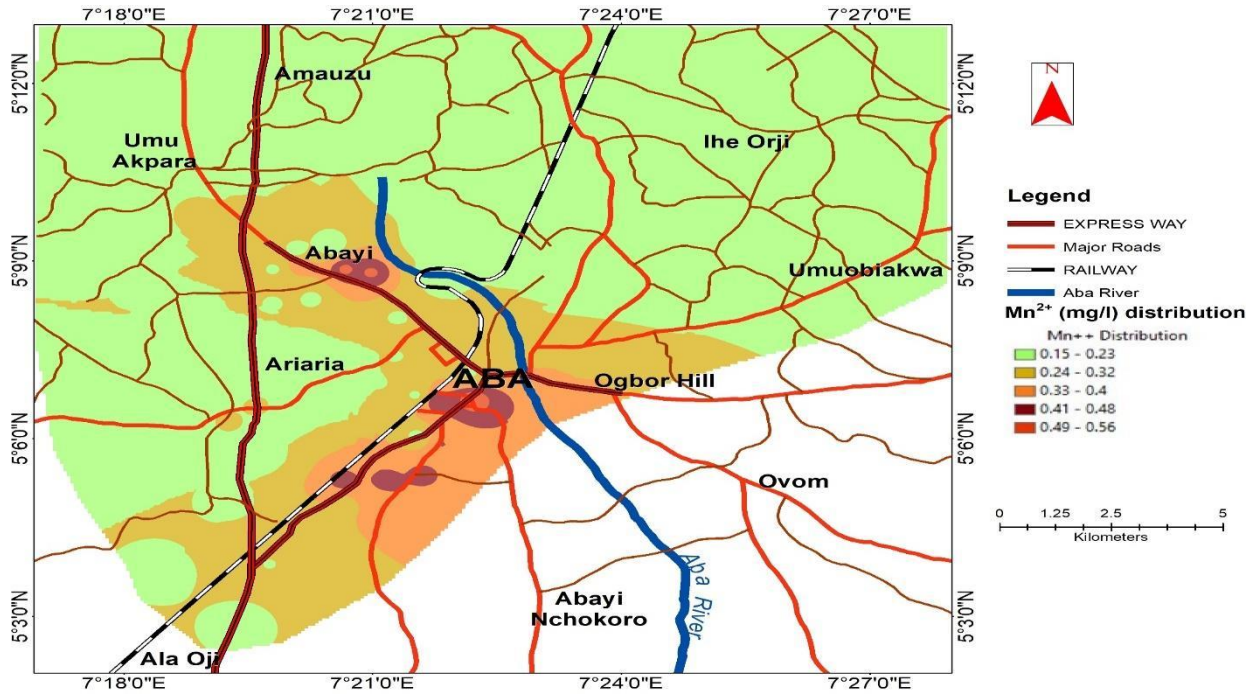

Fig 11: Distribution of Mn^{++} in Aba groundwater

CONCLUSION

Generally, there is an increase in the concentration of almost all the parameters towards the city center. These variations have been attributed to geogenic and anthropogenic factors. Background concentration and WHO (2006) and NAFDAC (2006) standards for drinking water were used to ascertain the level of pollution and quality of the groundwater. Except for Fe^{++} which has background concentration above the WHO standard in the entire groundwater samples, most of the water samples fall within WHO/NAFDAC limits for drinking water.

The use of background concentration, however, showed trends in the variations of the hydrochemical parameters resulting from anthropogenic pollution due to urbanization. This work also showed the limit to the applicability of the WHO and other standards in pollution studies as they are interventions only which do not account for processes but specific limits of acceptability.

It is recommended that groundwater in the study area be treated before use and appropriate measures should be taken by necessary authorities at protecting the groundwater from further pollution from anthropogenic sources. It is imperative that protected groundwater zones preferably at the outskirts of the metropolis be created where alternative water supply can be sourced.

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