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Assessment of the Groundwater Quality in Parts of Imo River Basin, Southeastern Nigeria: The Case of Imo Shale and Ameki Formations

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ABSTRACT

Hydro-geochemical survey is undertaken in parts of Imo River Basin, Southeastern Nigeria, particularly in the geologic formations of Imo Shale and Ameki, to assess the quality of groundwater. Eleven samples of groundwater are obtained from various boreholes in the study area and subjected to physico-chemical analysis using standard laboratory techniques. The study is aimed at the assessment of the groundwater quality indicators namely: pH, electrical conductivity (N), phosphate (PO_4), sulphate (SO_4), nitrate (NO_3^-) and total dissolved solids (TDS). The result shows that the water from boreholes in Umuahia has low pH, and is therefore acidic. The pH values range between 4.40 and 5.60, which is below the acceptable range of 6.5 - 8.5. The acidity probably results from carbonic acid derived from the solution of CO_2 from both the atmosphere and the decomposition of plant materials in the soil zone. The acidity of the groundwater gives slight sour taste to drinking water, due to the mobilization of trace metals from the aquifer material into the groundwater system, because of the corrosive effect of acidic water. Since borehole supply is rarely treated, these trace metals end up in domestic supplies resulting in health implications and complaints. Acidic waters are typically low in buffering calcium minerals, but are high in dissolved carbon dioxide gas, which can cause the low pH or acidity. Calcite neutralizer tanks with natural crushed and screened pure calcium carbonate easily neutralize acidic water from 6.0 to 6.9. Below 6.0 a blend of calcite and Corosex is recommended. Common systems used to treat low pH: Calcite Neutralizer, calcite & Corosex Blend Neutralizer, pflow Neutralizer, Soda Ash Feed Pump Injection System.

Keywords: Hydro-Geochemical; Imo River Basin; Physico-Chemical Analysis; Groundwater Quality; Acidity

1. 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. 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 chemical composition (Wadie and Abduljalil, 2010) which may be modified by natural and anthropogenic sources [1]. 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) [2]. 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) [3]. Poor environmental management creates havoc on the water supply, hygiene and exacerbating public health (Okoro *et al*., 2009) [4]. 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 [5]. Acidified groundwater has been reported from many parts of the world particularly in North America and Europe [6-8] (Hultberg & Wenblad, 1980; Appelo *et al*., 1982; Grimvall *et al*., 1986). Groundwater in most hard-rock aquifers are also known to be vulnerable to quality problems that may have serious impact on human health [9] (Smedley *et al*., 1995). The rocks are often carbonate-defficient and give rise to poorly buffered groundwater (acidic groundwaters) that encourage the dissolution of elements such as Al, Mn, Be and Fe from most minerals if they are present in the rock matrix into the groundwater and make the groundwater unsafe for drinking [10] (Kortatsi, 2003). Acidity of groundwaters can cause corrosion problems leading to high maintenance costs and shortened life of hand pumps and accessories. It can also lead to high metal concentrations in the borehole that may cause aesthetic problems and, in extreme cases, physiological problems.

Geology of the Study Area

The study area, shown in **Figure 1**, lies between latitudes 5˚42'N and 5˚45'N and longitudes 7˚15'E and 7˚30'E. Two geologic formations are covered in the study area, namely: Imo shale and Ameki formations respectively. Imo shale consists of a thick sequence of blue and dark grey shales with occasional bands of clay-ironstones and subordinate sandstones [11] (Swardt and Casey, 1961). It dips at angles 17˚ to 25˚ to the south-west and South [12] (Uma, 1986). It includes three constituent sandstones: the Igbabu, Ebenebe and Umuna Sandstones with the last two outcropping in the Imo River Basin. The Umuna sandstone is composed of thick sandstone units and minor shales and is generally less than 70 m thick. The Ebenebe Sandstone occurs as a lens in the northwestern extremity of the Imo River Basin. It is similar in lithology to the Umuna sandstone but is relatively thicker with a maximum thickness of 130 m (Uma, 1986). Ameki Formation (Eocene) consists of sand and sandstones. The lithologic units of the Ameki Formation fall into two general groups [13-15] (Reyment, 1965; Whiteman, 1982 and 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. The Imo River Basin has a large amount of recharge; estimated at 2.5 billion m^3 per annum, coming mainly from direct infiltration of precipitation. Average annual rainfall is about 2000 mm [16] (Onwuegbuche, 1993).

2. Methodology

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

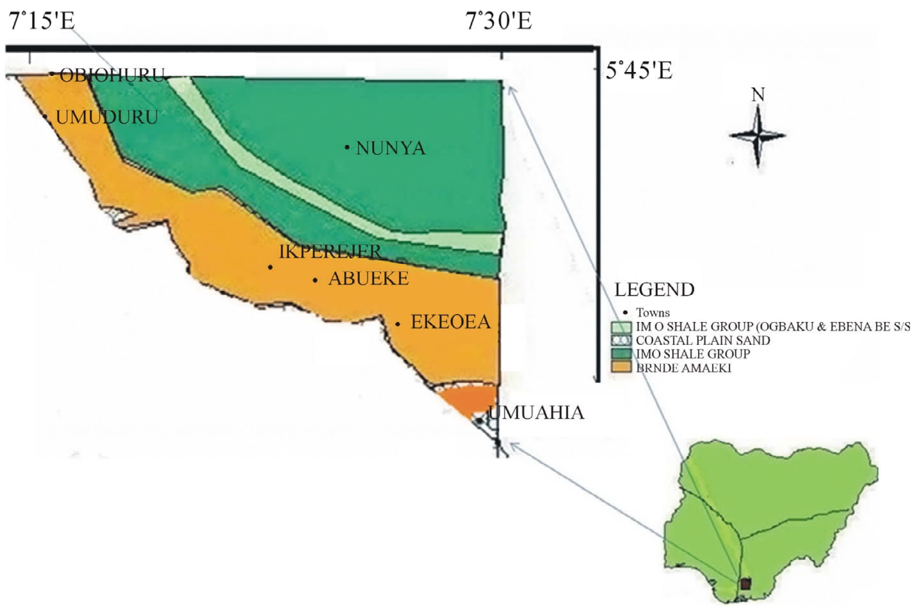

Figure 1. Map of the study area showing Imo Shale and Bende Ameki Formations.

study area. Water samples from 11 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 pH, electrical conductivity, sulphate, phosphate, total dissolved solids (TDS), salinity, nitrate respectively. 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 hours. All plastics and glass wares utilized were pre-washed with detergent water solution, rinsed with tap water and soaked for 48 hours 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 HA-CH sensor 3 pH meter. The turbidity was determined using a spectrophotometer. The result is presented in **Table 1**.

3. Results and Discussion

The specific parameter maps of groundwater quality indicators were developed to facilitate the rapid assessment of the extent of pollution of the various locations 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 turbity were also developed [17].

3.1. pH

Figure 2 shows the map of the spatial variation of pH in the study area. It can be seen from the map that much of the area around Umuahia have pH lower than 6.00. From the chemical data shown in **Table 1**, the pH values vary from 4.40 to 6.70. Areas within Umuahia metropolis show pH of 4.40 - 5.60. This indicates that the water is acidic. They are not within the acceptable WHO range for portable water (6.5 - 8.5) [18]. Only three boreholes within the study area fall within the acceptable range, BH21, BH28 and BH54 with pH of 6.5 - 6.7. The acidity probably results from carbonic acid derived from the solution of CO_2 from both the atmosphere and the decomposition of plant materials in the soil zone. The acidity of the groundwater gives slight sour taste to drinking water and has also led to the mobilization of trace metals particularly iron, manganese, aluminium and arsenic into the groundwater system, because of the corrosive effect of acidic water. It is the amount and type of dissolved minerals that give the groundwater its distinctive taste. Since borehole supply is rarely treated, these trace metals end up in domestic supplies resulting in health implications and complaints. Acidic waters are typically low in buffering calcium minerals, but are high in dissolved carbon dioxide gas, which can cause the low pH or acidity.

3.2. Electrical Conductivity

The map of the spatial variation of electrical conductivity is shown in **Figure 3**. Electrical conductivity of water is

Table 1. Groundwater quality data: imo shale and ameki formations.

S/N	borehole number	location	longitude	latitude	pH	Electrical conductivity (μs/cm)	tds (mg/l)	nitrate (mg/l)	sulphate (mg/l)	phosphate (mg/l)	salinity	turbidity (jtu)
		FMENV/WHO'S STANDARD			6.5 - 8.5	100	250	45	250	5	50	50
1	BH 1	UMUOSU	7.16002	5.67698	6.44	54	27	0.100	0.00	0.24	0.5	2
2	BH2	EZIAMA OSUAMA	7.17038	5.70800	5.88	77	38	4.100	2.00	0.38	0.3	1
3	BH3	UMUDURU	7.23028	5.71092	5.77	68	34	3.100	1.00	0.56	0.2	2
4	BH8	WINNERS UMUAHIA	7.51816	5.51907	5.45	52	26	0.900	2.00	0.10	3.4	121
5	BH9	OHOKOBE UMUAHIA	7.50943	5.51580	4.80	72	36	0.500	1.00	0.12	6.7	3
6	BH10	WBHE, UMUAHIA	7.49876	5.51425	4.82	85	42	0.200	0.00	0.20	1.2	9
7	BH11	AZIKIWE RD, UMUAHIA	7.49733	5.52588	4.40	53	27	1.900	1.00	0.34	1.8	8
8	BH12	AFARA UMUAHIA	7.48837	5.51725	5.60	77	38	1.100	2.00	0.28	1.1	6
9	BH21	AMAIGBO	7.10723	5.72322	6.50	41.1	22.1	41.00	11.20	-	18.5	16
10	BH28	UMUEZEALA-AMA	7.24280	5.67550	6.50	86.3	43.0	0.001	0.58	12.5	0.3	
11	BH54	UMUARIAM OBOWO	7.33831	5.55491	6.70	14.5	7.3	1.02	0.02	-	2.47	0.0

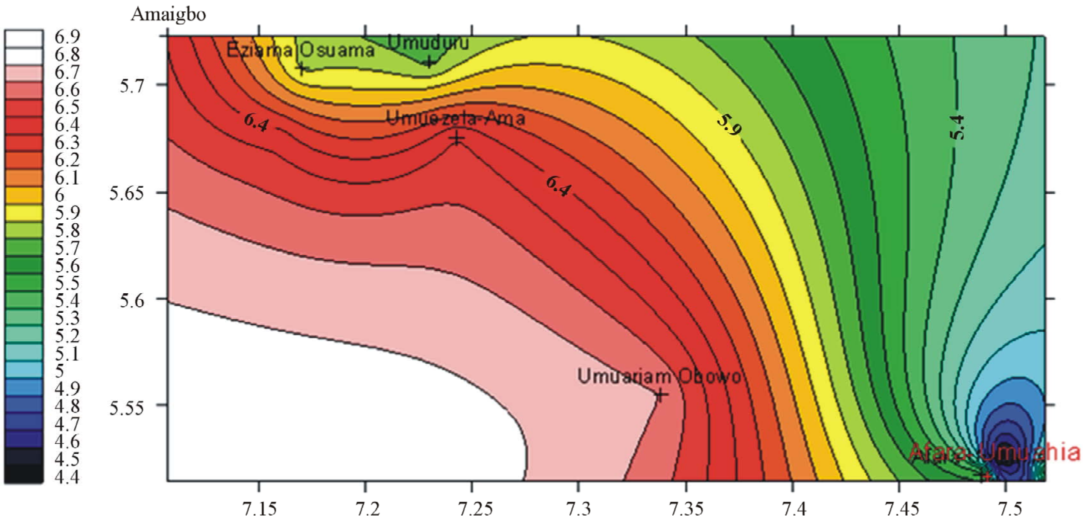

Figure 2. Spatial variation of pH in the study area.

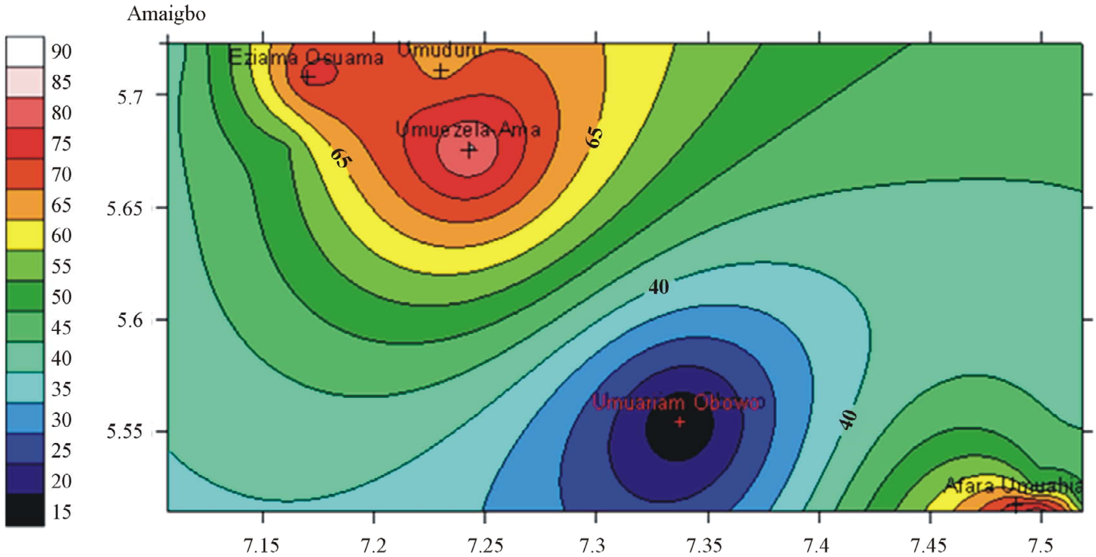

Figure 3. Spatial variation of electrical conductivity in the study area.

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. 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 30,000 µs/cm and 45,000 to 60,000 µs/cm respectively. Normal groundwater has a range of 100 to 2000 µs/cm [19] (Offodile, 2002). All areas within the study area fall within the WHO standard for electrical conductivity.

3.3. Phosphate

Figure 4 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 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 only in Umuezeala-ama, BH28 (12.50 mg/l). This is probably because of the extensive use of fertilizer for farming in the area. The rest of the area have generally low concentration of phosphate (≤2 mg/l), perhaps, due to less farming in those urban centers.

3.4. Nitrate

Figure 5 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

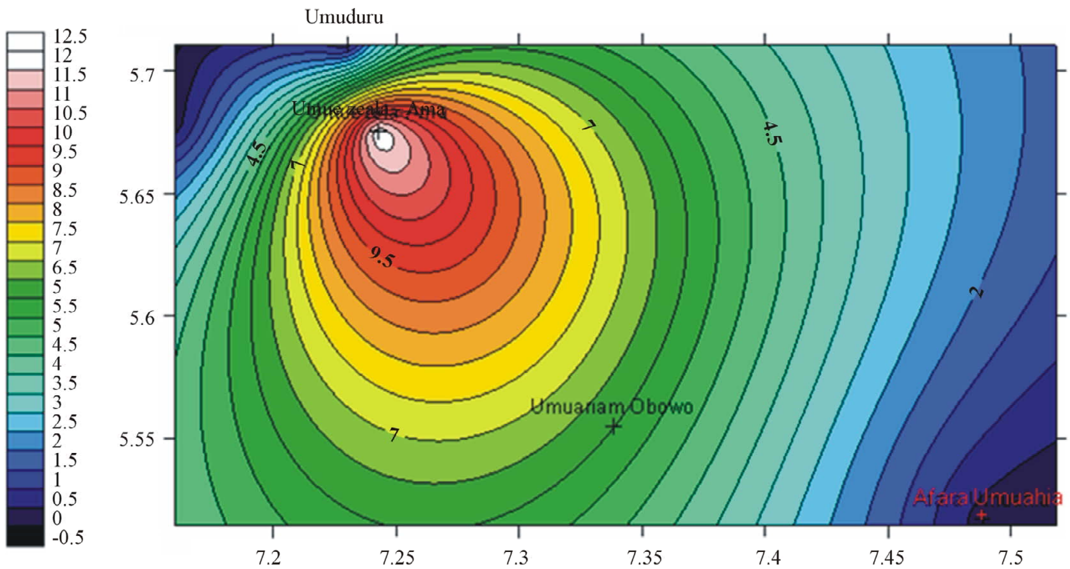

Figure 4. Spatial variation of phosohate in the study area.

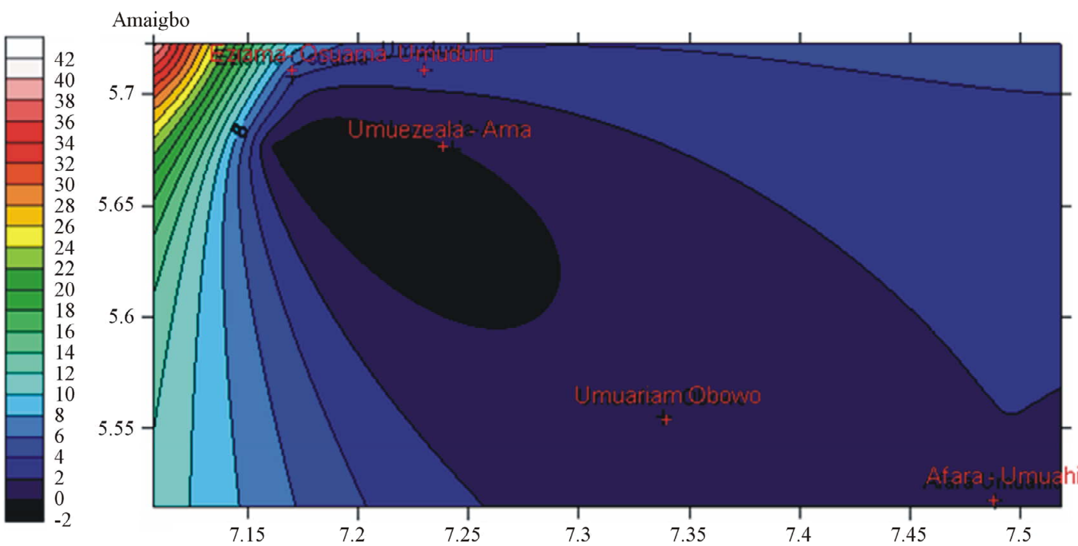

Figure 5. Spatial variation of nitrate in the study area.

[18] (Offodile, 2002). The WHO standard for nitrate in drinking water is 50 mg/l. This standard is not exceeded in any part of the area.

3.5. Sulphate

Figure 6 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. 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.

3.6. Total Dissolved Solids

Figure 7 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 Umuezela-ama, Umuduru, and Eziama Osuama. This may be due to increased pollution arising from increased fertilization and industrial waste.

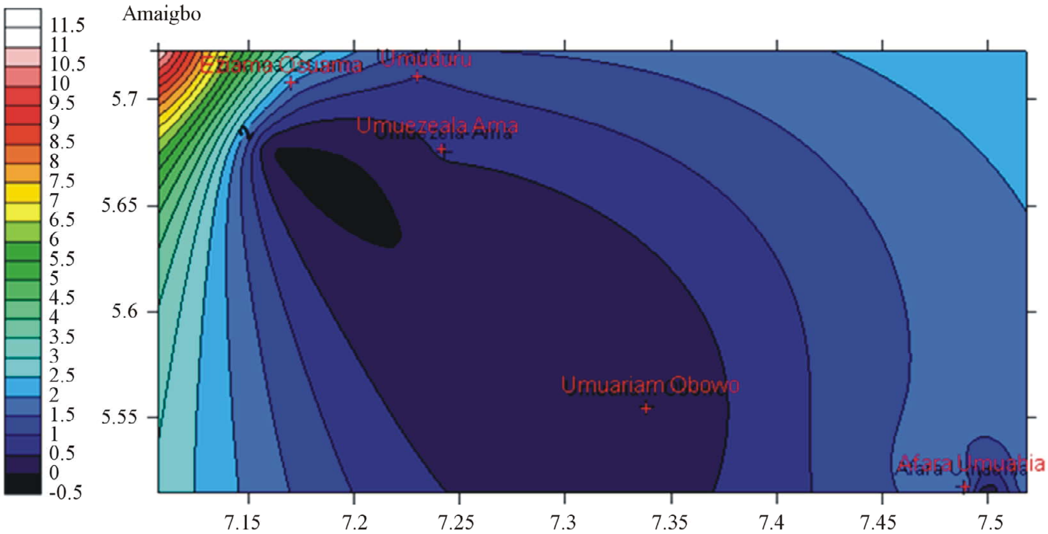

Figure 6. Spatial variation of sulphate in the study area.

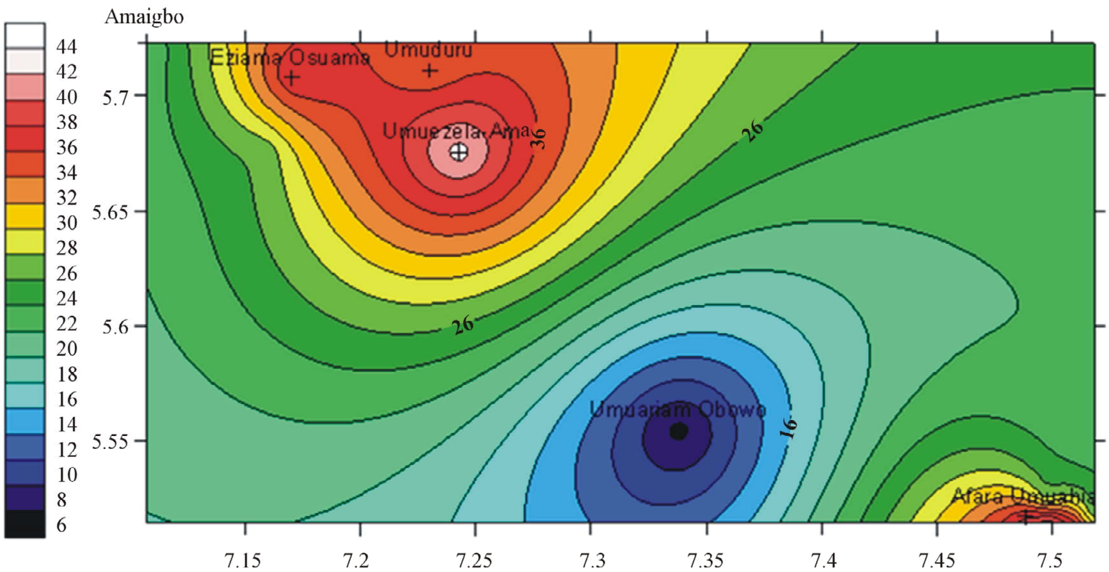

Figure 7. Spatial variation of total dissolved solid in the study area.

3.7. Turbidity

Figure 8 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 nephewlometric 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.

4. Conclusion

From the groundwater quality analysis, most of the groundwater quality parameters measured are within acceptable portable standards, except for the acidity of the groundwater around Umuahia area. Umuahia is the most densely populated part of the study area. The atmospheric condition of the city, possibly affected by industrial and domestic waste, may be the probable cause of acidification of the groundwater. Virtually all groundwater comes from precipitation that soaks into the soil and passes down to the aquifer. Rainwater has a slightly acidic pH, therefore it tends to dissolve solid minerals in the soil and in the aquifer. Different rocks, e.g., sandstone, limestone and basalt all have different minerals and therefore, groundwater in contact with these materi-

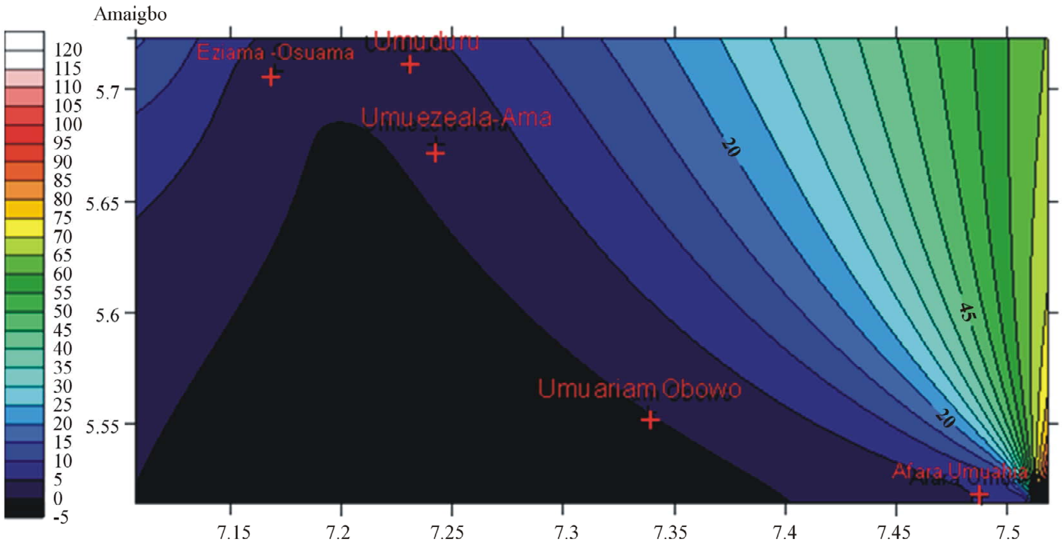

Figure 8. Spatial variation of turbidity in the study area.

als will have different compositions. Acidic waters are typically low in buffering calcium minerals, but are high in dissolved carbon dioxide gas, which can cause the low pH or acidity. Calcite neutralizer tanks with natural crushed and screened pure calcium carbonate easily neutralize acidic water from 6.0 to 6.9. Below 6.0 a blend of calcite and Corosex is recommended. Common systems used to treat low pH include Calcite Neutralizer, calcite and Corosex Blend Neutralizer, pflow Neutrilizer, Soda Ash Feed Pump Injection System. In neutralizer filters, acidic waters slowly dissolve the calcium and magnesium media on contact as the water flows through the filter, raising the pH of the water and increasing the alkalinity. This eliminates the effects of corrosive water chemistries and can help to prevent corrosion of piping and fixtures. Generally the lower the pH, the lower the hardness and alkalinity, and the higher the total dissolved solids will mean the water is more corrosive. Further studies can be undertaken to determine the amount and type of trace minerals present in the groundwater.

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