Assessment of Groundwater Quality from Domestic Boreholes in Parts of Owerri, Imo State

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ABSTRACT

Groundwater remains a major natural water resource tapped for drinking and other economic activities across the globe. This resource, however, cannot be optimally used and sustained unless there is constant and frequent assessment to guarantee its quality for consumption. In this study, groundwater quality and status in seven locations in Owerri was assessed. It was aimed at the assessment of groundwater quality from domestic boreholes in parts of Owerri, Imo State. Fourteen (14) water samples, two from each location, were collected from boreholes in Eziobodo (B1), Obinze (B2), Nekede (B3), World Bank (B4), Egbu (B5), Orji (B6) and Amajeke (B7). The physicochemical and biological parameters of these samples were investigated using standard laboratory techniques. Spatial distribution maps of SO_4^{2-}, total coliform count, turbidity, TSS, NH_3, and pH were generated using Geographical Information System (GIS). The values of the physicochemical parameters were juxtaposed with the World Health Organization (WHO) values. The results, relative to recommended standards by WHO, revealed that most of the groundwater samples were contaminated. This paper presents a pivotal contribution for understanding the relationship between land use and groundwater quality in some parts of Owerri.

Keywords: Groundwater; Spatial distribution; Geographical Information System; Physicochemical parameters.

1.0 INTRODUCTION

Groundwater is the most important natural water resource used for drinking by many people around the world. It is estimated that approximately one third of the world's population use groundwater for drinking (Nickson *et al*., 2005). Groundwater in many regions, especially in arid and semi-arid areas, is considered as a basic and reliable source of freshwater supply due to its freshness, constant temperature, lower pollution coefficient and higher reliability level.

However, groundwater pollution has become a global critical topic in the last few decades (Umar *et al*., 2009). Urbanization and population explosion have threatened groundwater quality because of the impact of domestic and industrial waste disposal. These phenomena, amongst other anthropogenic exertions, have resulted in massive deterioration of groundwater quality, since some of these waste products, including sewage and cesspool may eventually seep through the soil in the unsaturated zone to pollute the groundwater (Ijeh and Onu, 2013).

Furthermore, groundwater pollution does not only affect water quality but also threatens human health, economic development, and social prosperity (Milovanovic, 2007). The quality of groundwater has particularly received rapt attention from scientists since water of high quality is required for domestic and irrigation needs. The alarming degradation of water monitoring systems and the obsolescence of in situ measurement equipment in developing countries necessitated additional new solutions to improve water governance based upon reliable, comprehensive and timely water information (Macdonald, 2005).

Until recently, groundwater assessment has been based on laboratory investigation, but the advent of satellite technology and GIS has made it very easy to integrate various databases. Geographic Information System (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields (Lo and Yeung, 2003). GIS can be a powerful tool for developing solutions for water resources problems, assessing water quality, preventing flooding, determining water availability, understanding the natural environment and for managing water resources on a local or regional scale (Ketata-Rokbani *et al*., 2011).

This study evaluates the spatial variation of groundwater quality within Owerri to identify possible implication of land uses on groundwater. It employs GIS techniques to map the identified concentrations of groundwater parameters in some selected locations in Owerri.

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2.0 MATERIALS AND METHODS

2.1 Description of Study Area

This study was carried out in Owerri, Imo State, located in the South Eastern Geo–political zone of Nigeria. It lies between latitude 5°19'30" N and 5°29'50" N and longitude 6°56'50" E and 7°7'10" E. It comprises of three Local Governments Areas including Owerri North, Owerri West and Owerri Municipal and has an approximate area of 535.43 square kilometers (535.43 Sq. Km) with a population of about 750 000 (NPC, 2006). The city has undergone substantial industrial and population growth over the past two decades, resulting in massive waste generation. Waste generated in Owerri is disposed of in erosion sites, in open dumps, along river banks, abandoned borrow and quarry pits, abandoned septic tanks, and pit latrines. Other potential sources of pollution include petroleum products from numerous mechanic villages in Owerri, petrol stations and from industrial effluents. Open dumps, in particular, are sited indiscriminately in the study area without consideration to the protection of the underlying aquifers.

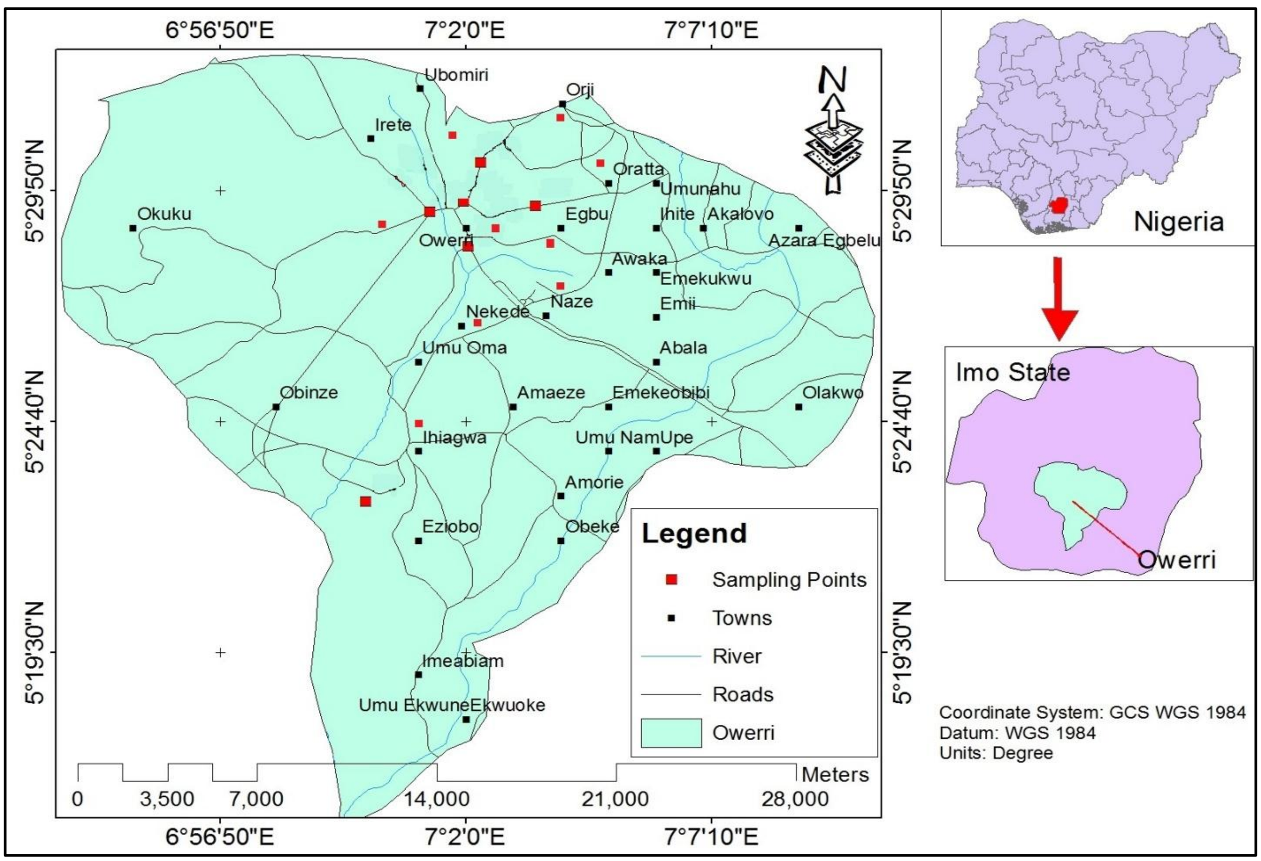

Fig. 1. Map of the study area showing sampling points

2.2 Sample Collection

Water samples were collected in duplicates from private boreholes from the seven study locations into pre-cleaned plastic bottles labeled B1 – B7. The locations and GPS coordinates from which the samples were taken are given in Table 1. Samples were collected in the early morning hours when pumped from the ground in compliance with the Nigeria Standard for Drinking Water Quality best practices for water quality analysis. Prior to collection of samples, all the bottles used for sample collection were washed and rinsed with distilled water. The bottles were also rinsed three times with water from the sampled borehole before collection. The bottles were held at the bottom during filling to avoid contamination of water from the hands or fingers. The distance from each borehole to a potential source of contamination which includes landfills, septic tank (sewers and latrines) was measured and recorded. All the sample containers were stored in ice boxes and transported to the laboratory for analysis.

2.3 Determination of Physicochemical Parameters

2.3.1 Nitrate ions

The cadmium reduction method as adopted from APHA (1998) was employed in the determination of nitrate levels of the water samples. A cadmium based reagent pillow was added into 25mL of the water sample in a cuvette and shaken for 1 minute and allowed to stand for another 5 minutes for complete reaction to occur. The absorbance and concentration in mg/L was read at 500nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

2.3.2 Sulphate ions

The barium chloride (Turbidometric) method (APHA, 1998) was adopted. The barium chloride based powdered reagent pillow was added into 25mLof water sample. The mixture was properly mixed and allowed to stand for 5 minutes for reaction to occur. The absorbance and concentration in mg/L was read at 450nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

2.3.3 Phosphate ions

The ascorbic acid method, according to APHA (1998) was adopted for the determination of phosphate level of the groundwater. Ascorbic acid based reagent powdered pillow was added into 25mL of the water sample in a cuvette. The sample was allowed to stand for 2 minutes for reaction to occur. The absorbance and concentration in mg/L was read at 890nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

2.3.4 Conductivity, pH, and Total Dissolved Solid

Temperature of the water samples was measured with a laboratory thermometer. A multi-purpose pH meter model D46 (pH/MV/OC meter) was used to determine the pH of the borehole water. TDS meter - 4-HMD was used to determine the Total Dissolved Solids in borehole water and Electrical Conductivity meter was used to determine the EC of the water samples.

3.0 RESULTS AND DISCUSSION

Table 1. Sampling locations and their distances from sources of contamination

Area	Sample Label	Depth to static water level (m)	Distance from closest sources of contamination (m)	Closest contamination source
Eziobodo	B1	46	20.6	Septic tank, Landfill
Obinze	B2	46	48.6	Septic Tank
Nekede	B3	47	14.9	Septic Tank, Latrines
World Bank	B4	46	50.4	Septic Tank
Egbu	B5	47	20.4	Septic Tank, Pit Latrines
Orji	B6	46	49.8	Septic tank
Amajeke	B7	46	24.2	Septic tank, Pit Latrines

Table 2. Borehole sampling locations and their GPS coordinates

Sample	Longitude	Latitude	Area Name
B1	7.002307	5.365425	Eziobodo
B2	6.957174	5.418661	Obinze
B3	7.031818	5.429654	Nekede
B4	6.988999	5.489832	World Bank
B5	7.072901	5.477681	Egbu
B 6	7.040497	5.519921	Orji
B 7	7.038183	5.485203	Amajeke

Table 3. Mean results of groundwater quality parameters of the study area (dept >120m)

Sample Name	WHO	B1	B2	B3	B4	B5	B6	B7
pH	6.5-8.5	5	5.05	5.3	4.94	6.15	5.23	6.2
Temperature (°C)	>30	28.5	27.8	28.3	29.0	27.5	29.4	28.1
Conductivity (µS/cm)	1000.00	11	13	23	20	14	6	12
TDS (mg/l)	500	7.15	8.48	7.15	13	9.32	3.9	10.08
Turbidity (NTU)	5	8.78	6.03	9.72	9.64	7.13	4.22	6.03
DO (mg/l)	4-6	6.2	6.4	6.2	6.1	7.4	4.8	5.9
BOD (mg/l)	NS	2	2.1	1	1	3.2	1.2	3.1
COD (mg/l)	NS	3.2	3.36	4.3	1.6	4.62	1.92	3.31
Nitrate (mg/l)	50	3.2	2.4	4.2	1.4	3.6	4.4	3.4
Phosphate (mg/l)	5	6.375	6.5	8.75	6.4375	7.2	5.125	5.25
Ammonia (mg/l)	0.3	0.133	0.05	0.133	0.09	1.12	0.302	0.13
Sulphate (mg/l)	250	175.29	97.94	190.21	189.29	102.9	299.57	107.14
Total Chloride (mg/l)	250	211.93	225.93	241.03	217.93	246.93	157.95	215.75
TOC (%)	5	0.13	0.48	0.58	0.33	1.02	0.93	0.39
TSS (mg/l)	>10.0	111.85	99.52	201.85	135	104.02	88.1	99.52
Total Solids (mg/l)	500-1000	119	108	132	148	113	97	201
$CaCO_3$ (mg/l)	150	6.6	1.2	7.6	7.31	8.2	9.28	3.9
Coliform (cfu/100ml)	0	2	1	1	5	2	8	1

3.1 The Spatial Distribution of Groundwater Quality Parameters

3.1.1 Sulphate

Sulphate occurs mostly as calcium sulphate (Gypsum). Sodium and magnesium sulphate are readily soluble in water while calcium sulphate is less soluble. Sulphate values for all the samples (B1 - B7) analyzed ranged from 97.94 - 299.97 mg/L. All values observed, except B6, were below the WHO stipulated levels. The presence of sulphate in drinking water can cause noticeable taste and very high levels might cause a laxative effect in unaccustomed consumers (WHO, 2004). The WHO standard for sulphur in drinking water is 250mg/l. From the study, no borehole was found to have excessive sulphate. The presence of sulphate at low concentrations in the water is natural and harmless, but becomes a serious public health concern at high concentrations. From Fig. 2, the spatial distribution map of sulphate revealed that the Northern and Central parts of the study location had concentrations above the WHO standards for drinking water. This could be as a result of seepage from latrines and septic tanks, located at close proximity to the boreholes, into groundwater aquifer.

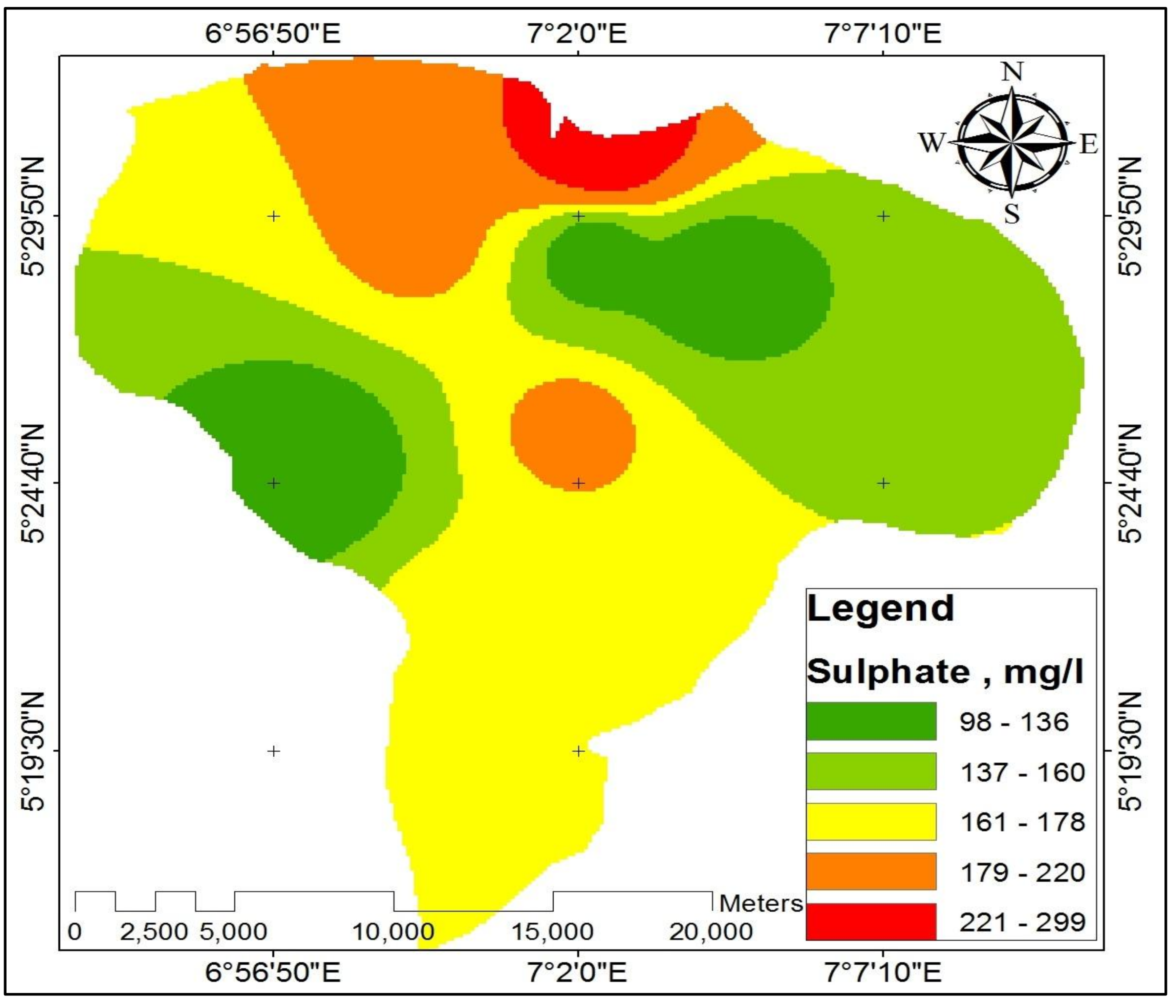

Fig. 2. Spatial Variation of Sulphate (mg/l) in the Study Area

3.1.2 Total Coliform Count

The groundwater quality assessment in the study location revealed that samples were contaminated with *E. coli*. From the result, all the borehole samples examined revealed concentrations above the WHO recommended standard and was considered harmful to human health. Water source used for drinking or cleaning purposes should not contain any organism of fecal origin (Abolude, 2007). The highest concentration was at Orji, the northern part of the study location, while the Southern part revealed low levels (Fig. 3). The presence of coliform observed in groundwater sample is an indication of feacal contamination which is likely to come from pit latrines and cesspool seepage to the groundwater system (WHO, 2011). *E. coli* in drinking water is of great concern because of the many health issues traceable to its contamination in water.

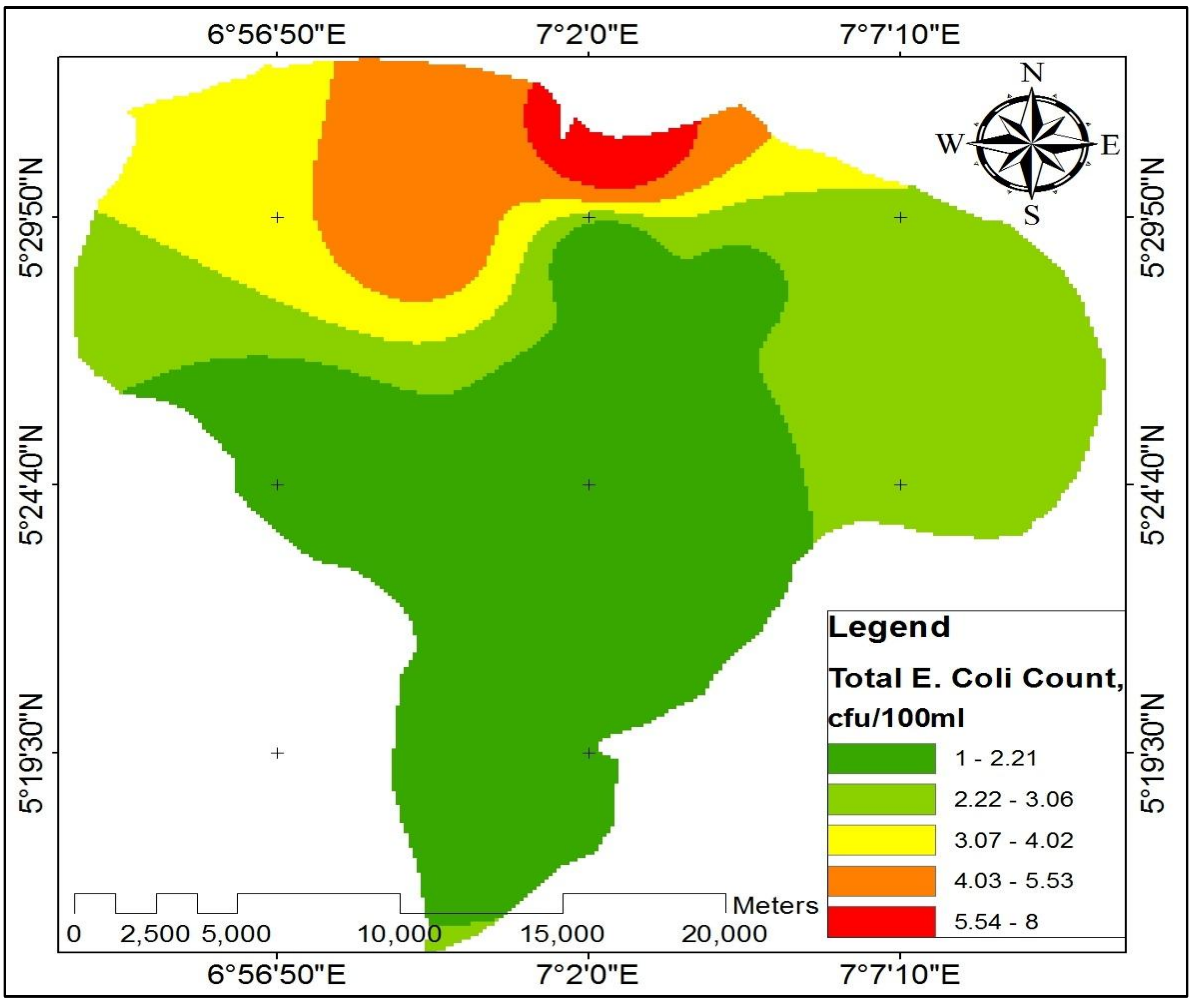

Fig. 3. Spatial Variation of Total *E. Coli* Count (cfu/100ml) in the Study Area

3.1.3 pH

The investigation of pH is one of the most common physicochemical parameters tested in groundwater and it is a good indicator for water quality assessment. A decrease in pH of water increases metal solubility and the metal particles become soluble (Koffi *et al.*, 2014). The pH of groundwater body can be affected by many factors such as bedrock and soil composition as well as the amount of plant growth and organic material within a water body.

The WHO standard for pH in drinking water is within the range of 6.5-8.5. The pH of the borehole wells ranged from 4.9 - 6.2. It was reported that though 7.0 is the neutral, up to 9.2 may be tolerated, provided microbiological monitoring indicated no deterioration in bacteriological quality (WHO, 2004). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. No health-based guideline value has been proposed for pH (WHO, 2011). However, the pH values in this study were below 6.5, and were not within the acceptable range for drinking water.

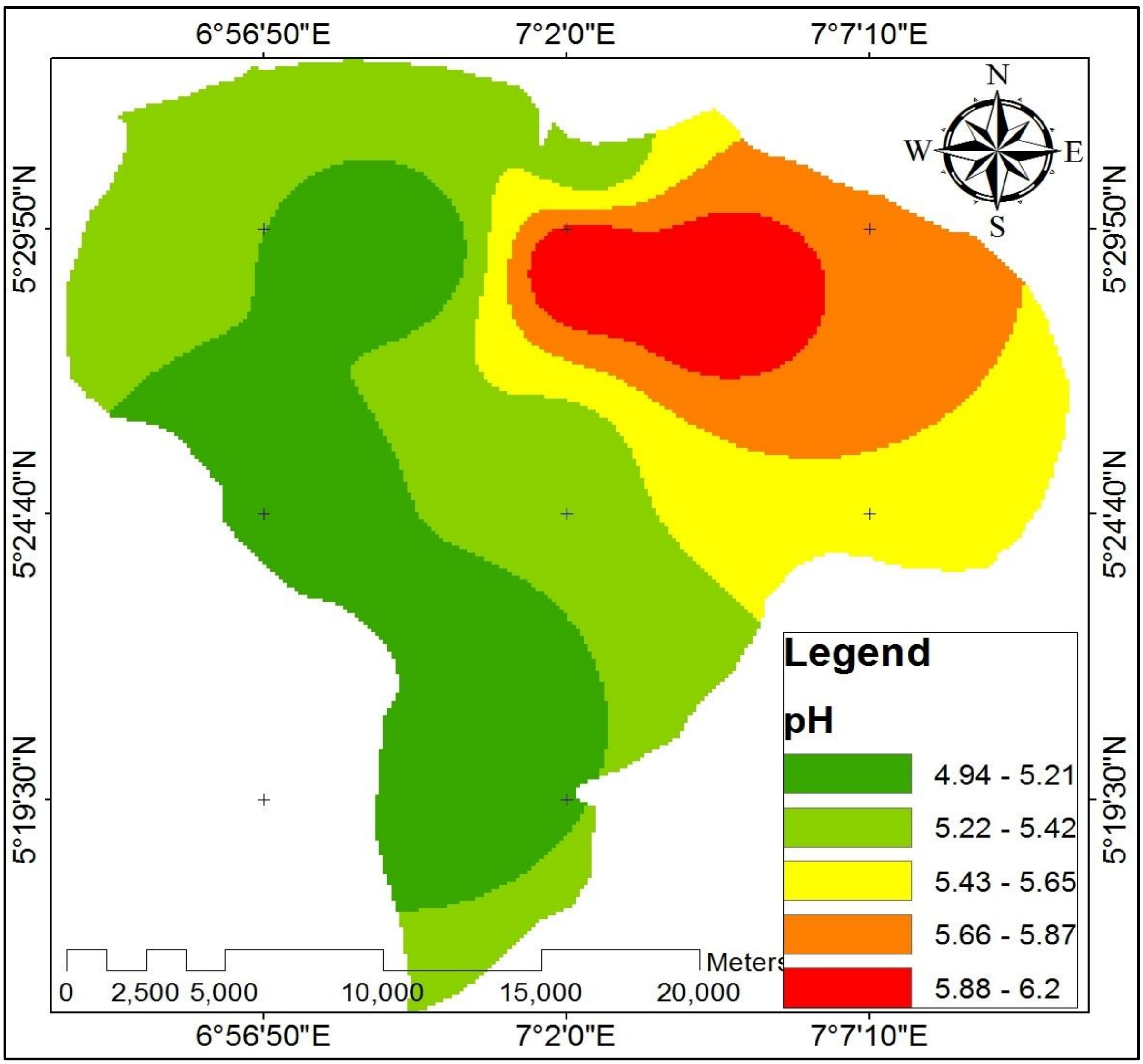

Fig. 4. Spatial Variation of pH Concentrations in the study locations

3.1.4 Ammonia

Fig. 5 below shows the map of spatial variation of ammonia concentration in the study area. The detection of ammonia in concentrations above the recommended standard poses great threats to health. Natural levels in groundwater are usually below 0.2mg/l, although levels up to 3mg/l have been reported in strata rich in humic substances or in forests (WHO, 2011). The results revealed that some locations had concentrations above the WHO standards for drinking water. The spatial variation of the concentration was within the range of 0.05-1.12 mg/l. The Southwestern and Northwestern part of the study area had NH_3 concentrations below the WHO standards, while the Eastern region of the study area revealed concentrations above the WHO standard of 0.3mg/l. The presence of NH3 at higher than geogenic levels is an important indicator of faecal pollution, and may result in taste and odour problems as well as decreased disinfection efficiency.

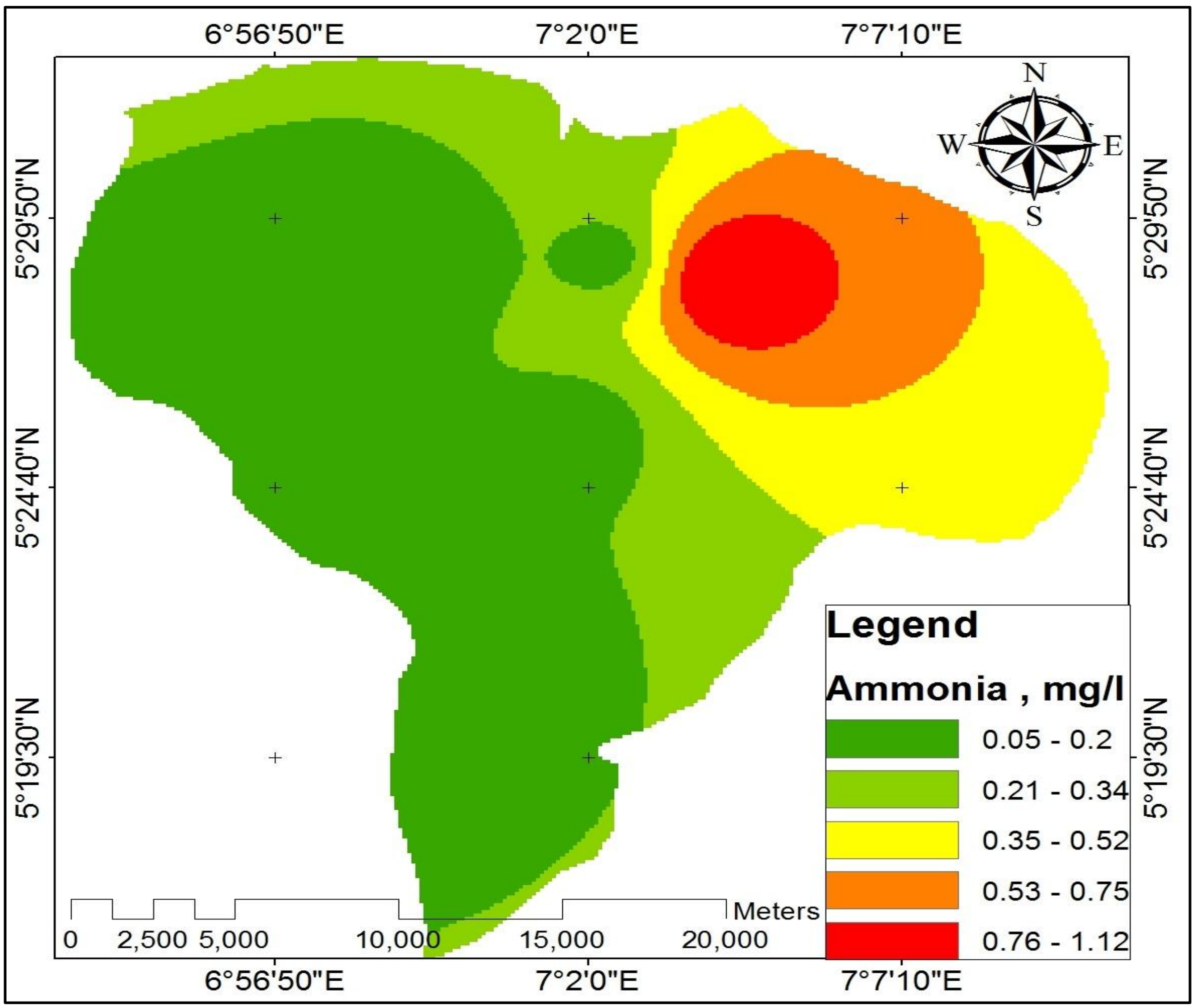

Fig. 5. Spatial Variation of Ammonia Concentration in the study Area

3.1.5 Total Suspended Solids

The spatial interpolation result for TSS revealed the distribution of the concentration of the TSS in the study area (Fig. 6). The WHO established standard for drinking water is <10.0mg/l. However, from the result, the distribution of TSS was above the WHO standard, and higher concentrations were obtained within the city center with range 180mg/l - 201mg/l. High concentrations of TSS can cause many problems for stream health and aquatic life. Also high levels of TSS could mean that there is increased concentration of bacteria, nutrients, pesticides and metals in groundwater.

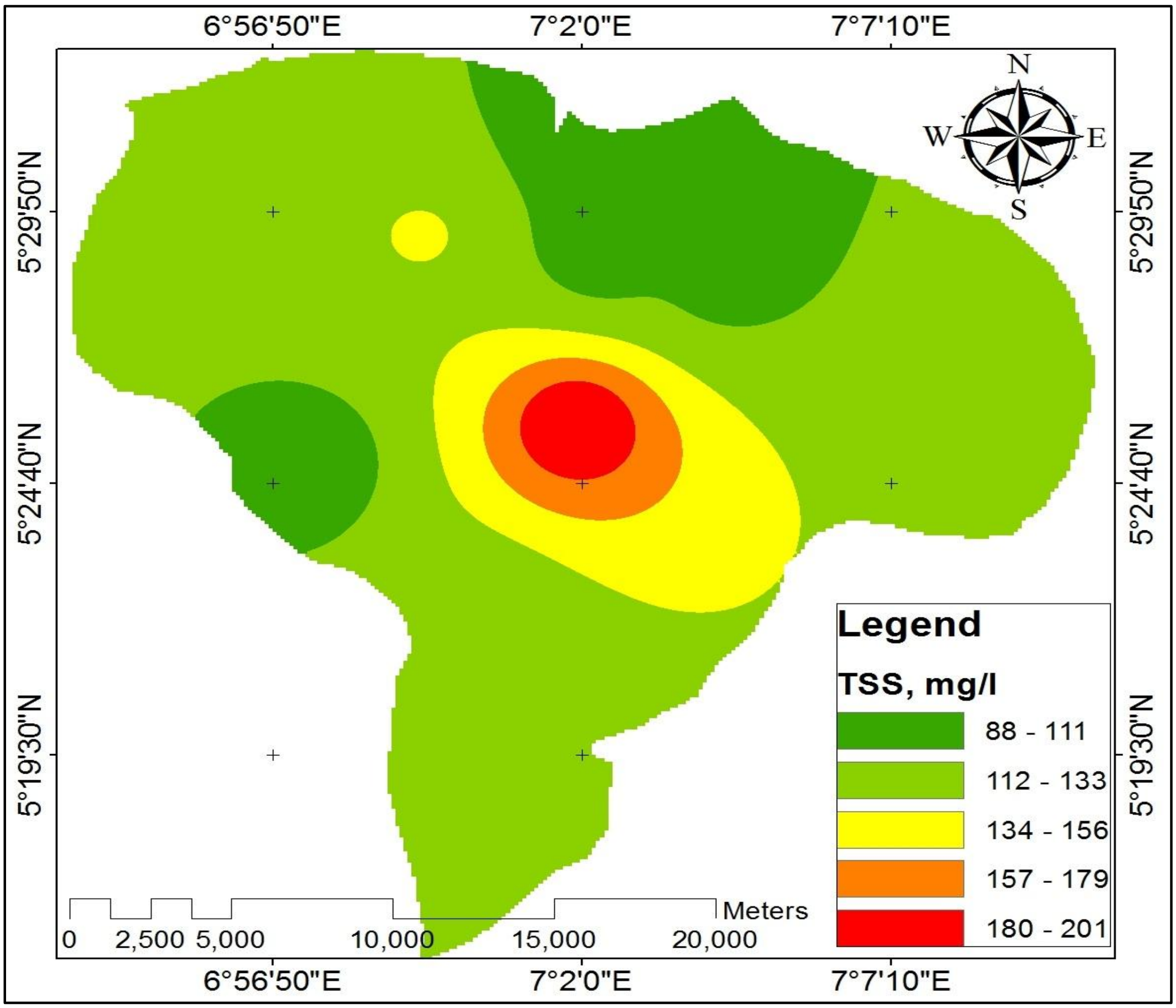

Fig. 6. Spatial variation of TSS in the Study Area

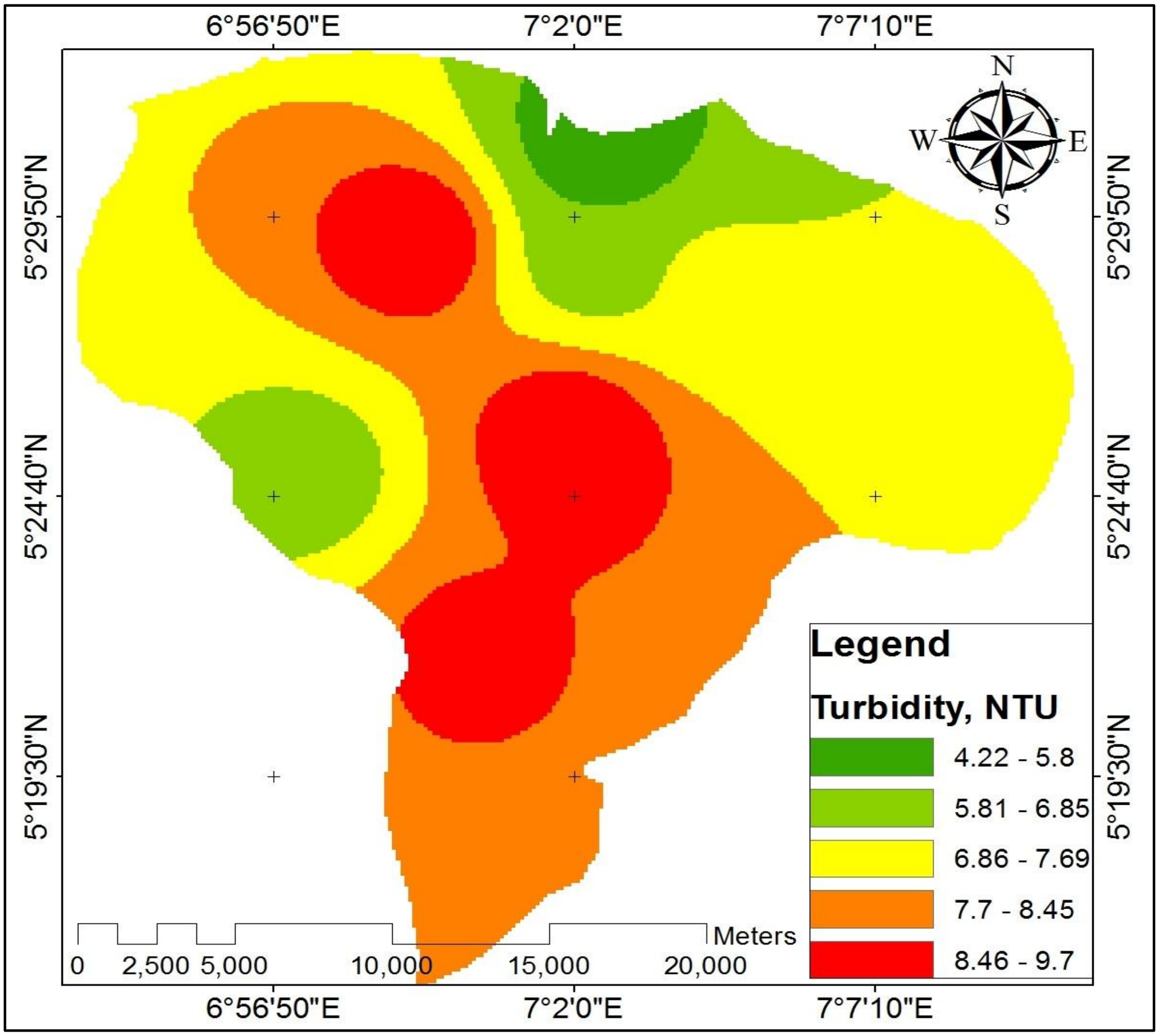

Fig. 7. Spatial Distribution of Turbidity in the Study Area

3.1.6 Turbidity

Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water (WHO, 2011). It may be caused by inorganic or organic matter or a combination of the two. The turbidity readings of the samples were above the WHO. High turbidity values observed could be an indication that the wells may be unlined (Abolude, 2007). The results of this study revealed that the turbidity in most locations in the study area was slightly above the WHO prescribed value of 5NTU. From Fig. 7 above, the entire concentration of turbidity in the study area was within the 4.22 NTU to 9.7 NTU. The Northern and Eastern parts of the study location recorded lower concentrations of the turbidity. However, other locations had levels above the recommended limits.

3.1.7 Nitrate

Nitrate levels in all samples (B1 – B7) were found to be below the stipulated value of 10 mg/L established by WHO, and also below the National Water Drinking Water Quality Standard of 50 mg/L. The samples with close proximity to pit latrine gave higher nitrate concentrations. Natural level of nitrate in groundwater is increased by municipal and industrial wastewater including leachate from sewage sludge disposal and sanitary landfills (Foster *et al*., 2002). High nitrate concentrations have detrimental effects on infants less than 3.6 months of age. Nitrate toxicity comes from the body's natural breakdown of nitrate to nitrite. This leads to "blue baby disease" which threatens the oxygen carrying capacity of the blood around the body (Chapman, 1996). Nitrate is an essential ingredient of plant nutrition. It is however regarded as an indicator of pollution in public water supply.

3.1.9 Phosphate

Phosphate levels in all the samples ranged from 5.12 - 8.75 mg/L. These values exceeded the WHO stipulated tolerance level, and this could be linked to seepage of sewage waste into the groundwater system. These high levels point to the fact that samples were located close to pit latrines which are a potential source of pollution to aquifers. Abolude (2007) reported that traces of PO_4^{3-} even at 0.1 mg/L in water could have deleterious effect on water quality and such traces could increase the growth of algae in the water. It is suggested that agricultural activities around these study areas could possibly contribute to the high values of phosphates recorded. Phosphates are not toxic to people or animals unless they are present in very high levels.

4.0 CONCLUSION

Groundwater in the study area serves as an important natural resource and is often considered as an appropriate alternative to surface water supply. The findings of this study showed that levels of coliform, TSS, and phosphates were above the WHO recommended limits in all samples. Also, all the samples revealed pH values that were not within the prescribed range. However, sulphate levels were within the WHO established benchmark except for sample B6, which also was the only sample with the acceptable range of turbidity. Nitrate in all samples were below the given threshold for pollution as was NH_3, except for sample B5, which exceeded the given limit. In conclusion, borehole distance from sanitary/septic tanks from households affected the groundwater quality and thus, has dangerous health consequences. It is recommended that adequate water treatment measures be engaged before water is fit for consumption. Also, boreholes should be sunk at least 200m away from potential contamination sources to prevent seepage and migration to aquifers. There should be environmental interventions through public health awareness and sensitization campaigns by community health workers and other health professionals around Owerri and its environs.

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