INVESTIGATING THE QUALITY STATUS OF GROUNDWATER IN PARTS OF EASTERN NIGER DELTA FOR IRRIGATION PURPOSES

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Abstract
Groundwater quality evaluation in Eastern Niger Delta, Nigeria for irrigation purposes was the sole aim of this research. The groundwater in the area was analyzed for pH (4.80-7.80, Ave. 5.65), conductivity (20.05-820.10, Ave. 260.04), total dissolved solids (10.20-568.50, Ave 245.20) as well as major cations and anions. The concentrations of some of the major ions were recalculated to determine the respective irrigation quality index. The value of SAR ranged from 0.1 – 8.45 meq/L with a mean value of 1.52 meq/L while the concentration of SSP varied from 4.64 – 28.08 meq/L with an average value of 12.38 meq/L. The concentration of PI ranged from 9.22- 43.75 meq/L with a mean value of 34.49 meq/L while the value of RSBC varied from 1.05 – 2.25 meq/L with an average value of 1.31 meq/L. The value of MAR ranged from 34.34 – 62.61 meq/L with an average value of 38.54 meq/L while the concentration of KR varied from 0.04 – 0.36 meq/L with a mean value of 0.12 meq/L The results of the analyses and interpretation of water quality for irrigation (SAR, SSP, MAR, RSBC, PI, KR, pH, TDS and EC), indicates that the groundwater in the area is suitability for irrigation purposes is in the order The observed low pH may be attributed to the various anthropogenic activities domiciled in the region. The plottings on the salinity diagram falls within the low salinity zone, which implies low sodic water and good for irrigation purposes. Based on the findings, the groundwater in Eastern Niger Delta, Nigeria is suitable for irrigation purposes.

Keywords: Groundwater Quality, Irrigation Purposes, Eastern Niger Delta, Nigeria

1.0.Introduction

Based on the quality attribute, surface and groundwater can be used for drinking, domestic, irrigational and industrial purposes. In terms of economic activities such as commerce, tourism and industry, water is an indispensable input. The chemical composition of water determines whether it can be used for irrigational purposes without deleterious effects. Other factors such as nature and composition of the soil and subsoil, depth of the water table, topography, climate, type of crop, vegetation and farming method affects plant productivity. Studies (Helena *et al*., 2000; Amadi *et al*., 2012a) have shown that the parameters affecting the suitability of water for irrigation purposes are Electrical Conductivity (EC), Soluble Sodium Percentage (SSP), Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Permeability Index (PI), Kelly's ratio (KR) and residual sodium bicarbonate (RSBC).

The prolonged use of certain irrigation water results in reduced yields due to deterioration in the soil physical properties. The adverse effects of irrigation water quality on soil physical properties is associated with the accumulation of sodium ion on the soil exchange complex, which imparts instability to the soil aggregates and this is followed by dispersion of clay particles resulting in clogging of soil pores. The water quality used for irrigation is very essential for the quality, yield and quantity of crops produced, maintenance of soil productivity and protection of the environment. At the same time, the quality of irrigation water is very much influenced by the geochemistry and geology of the water source (Singh and Singh, 2008; Amadi *et al.*, 2014a). According to Lambarkis (2004), the chemical constituents that affect the suitability of water for irrigation purposes include: total concentration of soluble salts, concentration of boron, relative proportion of sodium to calcium and magnesium as well as relative proportion of bicarbonate to calcium and magnesium. In terms of agricultural purposes, Sodium Adsorption Ratio (SAR) is the most useful parameter. Sodium is introduced into the aquifer in the area from rainwater and dissolution from rocks. Due to its effects on soils and plants, sodium is considered one of the major factors governing irrigation water (U.S Salinity Laboratory, 1954; Offodile, 2002). Suitability of water for irrigation is based on the Sodium Adsorption Ratio (SAR).

2.0 Materials and Methods

Study Area Description

The study area lies within the Eastern portion of Niger Delta region of Nigeria between latitude 4°40'N to 5°40'N and longitude 6°50'E to 7°50'E (Fig. 1). It covers parts of Port-Harcourt, Aba and Owerri and a total area of approximately 12,056 km^2. The topography is under the influence of tides which results in flooding especially during the rainy season (Etu-Efeotor and Odigi, 1983; Ngah, 2002; Nwankwoala *et al.*, 2015). The prevalent climatic condition in the area comprises of the rainy (March to October) and dry (November to February) seasons characterized by high temperatures, low pressure and high relative humidity throughout the year (Ezeigbo, 1989; Ibe et al., 1992).

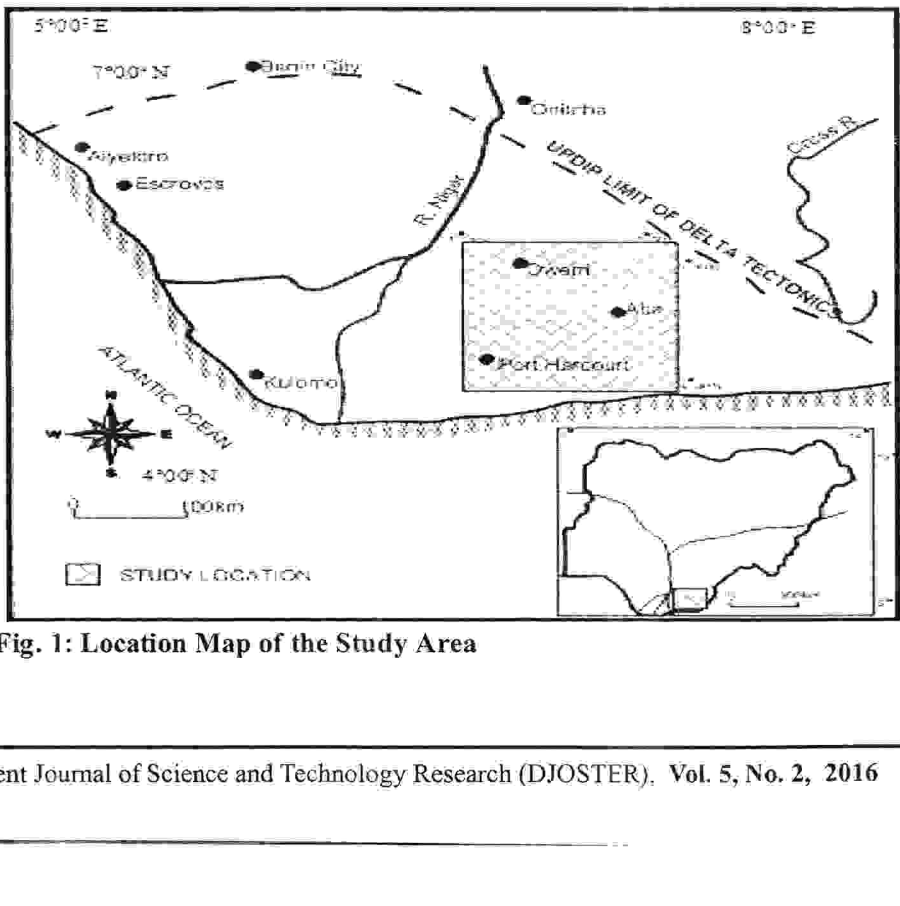

Fig. 1: Location Map of the Study Area

Sample Collection

A total of 25 surface water and 45 groundwater samples were collected in acid-washed polyethylene 500 ml bottle across Aba, Owerri and Port-Harcourt axes and suitable preservative were added for storage till completion of quantitative chemical analysis. Physical parameters such as pH, electrical conductivity, and total dissolved solids values were determined insitu using pHTestr 2, ECTestr+ by Eutech instruments and DIST 3 by Hanna Instruments respectively. The bottle was completely filled with water taking care that no air bubble was trapped within the water sample. Then to prevent evaporation, the bottles were sealed with double plastic caps and precautions were taken to avoid sample agitation during transfer to the laboratory. The samples were immediately transferred to the laboratory.

Laboratory Analysis

Samples were analyzed in the laboratory for the major ionic concentrations employing standard methods. Calcium and magnesium were determined titrimetrically using standard EDTA, chloride by standard $AgNO_3$ titration, bicarbonate by titration with HCl while sodium and potassium were determined through flame photometry. Sulphate and phosphate were determined by spectrophotometer CL 22D while nitrate and fluoride concentration were obtained using ion selective electrode. The analytical precision for the major ions was determined by the ionic balance calculated from 100*(cations – anions) ÷ (cations + anions) and the value obtained was ±3.5% which falls within the acceptable limit of ±5% in accordance with APHA, (1995).

Irrigation Quality Index

Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio is a measure of the sodicity of the soil determined through quantitative chemical analysis of water in contact with it. An excess of HCO_3^- and CO_3^- ions in water reacts with Na^+ in soil resulting in a sodium hazard. The SAR was calculated using the following equation: $SAR = [Na+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$. The concentrations of all ions are in meq/L.

Soluble Sodium Percentage (SSP)

High sodium ion concentration in soil can take a toll on internal drainage patterns in soil as release of calcium and magnesium ions are facilitated due to adsorption of sodium by clay particles. SSP was calculated using the following equation:

$SSP = [(Na^+ + K^+) * 100] / [Ca^{2+} + Mg^{2+} + Na^+ + K^+]$. The calculations were done in meq/L.

Residual Sodium Bicarbonate (RSBC)

The residual sodium carbonate index of water/soil signifies the alkalinity hazard posed by it and it finds the suitability of water for irrigation in case of clay soils. It is given by the following equation: $RSBC = (HCO_3^- + CO_3^-) - (Ca^{2+} + Mg^{2+})$ and the concentrations expressed in meq/L.

Residual sodium carbonate values should preferably be less than 1.25 for water intended for irrigation purposes.

Permeability Index (PI)

Another modified criterion has evolved based on the solubility of salts and the reaction occurring in the soil solution from cation exchange for estimating the quality of agricultural waters. Soil permeability is affected by the long term use of irrigation water and is influenced by the following: total dissolved solids, sodium contents and bicarbonate content. In order to incorporate the first three items Doneen developed an empirical formula called 'Permeability Index' after conducting a series of tests and experiments for which he had used a large number of irrigation waters varying in ionic relationships and concentration. The permeability index is given by the following formula: $PI = Na^{+} + [\{HCO_3^{-}\}^{1/2} / (Ca^{2+} + Mg^{2+} + Na^{+})\} * 100]$ and the concentrations of the ions are in meq/L.

Magnesium Adsorption Ratio (MAR)

Generally, in most groundwaters Ca^{2+} and Mg^{2+} maintain a state of equilibrium. During equilibrium more Mg^{2+} in groundwater adversely affects the soil quality rendering it alkaline which result in decrease of crop yield. Paliwal developed an index for calculating the magnesium hazard called Magnesium adsorption ratio (MAR). MAR is calculated using the formula:

$MAR = (Mg^{2+} * 100)/(Ca^{2+} + Mg^{2+})$ with the concentrations in meq/L.

Kelly's Ratio (KR)

Kelly's Ratio was devised by Kelly and is measured considering sodium ion concentration against calcium and magnesium ion concentrations. The formula is given as:

$KR = Na^{+} / (Ca^{2+} + Mg^{2+})$ and concentrations of the ions are in meq/L. Waters with a KR value <1 are considered suitable for irrigation, while those with greater ratios are unsuitable.

3.0. Results and Discussion

The pH ranged from 3.80 and 7.78 with a mean value of 5.65 (Table 1). The pH is an important indicator of water quality for irrigation as it influences the rate at which plants take up nutrients from the soil. The observed low pH in the region could be attributed to the impact of acid rain witnessed in the area, which might have resulted from the accumulation effect of gas flaring in the area as well as incessant oil spills.

Total dissolved solid (TDS) values are important parameter in determining the usage of water and TDS value greater than 500 meq/L are not suitable for both irrigation purposes. It is a measure of the combined content of all inorganic and organic substances present in water. The TDS concentration ranged 10.20 meq/L to 568.50 meq/L and a mean concentration of 245.20 meq/L (Table 1). Electrical conductivity (EC) of water is the ability of water to conduct electrical current and it is a function of the amount of dissolved solids in water. The EC is a useful parameter in categorizing salinity hazard as well as suitability of water for irrigation purposes. The EC concentration varied from 20.05 meq/L to 820.10 meq/L with an average value 260.04 meq/L. High concentration of sodium in water or soil is detrimental to plants. The toxicity level in plants and trees are leaf burn and dead tissue along the edges of leaves. The adverse effect of sodium to on the soil is a function of the ratio of sodium to the total cations in the irrigation water. The concentration of sodium 0.40 meq/L to 160.00 meq/L with a mean value of 60.50 meq/L. Chloride is the most common toxicity in water used for irrigation purposes. It is neither adsorbed nor held back by soils, rather it moves readily with the soil-water and gets adsorbed by crops and accumulates in the leaves (Amadi *et al.*, 2014b; Nikolaidis *et al.*, 2008). High intake of chloride in plants develops symptoms such as leave burn and drying of tissues. The concentration of chloride in the area ranged from 10.02 meq/L to 485.05 meq/L with a mean value of 170.60 meq/L. Sulphate is an essential element in plant nutrition. It is however believed that high sulphate content in water can enhance the salinity of the soil solution. The sulphate 1.00 meq/L to 250.00 meq/L and an average value of 89.50 meq/L (Table 1).

Richards (1954) classified the concentration of soluble salt in irrigation water (salinity hazard) into four classes on the basis of electrical conductivity, EC and SAR (sodium hazard). The different classes of salinity hazard include low, C1 (EC < 250μS/cm); medium, C2 (EC 250 – 750μS/cm); high, C3 (EC 750 -2250μS/cm); and very high, C4 (EC > 2250μS/cm). The sodium hazard classes include: low, SI (SAR < 10); medium, S2 (SAR 10 -18); high, S3 (SAR 18 – 26); and very high, S4 (SAR > 26). Water with high EC leads to formation of saline soil, a high Na^+ leads to development of an alkaline soil (Ayers and Westcot, 1994).

The Na or alkaline hazard in the use of water for irrigation is determined by absolute and relative concentrations of cations. If water used in irrigation is high in Na^+ and low in Ca^{2+}, the cation exchange complex may become saturated with Na. This can destroy the soil structure owing to dispersion of clay particles. The calculated SAR (Table 1) for the waters ranges from 0.01 – 8.45 meq/L with a mean value of 1.52 meq/L. The data show that the samples fall between S1, indicating low salinity and low Na water for irrigation purposes for most soils and crops with no danger of development of exchange Na and salinity (Fig. 2). This implies that the water from the study area is good for irrigation. Also, according to Johnson (1975), SAR values below 10 meq/L is good for irrigation. High SAR values (>10) could cause sodium to replace adsorbed calcium or magnesium, thereby damaging the soil structure.

When the concentration of sodium is high in irrigation water, sodium ions tend to be absorbed by clay particles, displacing magnesium and calcium ions. The exchange process of sodium in water for magnesium and calcium in soil reduces permeability and eventually results in soil with poor drainage. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (Amadi *et al.*, 2012b; Olasehinde *et al.*, 2015).

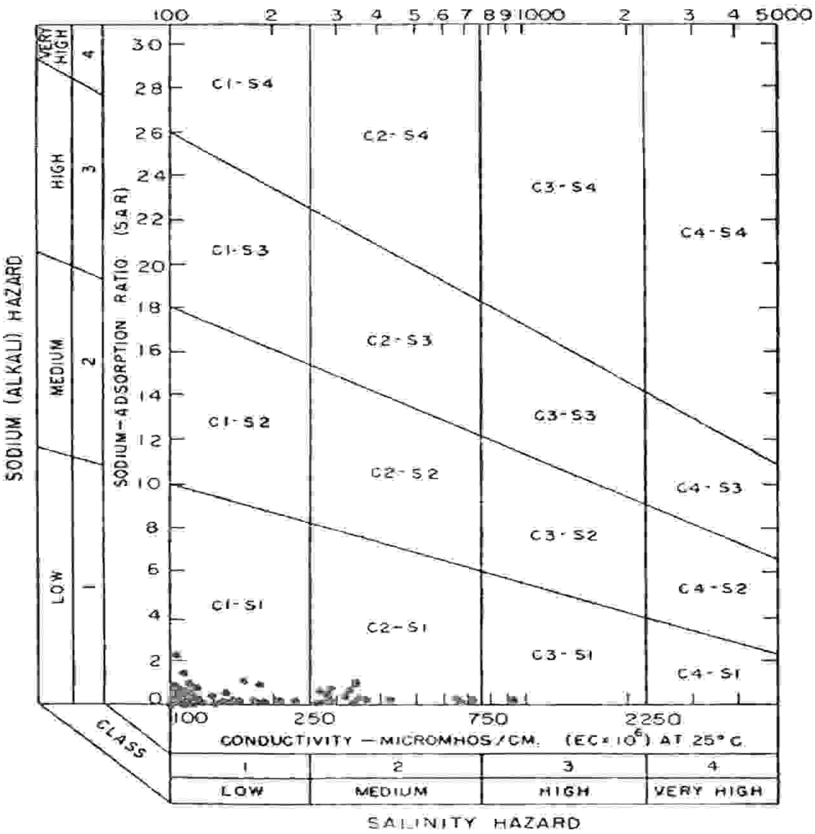

Fig. 2: The U.S Salinity diagram for the Study Area

Table 1: Descriptive Statistics of Irrigation Quality Parameters

Parameters	Minimum	Maximum	Mean
SAR	0.01	8.45	1.52
SSP	4.64	28.08	12.38
PI	9.22	43.75	34.49
RSC	1.05	2.25	1.31
MAR	34.34	62.61	38.54
KR	0.04	0.36	0.12
Conductivity	20.05	820.10	260.04
TDS	10.20	568.50	245.20
pH	3.80	7.80	5.65
Sulphate	1.00	250.00	89.50
Sodium	0.40	160.00	60.50
Chloride	10.02	485.05	170.60

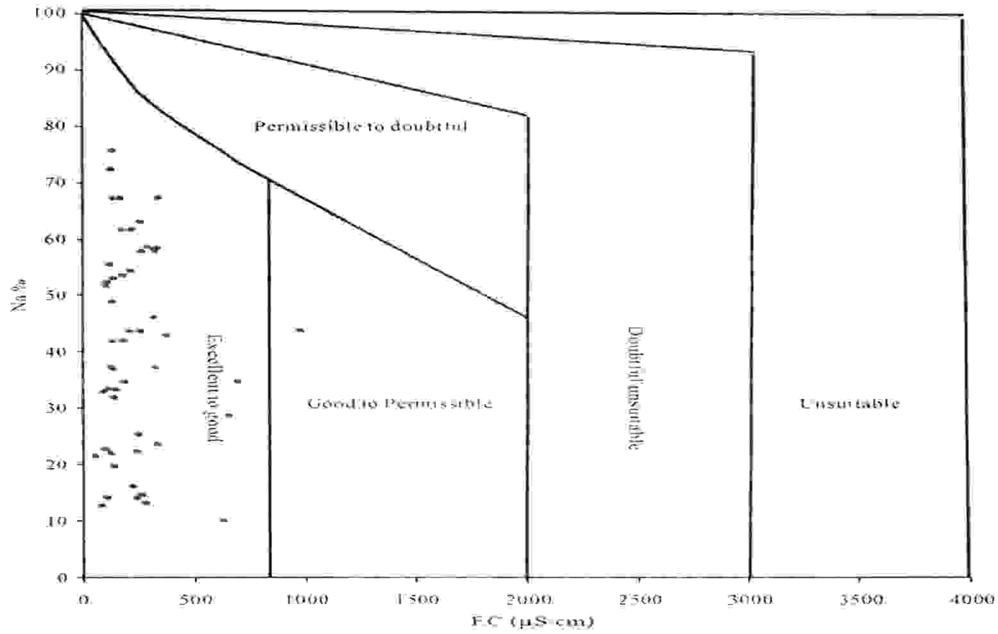

Fig. 3: Wilcox Permeability Diagram for the Study Area

The value of SSP varied from 4.64 – 28.08 meq/L with an average value of 12.38 meq/L (Fig. 3) while that of PI is of the order of 9.22 – 43.75 meq/L and a mean value of 34.49 meq/L (Table 1). The value of RSC ranged from 1.05 – 2.25 meq/L with a mean value of 1.31 meq/L while the value of MAR varied from 34.34 – 62.61 meq/L with an average value of 38.54 meq/L (Table 1). The value of KR is of the order of 0.04 – 0.36 meq/L with a mean value of 0.12 meq/L. These recalculated irrigation quality index were found to be within the permissible limit for water meant for irrigation activity.

1.0.Conclusions

The quality of groundwater in Eastern Niger Delta, Nigeria has been assessed for irrigational purposes in this study. The electrical conductivity values and the total dissolved solids values of the groundwater samples were within the acceptable limit for water intended to be used for irrigation. Based on the quality parameters analyzed (SAR, SSP, MAR, RSBC, PI and KR), the suitability of groundwater samples for irrigation is in the area is very good. The plots on the salinity and permeability charts also confirm the suitability of the groundwater for irrigation.

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