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# Evaluation of pollution levels of groundwater in Imo River Basin, South Eastern Nigeria

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**Twenty five samples of groundwater were obtained from various boreholes in the study area and subjected to physico-chemical analysis using standard laboratory techniques. The study was aimed at the assessment of the pollution status of the groundwater supply in parts of Imo River Basin and its environs using some pollution indications namely: electrical conductivity, phosphate ($PO_4$), total dissolved solids (TDS), nitrate ($NO_3^{--}$), sulphate and turbidity. The values of the physico-chemical parameter were correlated with the World Health Organisation (WHO) values. The result shows that the level of pollution is relatively high in Owerri. The highest concentration of electrical conductivity and nitrate were obtained at Owerri. The highest concentration of phosphate was observed at Mbaise area. The most saline part is the southern part proximate to the delta area. Moderate to higher values of TDS were observed at the densely populated areas of Owerri, Umuahia and Aba. Electrical conductivity in Owerri ranged from 101 to 181.6 NS/cm which exceed the WHO standard of 100 NS/cm. Phosphate levels exceeding the WHO standard of 5 mg/L were observed at the Mbaise axis. No borehole location exceeded the required maximum standard for TDS which show general stability.**

**Key words:** Groundwater, physico-chemical analysis, pollution status, Imo River Basin, borehole.

## INTRODUCTION

Water is essential for livelihood as well as socio-economic development of any community. Many communities in Nigeria, especially in the Imo River Basin area rely on surface and groundwater for both domestic and agricultural water supplies. It is estimated that approximately one third of the world's population use groundwater for drinking (Nickson et al., 2005). Groundwater pollution is a growing environmental problem, especially in developing countries. Many major cities and small towns in Nigeria depend on groundwater for water supplies, mainly because of its abundance, stable quality and also because it is inexpensive to exploit. However, the urbanization process threatens the groundwater quality because of the impact of domestic and industrial waste disposal. This results in aquifer deterioration, since some of these waste products, including sewage and cesspool may be discharged directly into the aquifer system. Water soluble wastes and other materials that are dumped, spilled or stored on the surface of the land or in sewage disposal pits can be dissolved by precipitation, irrigation waters or liquid wastes and eventually seep through the soil in the unsaturated zone to pollute the groundwater. Once contaminated, it is difficult, if not impossible, for the water quality to be restored. Thus constant monitoring of groundwater quality is needed so as to record any alteration in the quality and outbreak of health disorders. Groundwater quality depends, to some extent, on its

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chemical composition (Wadie and Abduljalil, 2010) which may be modified by natural and anthropogenic sources. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste disposal practice, especially in urban areas. Once groundwater is contaminated, its quality cannot be restored by stopping the pollutants from source (Ramakrishnaiah et al., 2009). As groundwater has a huge potential to ensure future demand for water, it is important that human activities on the surface do not negatively affect the precious resource (Sarukkalige, 2009). Poor environmental management creates havoc on the water supply, hygiene and exacerbating public health (Okoro et al., 2009). Tay and Kortatsi (2008) emphasize on the importance of groundwater globally as a source for human consumption and changes in quality with subsequent contamination can, undoubtedly, affect human health.

### Geology and hydrogeology of the study area

The Imo River Basin lies between Latitudes 4° 38'N and 6° 01'N and between Longitudes 6° 53'E and 7° 32'E and covers an area of about 9100 $km^2$. The boundaries are defined by its surface drainage divides. There are two main sub- basins within the basin: The Oramirukwa—Otamiri sub- basin and the Aba River sub-basin. The estuary of the Imo River at the Atlantic Ocean forms the southern boundary. There are two prominent features at north-eastern and north-western boundaries; these are the Udi-Okigwe-Arochukwu and the Awka-Umuchu-Umuduru sedimentary cuestas, respectively (Uma, 1989).

The Imo River Basin is based on a bedrock of a sequence of sedimentary rocks of about 5480 m thick and with ages ranging from Upper Cretaceous to Recent (Uma, 1986). The deposition of these sedimentary rocks is related to the opening of the South Atlantic Ocean and the formation of the rift-like Benue Trough of Nigeria in the Mesozoic (225-65 M.Y.B.P.) (Schlumberger, 1985).

Generally, there are two different classes of formations underlying the Imo River Basin. About 80% of the basin consists in Coastal Plain Sand, which is composed of non-indurated sediments represented by the Benin and Ogwashi-Asaba Formations, and alluvial deposits at the estuary at the Southern end of the Imo River Basin. The remaining 20% is underlain by a series of sedimentary rock units that get younger southwestward, a direction that is parallel to the regional dip of the formations.

The Ajali Sandstone of Maastrichtian age is the oldest exposed formation in the basin, outcropping at its north-eastern fringe along a NW-SE band (2 to 4 km width). It consists of thick friable, loosely consolidated sandstones (Uma, 1989). Overlying the Ajali Sandstone conformably is the Nsukka Formation (Maastrichtian-Lower Paleocene), which extends to a relatively broader stretch of land than the former. It consists of alternating sequences of sandstones, shales and sandy shales. It dips at about 6°, on the average, to the south-west. The Imo Shale of Paleocene-Lower Eocene age overlies the Nsukka Formation unconformably. It consists of a thick sequence of blue and dark grey shales with occasional bands of clay-ironstones and subordinate sandstones (Ekwe et al., 2006). Next in the depositional sequence is the Ameki Formation (Eocene), which consists of sand and sandstones. The lithologic units of the Ameki Formation fall into two general groups (Whiteman, 1982; Arua, 1986); an upper grey-green sandstones and sandy clay and a lower unit with fine to coarse sandstones, and intercalations of calcareous shales and thin shelly limestone. Next in the depositional sequence is the Ogwashi/Asaba Formation (Oligocene to Miocene), which is generally made up of clays, sands, grits and seams of lignite alternating with gritty clay.This formation is characterized by its up dip and down dip pinch outs within the Imo Basin. The Ogwashi/Asaba Formation is overlain by the Benin Formation (Miocene to Recent) which is the most extensive of all the formations, which covers more than half of the area of the basin. It consists of sands, sandstones, and gravels, with intercalations of clay and sandy clay. The sands are fine-medium-coarse grained and poorly sorted. The map of the study area is shown in Figure 1.

## METHODOLOGY

Twenty-five groundwater samples were collected from wells located around the Imo River Basin of South Eastern Nigeria. The samples were stored in a sterilized 250 ml bottles and then taken to the laboratory for analysis. The electrical conductivity, total dissolved solids, Nitrate, sulphate, phosphate and salinity were determined using a HA-CH 44600-00 Condutivity/TDS meter at a temperature of 20°C. These samples were refrigerated and analyzed within 24 h. All plastics and glass wares utilized were pre-washed with detergent water solution, rinsed with tap water and soaked for 48 h in 50% $HNO_3$ then rinsed thoroughly with distilled- deionized water. They were then air-dried in a dust free environment. The pH was determined using a HACH sensor 3 pH meter. The turbidity was determined using a spectrophotometer. The result is presented in Table 1.

## RESULTS AND DISCUSSION

Investigations of the pollution status of groundwater in the study area were conducted recently by collecting water samples from boreholes in different locations in the study area (Table 1). Water samples from 25 randomly selected boreholes in the study area were analyzed for chemical quality at the UNICEF Water Project, Owerri, and Imo State Environmental Protection Agency, respectively. The result was geo-processed to obtain groundwater quality maps showing the spatial variation of electrical conductivity, sulphate, phosphate, total dissolved solids (TDS), salinity, nitrate respectively. There specific parameter maps facilitate the rapid assessment of the extent of pollution of the various locations

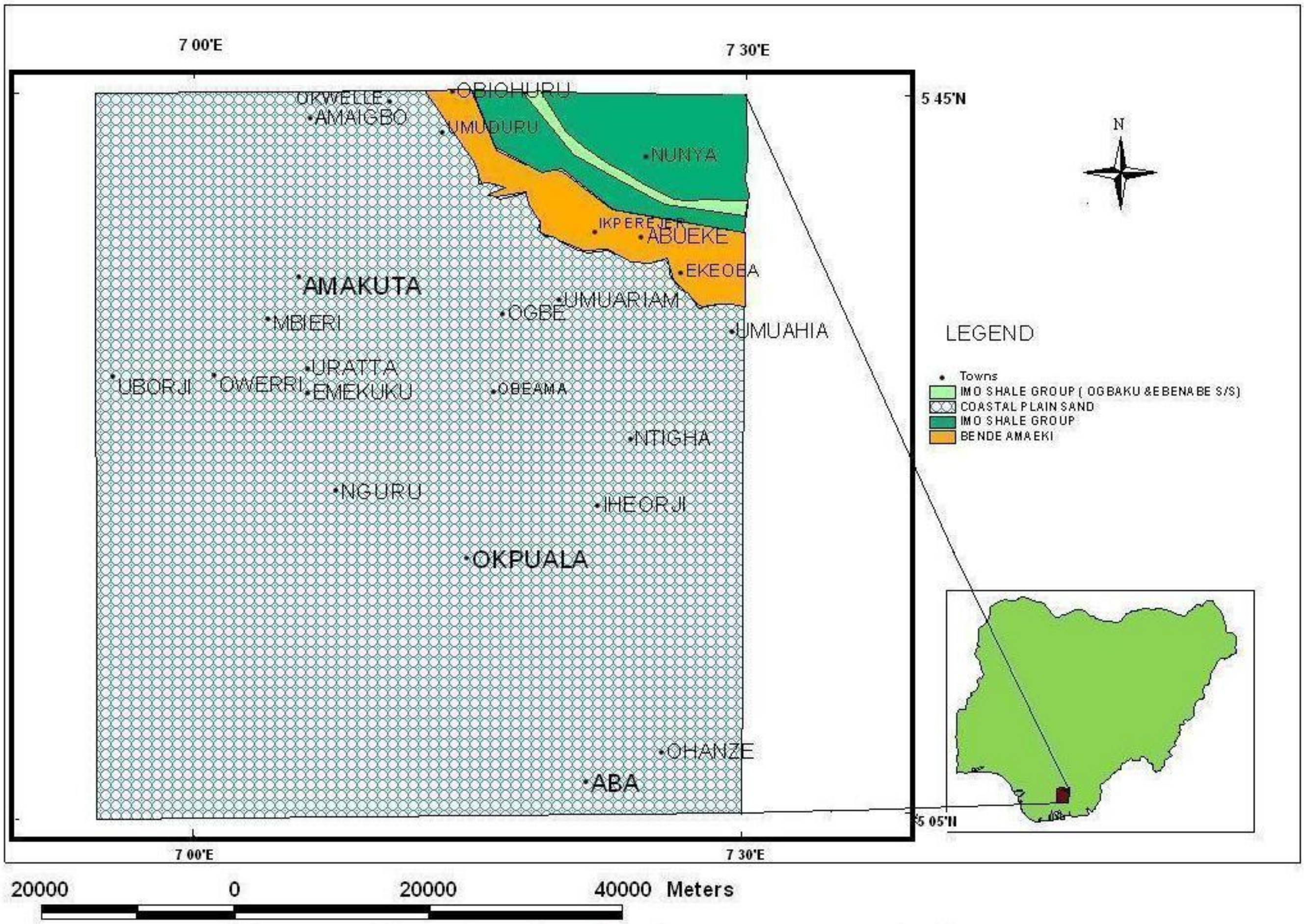


**Figure 1.** Location map of the study area.

within the study area in terms of their respective concentrations. Contour maps of the spatial variation of electrical conductivity, phosphate, sulphate, salinity, total dissolved solid, nitrate, and turbidity were also developed. The highest conductivity was obtained at BH35 in MCC Road, Owerri (181.6 µs/cm).

### Electrical conductivity

The map of the spatial variation of electrical conductivity is shown in Figure 2. Electrical conductivity of water is used as an indicator of how salt- free, ion-free, or impurity-free the sample is; the purer the water the lower the conductivity (the higher the resitivity). The World Health Organization standard for acceptable electrical conductivity is 100 µs/cm. In addition to BH35m, other areas with electrical conductivity above the WHO standard are at BH39 (111.32 µs/cm), BH141 (148 µs/cm), BH42 (101.0) µs/cm), BH59 (153.0 µs/cm), BH65 (135.0 µ/cm) and BH66 (136.0 µs/cm). Except for Amauzi Obowo (BH59) and Avu Amaaku (BH66), all the other locations with electrical conductivity above 100 µs/cm are located within Owerri Municipal. Pure water has an electrical conductivity of 5.5 µs/cm, a measure of the total dissolved solid (TDS), while rain water and ocean water have 5000 to 30000 µs/cm and 45,000 to 60,000 µs/cm respectively. Normal groundwater has a range of 100 to 2000 µs/cm (Offodile, 2002). It is interesting to note that in spite of the huge populat ion in Aba the electrical conductivity is not quite high. This is a possible indication that the hydro-geological factors that determine the rate of pollution are favorable in Aba, making it less vulnerable to pollution. The location on the map corresponding to Nkwo Obohia, which had the highest resistivity, shows lower electrical conductivity.

### Phosphate

Figure 3 shows the map of phosphate concentration in the study area. Phosphorus is one of the key elements necessary for the growth of plants and animals. Phosphates are not toxic to people or animals unless

**Table 1.** Results of groundwater quality analysis of samples collected from selected boreholes in the study area.

| S/N | CODE | | pH | ELECTRICALCONDUCTIVITY(μs/cm) | TDS (mg/l) | NITRATE(mg/l) | SULPHATE(mg/l) | PHOSPHATE(mg/l) | SALINITY | TURBIDITY(NTU) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **WHO STANDARD (WHO,2011)** | **6.5-8.5** | **100.0** | **250.0** | **50.000** | **250.00** | **5.00** | **50.0** | **50.0** |
| **1** | BH27 | UMUBIAM, ABOH MBAISE | 6.80 | 98.2 | 49.0 | 0.002 | 0.02 | 16.05 | 0.5 | **0.1** |
| **2** | BH28 | UMUEZEALA-AMA | 6.50 | 86.3 | 43.0 | 0.001 | 0.58 | 12.50 | 0.3 | **BDL** |
| **3** | BH30 | IFE, EZINIHITTE MBAISE | 6.3 | 86.3 | 42.9 | 5.000 | 0.50 | 6.07 | 0.5 | **0.0** |
| **4** | BH31 | NKWOGWU, ABOH MBAISE | 6.3 | 83.1 | 41.5 | 0.020 | 0.45 | 14.20 | 0.6 | **0.1** |
| **5** | BH32 | ASSUMPTA, CATH., OWERRI | 6.8 | 44.8 | 22.6 | 1.200 | 0.80 | 2.40 | BDL | **BDL** |
| **6** | BH33 | OFOROLA, OWERRI WEST | 6.5 | 94.1 | 47.0 | 0.100 | BDL | BDL | 16.5 | **BDL** |
| **7** | BH34 | URATTA, OWERRI NORTH | 6.0 | 95.6 | 47.9 | 0.020 | 0.40 | BDL | 13.2 | **BDL** |
| **8** | BH35 | MCC RD. OWERRI NORTH | 7.3 | 181.6 | 91.6 | 13.200 | BDL | 0.85 | 13.2 | **10.0** |
| **9** | BH36 | TIMBER SHADE OWERRI | 6.5 | 21.1 | 36.5 | 13.500 | 2.00 | BDL | 3.3 | **BDL** |
| **10** | BH37 | UBOMIRI MBAITOLU | 6.5 | 5.3 | 2.6 | 27.200 | 1.00 | BDL | 2.5 | **BDL** |
| **11** | BH38 | OKWU NGURU ABOH MBAISE | 6.5 | 36.2 | 19.0 | 0.300 | 0.01 | BDL | 11.5 | **0.5** |
| **12** | BH39 | OWERRI GIRLS' SEC, OWERRI | 7.0 | 111.3 | 58.7 | 1.300 | 0.80 | BDL | 7.42 | **BDL** |
| **13** | BH40 | MBIERI, MBAITOLU | 6.9 | 81.0 | 44.2 | 0.150 | 3.00 | BDL | 1.65 | **BDL** |
| **14** | BH41 | ALADINMA OWERRI | 7.1 | 148.6 | 77.7 | 0.130 | 4.00 | BDL | 2.48 | **BDL** |
| **15** | BH42 | UGAKWOCHE OBUBE, OWERRI | 6.0 | 101.0 | 51.0 | 11.000 | 12.50 | BDL | 1.68 | **BDL** |
| **16** | BH43 | UMUCHOKU OBUBE, OWERRI | 6.5 | 53.0 | 26.5 | 15.000 | 0.30 | BDL | 0.75 | **BDL** |
| **17** | BH44 | UMUAKPAA OBUBE, OWERRI | 6.3 | 82.0 | 41.0 | 0.120 | 2.50 | BDL | 1.16 | **BDL** |
| **18** | BH45 | OBOAME, ABOH MBAISE | 6.0 | 36.3 | 19.0 | 7.000 | 0.20 | BDL | **11.55** | **BDL** |
| **19** | BH46 | VILLA MARIA OWERRI | 6.9 | 49.0 | 25.0 | 0.000 | BDL | BDL | 4.95 | **BDL** |
| **20** | BH48 | UMUGUMA AMAAKU, OWERRI WEST | 7.0 | 16.7 | 8.3 | 32.800 | 1.20 | BDL | 2.50 | **0.3** |
| **21** | BH49 | UGORJI OWERRI WEST | 6.7 | 20.8 | 10.5 | 35.200 | 4.00 | BDL | 6.60 | **2.0** |
| **22** | BH50 | OBINZE BARACK OWERRI WEST | 6.8 | 36.5 | 18.0 | 39.600 | 3.00 | BDL | 3.30 | **5.0** |
| **23** | BH51 | OBINZE MAMI MKT | 7.5 | 5.3 | 2.6 | 37.200 | 1.00 | BDL | 2.50 | **10.0** |
| **24** | BH52 | UZII PRIMARY SCH. OWERRI | 7.2 | 66.6 | 33.3 | 50.600 | 0.01 | BDL | 3.30 | **0.1** |
| **25** | **BH53** | **UDO EZINIHITTE MBAISE** | **6.9** | **90.6** | **49.3** | **0.120** | **BDL** | **BDL** | **3.30** | **5.0** |

*****BDL : Below detectable limit.

they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate. The WHO standard for phosphate in drinking water is 5 mg/L. This standard is exceeded in the following areas: BH27 (16.05 mg/L); BH28 (12.50 mg/L); BH30 (6.07 mg/L); BH31 (14.20 mg/L). BH27, BH28 and BH31 are in Mbaise area, which is reported to be the most densely populated rural area in Nigeria (Onwuegbuche, 1993). They also engage in a lot of farming requiring the use of fertilizer. Much of the areas around Aba, Umuahia and Owerri have generally low concentration of phosphate (≤ 2 mg/L), perhaps, due to less farming in those urban centers.

### Nitrate

Figure 4 shows the contour map of spatial variation of nitrate concentration in the study area. Nitrate is an essential ingredient of plant nutrition. It is, however regarded as an indicator of pollution in public water supply (Offodile, 2002). The WHO standard for nitrate in drinking water is 50 mg/L. This standard is exceeded in BH53 (50.6 mg/L).

### Total dissolved solids

Figure 5 shows the map of the spatial variation of the total dissolved solids (TDS) in the study area. The total dissolved solids (TDS) provide a rough indication of the overall suitability of water for whatever purpose. The WHO standard for TDS in drinking water is 250 mg/L. No borehole location exceeded the required maximum standard. The map indicates higher values around the densely populated areas of Owerri, Umuahia and Aba.

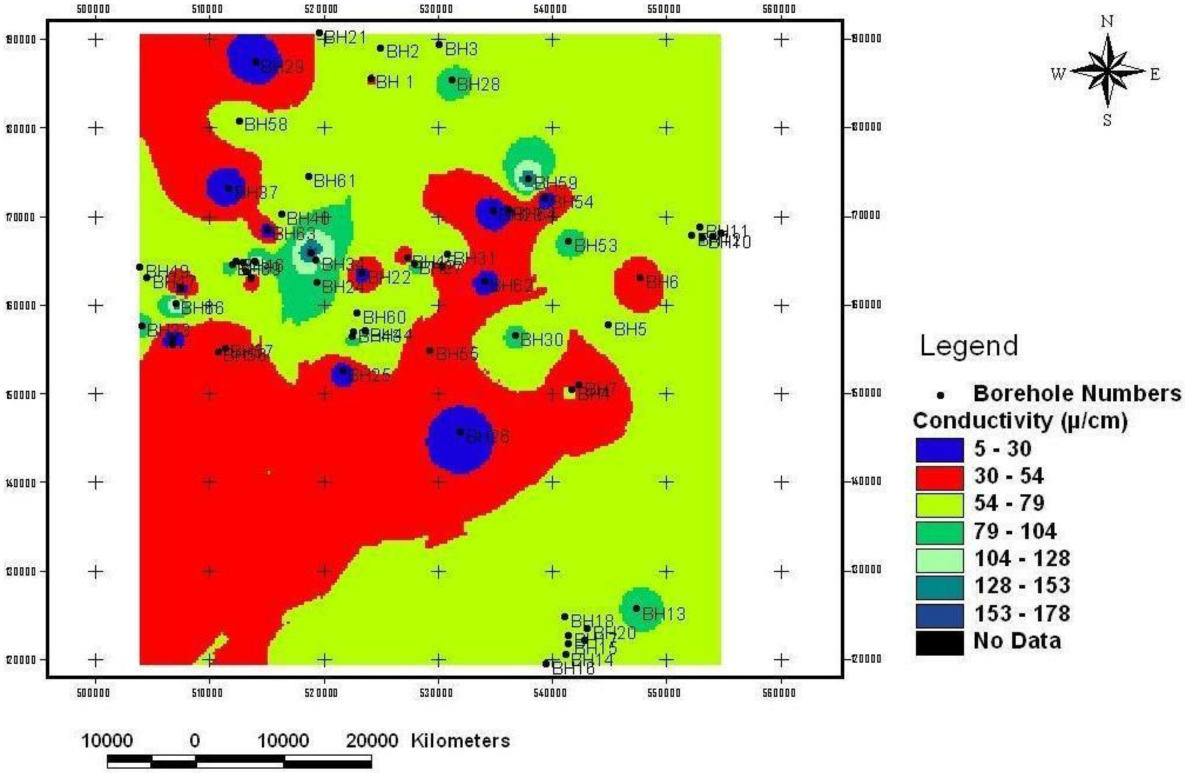


**Figure 2.** Spatial variation of electrical conductivity in the study area.

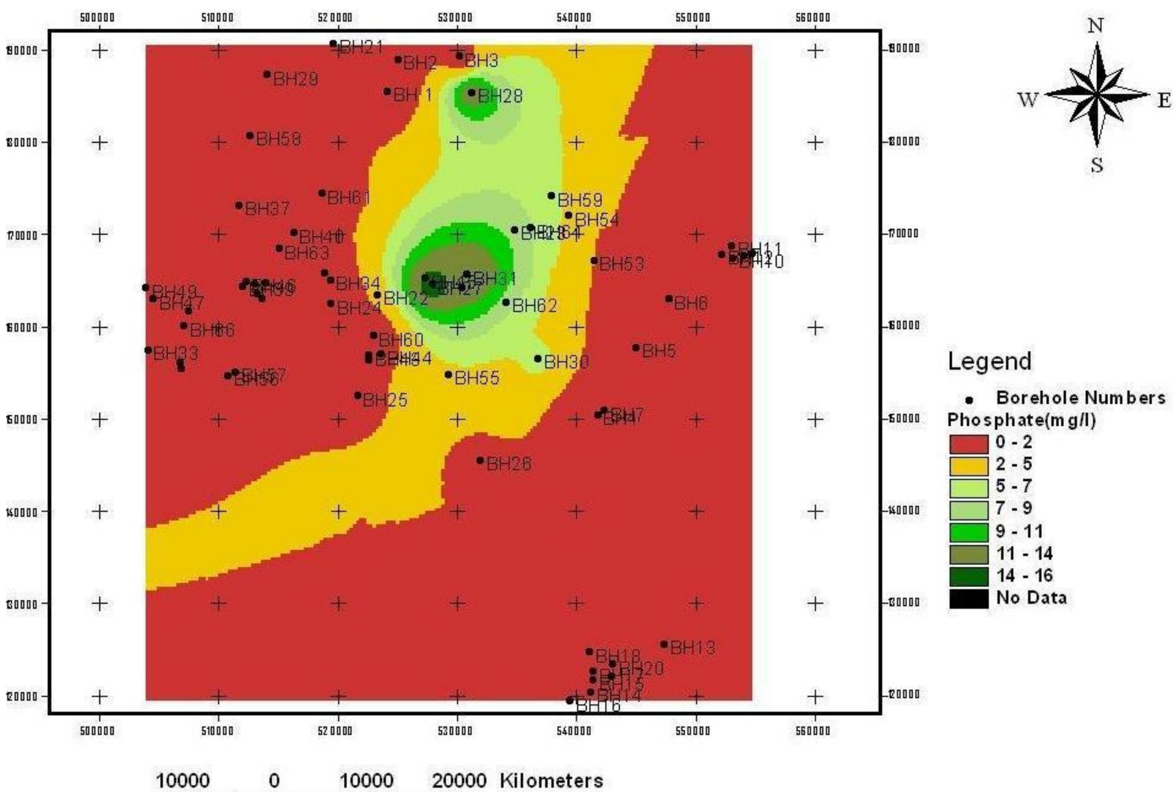


**Figure 3.** Spatial variation of phosphate concentration in the study area.

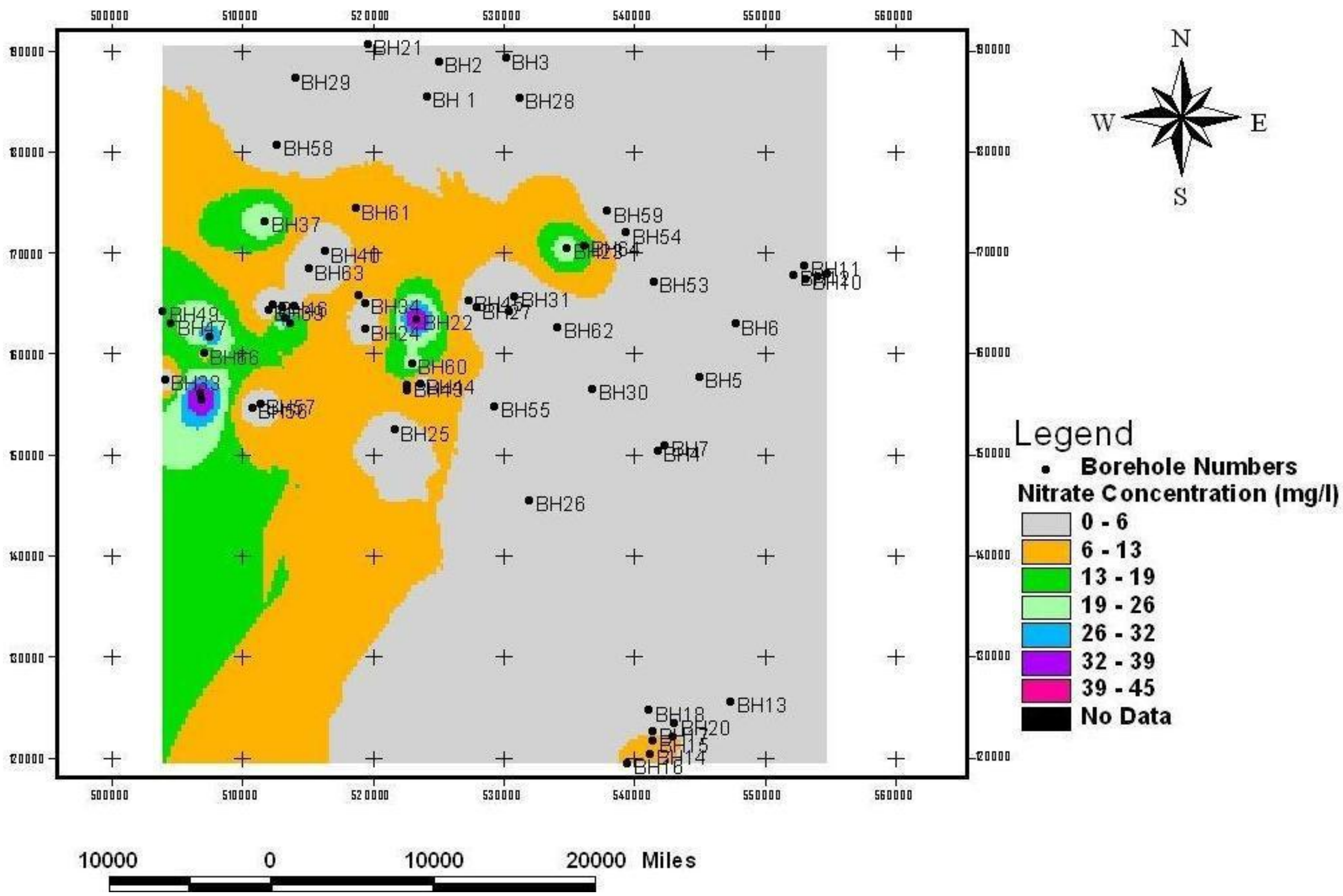


**Figure 4.** Spatial variation of nitrate concentration in the study area.

There are also higher values around Mbaise area (BH62). This may be due to increased pollution arising from increased domestic activity, fertilization and industrial waste.

## Turbidity

Figure 6 shows the contour map of the turbidity in the study area. Turbidity is the amount of cloudiness in the water. This can vary from a river full of mud and silt where it would be impossible to see through the water (high turbidity), to a spring water which appears to be completely clear (low turbidity).Turbidity can be caused by silt, sand and mud, bacteria and other germs, and chemical precipitates. It is very important to measure the turbidity of domestic water supplies, as these supplies often undergo some type of water treatment which can be affected by turbidity. Turbidity was measured in nephelometric turbidity units (NTU), using a turbidity meter because of its accuracy. The map shows that most of the areas investigated are within acceptable WHO standard.

## Sulphate

Figure 7 shows the map of the spatial variation of sulphate concentration in the study area. Sulphate occurs mostly as Calcium Sulphate (Gypsum). Sodium and Magnesium Sulphate are readily soluble in water while Calcium Sulphate is less so. Sulphur is useful to plants (Offodile, 2002). High levels of sulphate in drinking water can cause diarrhea (EPA/CDC, 1999). The WHO standard for Sulphate in drinking water is 250 mg/L. From the study no borehole was found to have excess sulphate. The map shows that the northeast quadrant of the study area and a bit of the southeast have generally less concentration of sulphate than the west, northwest and south of the study area.

## Conclusion

From the groundwater quality analysis, the highest concentration of electrical conductivity and nitrate were obtained at Owerri. This may have resulted from the domestic and industrial activities typical of a hugely populated

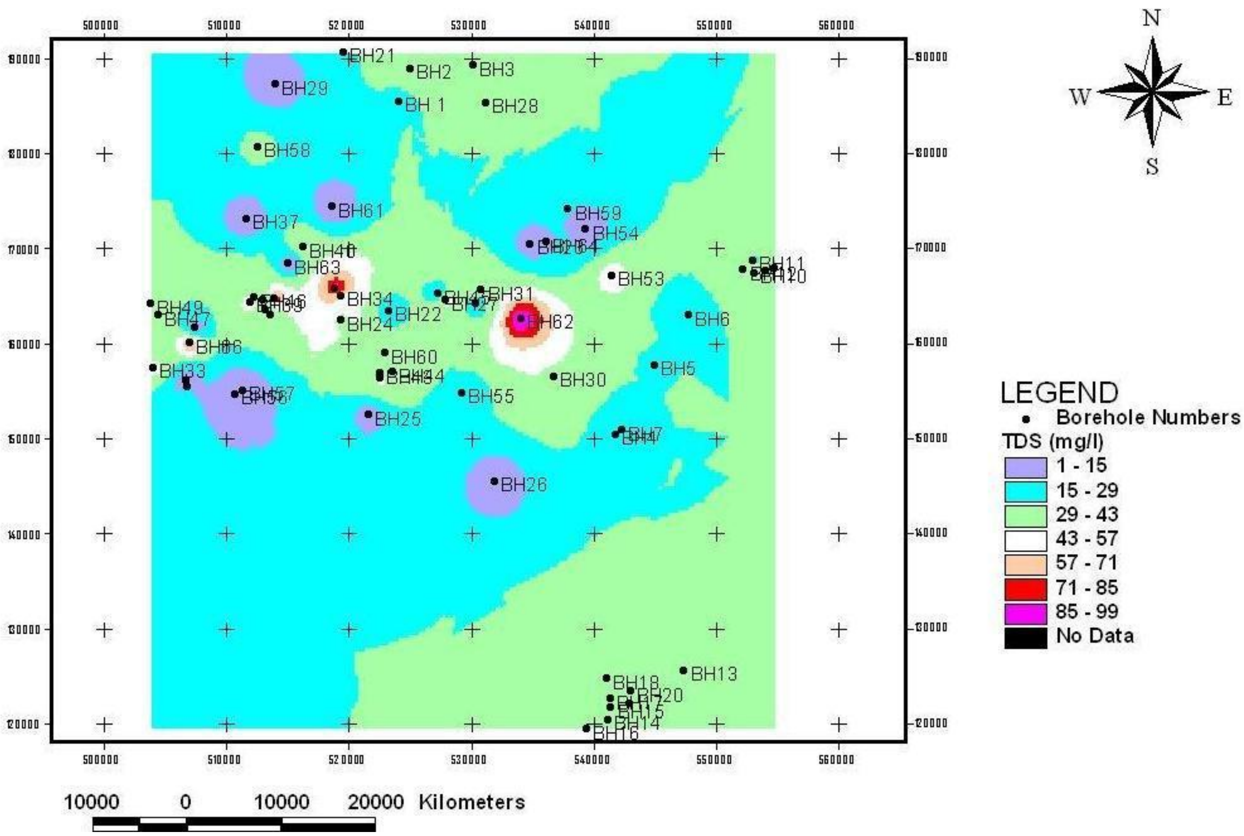


**Figure 5.** Spatial variation of totalled dissolved solid in the study area.

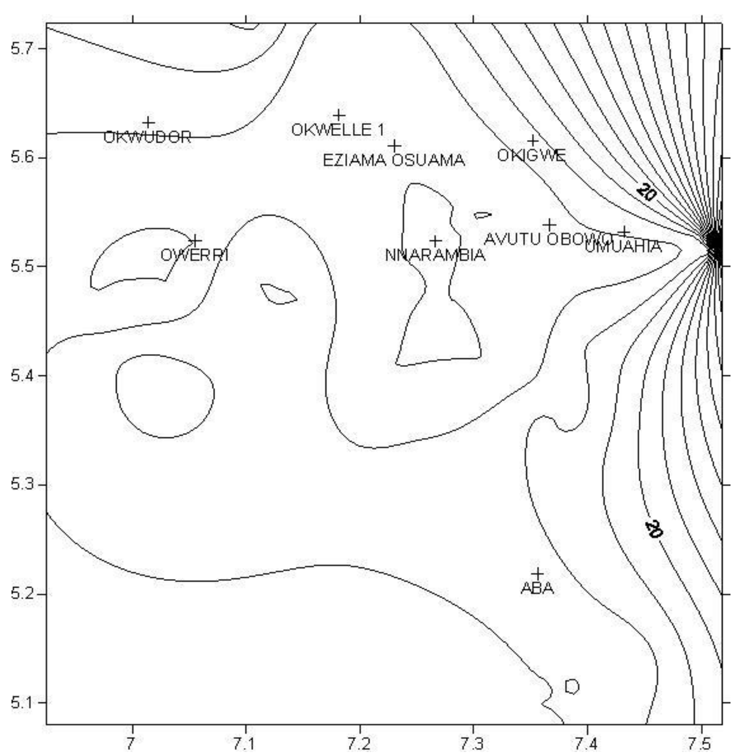


**Figure 6.** Contour map of turbidity in the the study area (C. I. = 5NTU).

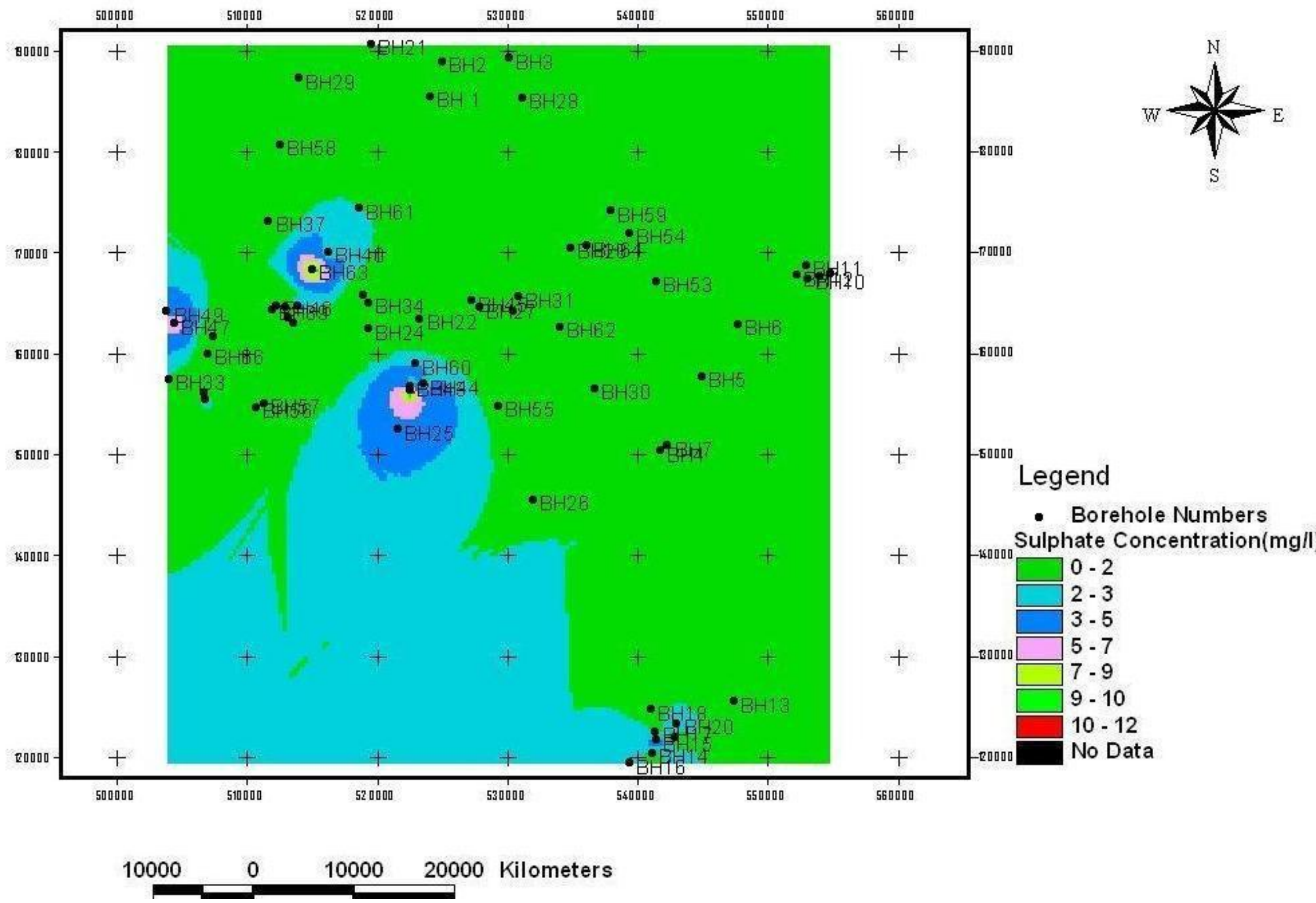


**Figure 7.** Spatial variation of sulphate concentration in the study area.

area as Owerri. The location on the map corresponding to Nkwo Obohia shows lower electrical conductivity. The highest concentration of phosphate was observed at Mbaise area, the most densely populated rural area in the study area (Onwuegbuche, 1993). Their extensive farming practice with the use of fertilizer can account for this unusual concentration of phosphate. The most saline part of the study area is the southwestern part, probably because of its proximity to the delta area. From the study no borehole was found to have excess sulphate or TDS, but higher values of TDS were observed at the densely populated areas of Owerri, Umuahia and Aba. There are also higher values around Mbaise area. This may be due to increased pollution arising from increased domestic activity, fertilization and industrial waste.

It is recommended that there should be environmental interventions through public health education by community based health workers, awareness and sensitization campaigns be carried out for improved household and community sanitation around Owerri and Nkwo Obohia. Wells located within 50 m from pollution source should be abandoned and future wells should be constructed beyond 250 m from pollution source. Adequate solid disposal method should be adopted, phasing out open dumpsites to safeguard public health from water borne diseases.

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