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An Assessment of Nitrate Groundwater Pollution in an Agricultural Area in Akwa Ibom State, Nigeria

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ABSTRACT

An assessment of nitrate groundwater pollution in an agricultural area in Akwa Ibom State, Nigeria was carried out with the aim of mapping out areas that are polluted due to leached fertilizers from agricultural activities. Water from twenty sample wells were collected and analysed for physio-chemical properties using standard techniques. Results showed that the NO_3^- which constituted the contaminant of groundwater ranged from 4.68 mg/L to 90.2 mg/L within the sampled wells. Areas that were found to have high concentration of NO_3^- above the WHO recommended 50 mg/L were mainly located within the intensive agricultural areas, implying that frequent use of fertilizers is a major contributor to nitrate pollution of groundwater within the area.

Keywords: Groundwater, Kriging, Nitrate, Pollution, Vulnerability

1. INTRODUCTION

A global challenge is to produce sufficient food for sustenance of the ever-growing population and at the same time minimize the loss of nitrates to the environment.

The production of nitrogen fertilizers has been the main reason for the increase in world crop productivity, thus supporting the human population growth; but nitrogen

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fertilizers also cause nitrate imbalances in agricultural development in all parts of the world [1], [2]. The pollution of soil and groundwater with nitrate from agricultural operations is a global water quality issue that has been extensively documented [3], [4], [5], [6], [7],[8],[9], [10]. On the local scale, water soluble components used in agriculture, industrial refuse, dry waste deposits, etc., may be caught by water and produce groundwater pollution, which will remain undetected until the polluted water passes through a local well [11]. Nitrate is one of the most startling and widespread pollutant of groundwater and surface water resources reported around the world[12]. Fertilizers and pesticides applied to cropland are the leading sources of chemical pollution of groundwater in farming regions around the world. These mortify the quality of aquifers by introducing large quantities of nitrates into the groundwater system[13]. Nitrate pollution of groundwater has become particularly severe in places where human population and the demand for high food productivity is most concentrated [14]. The amount of this pollutant that reaches groundwater depends on a number of factors: the amount used above the ground, the geology of the region, climate, cropping practices, and the characteristics of the chemical itself, such as how mobile and soluble it is in water. These factors combine to determine the vulnerability of the aquifer. Nitrate is soluble and negatively charged and thus has a high mobility and potential for loss from the unsaturated zone by leaching [15]. Some of the fertilizers infiltrate with the irrigation and/or rainwater to recharge the aquifer. Nitrate enters the hydrosphere easily, and its ingestion causes various health risks such as methemoglobinemia, cancer, diabetes, etc. on humans and to some extent on livestock populations as well. The environmental effects include a decline in biodiversity, eutrophication of ecosystems and surface waters, acidification, global warming, air pollution and diffuse nitrate pollution of groundwater [16]. Given that consumption of water with high concentrations of nitrate can cause risks to human wellbeing, organizations such as the World Health Organization (WHO) and the US Environmental Protection Agency (EPA), have established quality standards for water resources and developed regulations and action guidelines for the use of water in the consumption sector. WHO standard for drinking water quality are 50 mg/L NO_3, whereas EPA set a maximum of 10 mg/L NO_3 as an acceptable concentration level of nitrate for drinkable water [17], [18].

The objective of the present study is to determine the spatial distribution of nitrates together with other hydrochemical parameters in groundwater within Ini Local Government Area of Akwa Ibom State which is the major agricultural zone of the state.

1.1 Geologic Description of the Study Area

Geologically, the study area is underlain by two main rock types which are Clay/shale and sandstone to the north [19] and coastal plain sand to the south[20]. The shale is bluish to dark gray in colour. It is fissile and flat lying. The upper part grades into a mixture of clay and shale and finally into light brownish gray to reddish brown clay. Observation from gullies shows that the clay-shale sequence is over five metres thick, becoming silty clay in some localities. Carbonized streaks of plant remains are locally present in the dark gray portion of the shale particularly in the area towards the boundary between Akwa-Ibom and Abia State [21]. Pebbles, boulders and lenses of limestone are common in the clay portion. The sandstone is essentially massive over six to eight metres in some exposures particularly around Ebo, Okpoto and Iwere area in Ini Local Government Area [19]. It is characterized by fine lamination probably as a result of grading and streaks of whitish clay (kaolin). It is generally friable and whitish beyond the laterized portions. Texturally it is medium to coarse grained and fining upwards[22].

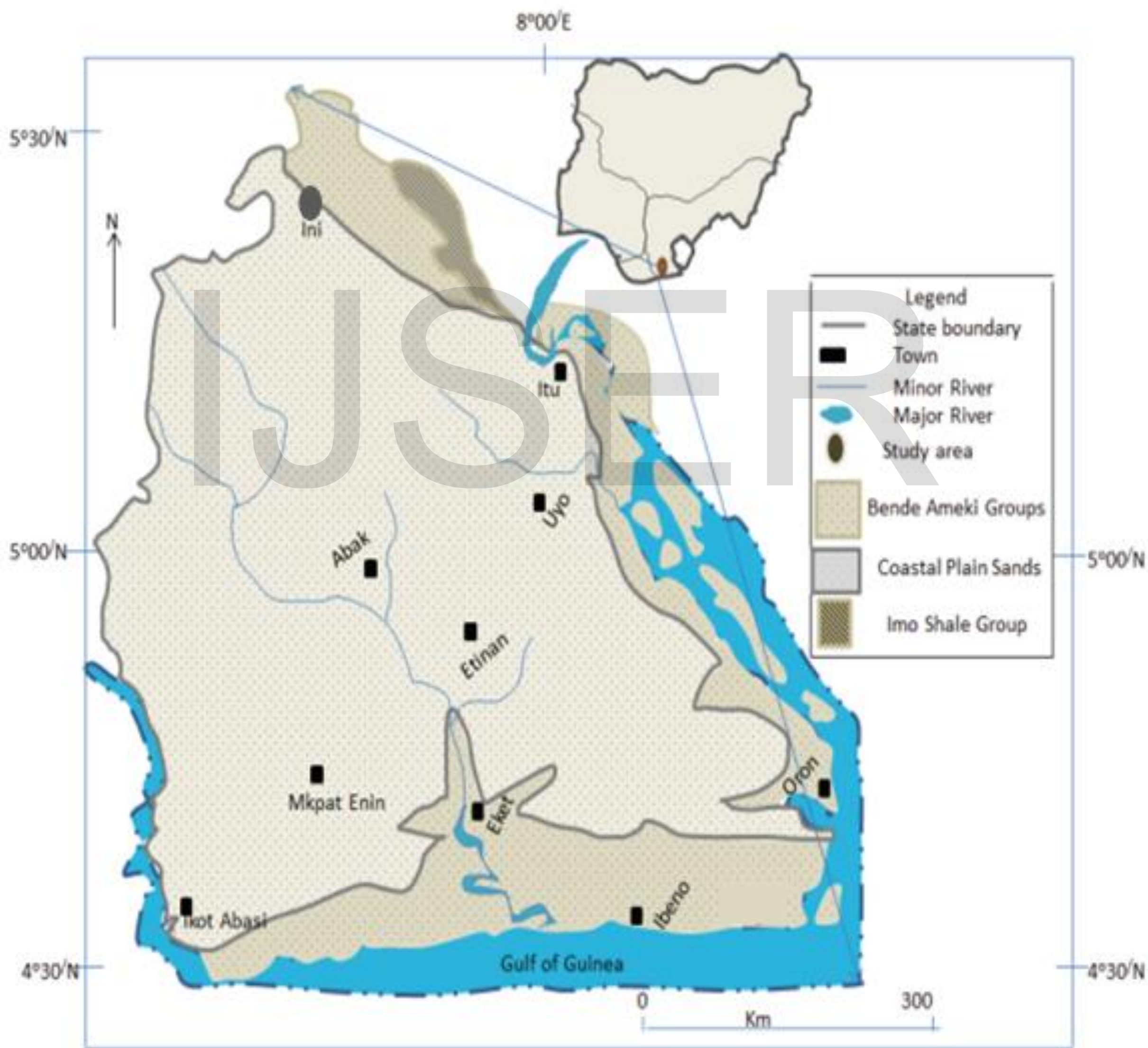

Figure 1 Geologic Map of Akwa Ibom State showing the study area.

2. METHODOLOGY

This study examines the hydrochemical characteristics of 20 groundwater sampling sites located in Ini local Government Area of Akwa Ibom State, Nigeria. The sampling campaign was carried out in July 2018 during the peak of the rains, when groundwater samples were collected from 15 functional boreholes and 5 hand-dug wells. The coordinates of the sampling sites were identified using a GPS. *In situ* physical-chemical water quality parameters including pH, electrical conductivity (EC), Total Dissolved Solids (TDS) and Water Temperature (T_W) of the water samples were measured with a portable multi-parameter water quality analyzer (HACH HQ40d). Water samples were filtered by 0.45 µm acetate cellulose filter membranes and were stored at 4°C. Concentrations of NO_2^-, NH_4^+, SO_4^{2-}, Cl^- and NO_3^-, were analyzed by Auto Discrete Analyzers (Clever Chem200, Hamburg, Germany). Concentrations of Na^+, K^+, Ca^{2+} and Mg^{2+} were determined using an optical emission spectrometer. The HCO_3^- and CO_3^{2-} contents were analyzed by acid-base titration.

3. RESULTS AND DISCUSSION

Water quality

The descriptive statistics for the measured parameters in groundwater from the twenty sampled locations is summarized in Table 1. All water samples were relatively akin in pH, ranging from 7.1 to 8.3, with a mean value of 7.57, signifying a slight alkaline nature of water samples. The pH (hydrogen-ion concentration) of a solution is used to express the intensity of acidity or alkalinity of a solution. The pH from the sampled wells contradicted the findings of [23], who claimed that water samples within the Niger Delta usually have low pH value (acidic). This could be because the study area is located in the hinterlands, away from sea water intrusion and gas flaring. The electrical conductivity values of the water samples showed a spatial variation between the sampled wells.

Electrical conductivity is the measure of the amount of electrical current a material can carry or it's ability to carry a current. It had a minimum value of 512.3 µS/cm while the maximum value was 9720.6 µS/cm with a mean value of 3447.65 µS/cm. Total dissolved solid (TDS) is an appraisal of the combined total of organic and inorganic substances contained in a liquid. This includes anything present in water other than the pure H_2O molecules. These solids are primarily minerals, salts and organic matter that can be a general indicator of water quality. Within the study area, TDS ranged from 1124 mg/L to 201 mg/L with a mean of 404.2 mg/L. The temperature of the water samples showed a slight variation, ranging from 25.5°C to 19.4°C with a mean of 23°C. NO_2^-, NO_3^-, NH_4^+, SO_4^{2-}, and Cl^- ranged from 0.004 to 0.42 mg/L, 4.68 to 90.2 mg/L, 0.003 to 1.21 mg/L, 10.5 to 32.5 mg/L and 2.1 to 26.7 mg/L respectively. The average value for these ions from the sampled wells stood at 0.012 mg/L, 19.5 mg/L, 0.12 mg/L, 15.42 mg/L and 7.2 mg/L respectively. The highest concentration of NO3- was found in areas where intensive rice cultivation is carried out within the study area.

The respective concentration range of Na^+, K^+, Ca^{2+} and Mg^{2+} in the samples were 34.1 to 113.2 mg/L, 1.32 to 12.48 mg/L, 2.11 to 16.26mg/L and 1.02 to 9.32 mg/L. the mean values were 56.2 mg/L, 4.73 mg/L, 6.24 mg/L and 5.41mg/L. Calcium and magnesium in groundwater are generated by the action of carbon dioxide in water on carbonate rocks such as limestone and dolomite [23]. Elevated calcium content of groundwater samples in the northeastern part of the study area originates mainly from limestone dissolution. The enrichment of groundwater samples in Na and Cl ions around sample sites close to Nkana area is attributed to groundwater mixing with the river. Potassium occurs in various minerals, from which it may be dissolved through weathering processes. The range of values for potassium in groundwater samples in the study area lie within the permissible limits of 200mg/L for potassium in portable drinking water [17].

Table 1: Statistical parameters of variables determined in the groundwater samples.

Parameter	Unit	Mean	Min	Max	STDV
pH	(pH unit)	7.57	7.1	8.3	0.21
EC	(µS/cm)	3447.65	512.3	9720.6	13.6
TDS	(mg/L)	404.2	201	1124	12.2
Tw	(°C)	23	19.4	25.5	1.13
NO_2^-	(mg/L)	0.012	0.004	0.42	0.93
NO_3^-	(mg/L)	19.5	4.68	90.2	3.32
NH_4^+	(mg/L)	0.12	0.003	1.21	0.11
SO_4^{2-}	(mg/L)	15.42	10.5	32.5	5.39
Cl^-	(mg/L)	7.2	2.1	26.7	4.9
Na^+	(mg/L)	56.2	34.1	113.2	6.71
K^+	(mg/L)	4.73	1.32	12.48	2.80
Ca^{2+}	(mg/L)	6.24	2.11	16.26	3.12
Mg^{2+}	(mg/L)	5.41	1.02	9.32	2.30

3.1 Spatial Distribution of Nitrate Pollution and Its Controlling Factors

Based on the drinking water standard [17], four levels of nitrate concentration; namely:

(level I of 0–10 mg/L for background level water, level II of 10–45 mg/L for water unpolluted but in a critical condition, level III of 45–90 mg/L for slight polluted water and level IV of the concentration above 90 mg/L for severely polluted water) were generated to evaluate nitrate pollution within the study area using surfer software with Kriging interpolation method. The basic idea of kriging is to predict the value of a function at a given point by computing a weighted average of the known values of the function in the neighborhood of the point. The output is presented in Figure 2.

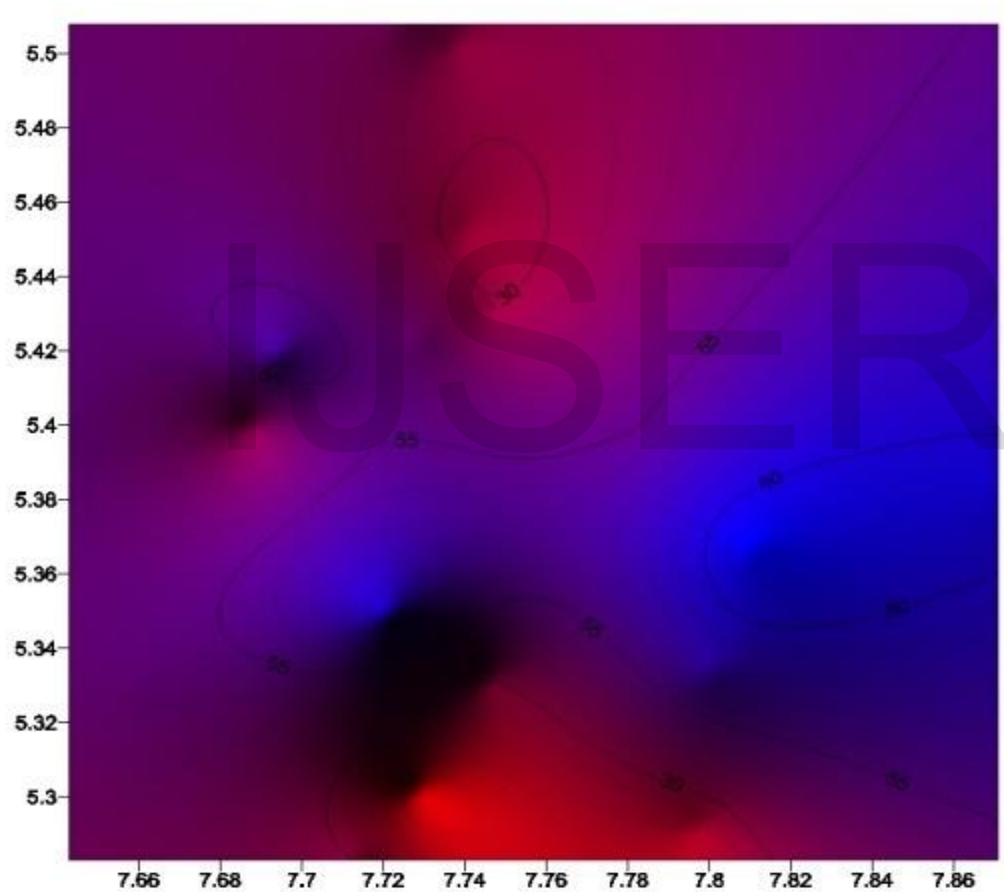

Figure 2: Nitrate distribution in groundwater within the study area

About 50% of the area is classified into level III and IV. These are areas with intensive rice and vegetable farming within the study area. Since there are no major sources of nitrates within the area apart from fertilizers, it is believed that an elevated nitrate concentration in groundwater within these areas is due to frequent use of nitrate fertilizers. Though the groundwater within the area is slightly polluted; as nitrate concentration was found to lie between 55 mg/L to 90 mg/L, an early enlightenment is required. Continuous future use of nitrate fertilizers by the farmers is likely to raise the contamination level beyond this manageable level.

4. CONCLUSION

In view of the long and short term negative effects of NO_3^- in drinking water on humans, this study was conducted to determine the spatial distribution of water quality parameters in Ini Local Government Area of Akwa Ibom State. Results revealed that the values of NO_3^- in about 50% of the study area are higher than the WHO recommended level of 50 mg/L. The major reason for this is the high use of nitrogen chemical fertilizers for agriculture. The study recommends that extension workers should enlighten the rural farmers on the side effects of elevated nitrate concentration in groundwater.

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