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Assessment of Ground Water Quality for Multipurpose Use in Parts of Andoni Rivers State Nigeria

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ABSTRACT

The quality and suitability of ground water in parts of Andoni Local Government Area were assessed for portability and irrigation purposes by analyzing the water for physico-chemical parameters, Heavy metals (Mg, Mn, Fe and Pb), microbial contents and irrigation indices using standard methods. The results obtained were compared with permissible limits for drinking water provided by World Health Organization, Standard Organization of Nigeria and National Agency for Food and Drugs Administration and Control. The results in the groundwater were <0.001 – 7.5mg/l Mg^{2+}, <0.001 – 0.0053mg/l Mn^{2+}, <0.001 mg/l Fe, and <0.001mg/l Pb, 4.6 – 7.4 pH, 20.6 – 72.5µS/cm EC, 0.03 – 2.63NTU Turbidity, 0.01 – 0.12‰ Salinity, 26.0 – 29.3°C Temperature, 12.7 – 169mg/l TDS, 5.7 – 7.3mg/l DO, 0.8 – 18.3mg/l BOD, <1.0 – 12.2mg/l SO_4^{2-}, <0.05mg/l PO_4^{3-}, <0.02mg/l NH_4^+, 3.0 – 21.7mg/l Cl^-, <0.01 – 68.97mg/l Hardness, 4.0 – 24.0mg/l Alkalinity, <0.001 – 15.3mg/l Ca^{2+}, <0.02 – 0.13mg/l THC, 2.864 – 42.392mg/l Na^{2+}, 3.999 – 23.939mg/l HCO_3^-, $2.99x10^{-5}$ – $5.65x10^{-2}$mg/l CO_3^{2-}, 2.054 – 5.245mg/l K^+. The pH of the groundwater in four of the five stations is acidic and not good for drinking and domestic purposes. Bacteriological contents of the ground were high and therefore pose serious concerns. The irrigation indices showed Soluble Sodium Percent values >50% and Kelly's ratio values >1meq/l at Asarama groundwater which is considered unsuitable for irrigation. The groundwater in the area should be regularly monitored to avoid serious pollution problems especially water borne diseases in the area.

KEYWORDS Water Quality, Andoni, Groundwater, Irrigation indices

INTRODUCTION

Water is considered absolutely essential to sustain life (Hiremath *et al* 2011). It is increasingly recognized that the provision of good quality water is central to any meaningful human development (Ahmed *et al*, 2003). People can survive days, weeks or even longer without food, but only about few days without water. Water is one of the essential commodities of everyday life and is placed in position just after air. Although it is nature's abundant gift but most of it is present in Oceans (97%) and in the icebergs in the Polar Regions (2%) which are of no use for utilization and the remaining (1%) of the earth's water, which is available in lakes, Rivers and underground for utilization. This available water found in nature is never H_2O alone. (DILIP and Nagarnalk, 2011).

This available water is contaminated day by day due to different anthropogenic sources (human activities). These pollutions are mainly due to rising standard of living, expansion of agriculture and increase in population, which indicate the large demand of water for domestic purpose. The ill heath in the developing and under-developing countries is mainly due to lack of quality drinking water. (DILIP and Nagaraik (2011).

Drinking water is never pure. Water naturally contains minerals and microorganisms from the rocks, soil and air with which it comes in contact. Human activities can add many more substances to water, but drinking water does not need to be pure to be safe. In fact, some dissolved minerals in water can be beneficial to health. (DILIP and Nagaraik (2011). The National Research Council (National Academy of Science) states that drinking water containing dissolved calcium and magnesium generally contributes a small amount of calcium and magnesium human dietary needs.

Majority of the population in developing countries are not adequately supplied with potable water and are thereby compelled to use water from sources like shallow wells, streams and boreholes that render the water unsafe for domestic and drinking purposes due to high possibilities of contamination (WHO, 2006 and 2011). In 1997, World Health Organization (WHO) reported that Forty percent (40%) of deaths in developing nations occur due to infections from water related diseases (Olutona *et al,* 2012). Diseases contacted through drinking water kill about 5 million children annually and make one – sixth of the world population (WHO, 2004) and an estimated 500 million cases of diarrhorea occur every year in children below 5 years in parts of Asia, African and Latin American (WHO, 2011). The chemical compositions of groundwater are influenced by many factors which include precipitation, mineralogy of water shed, aquifer, climate and topography.

For decades, the people depend solely on ground and surface waters for drinking, domestic and fishing activities. There has been recent out break of cholera, skin and other water-borne diseases in the Andoni area of Rivers State. The objective of this study is to determine the levels of heavy metals (Mg, Pb, Mn, Fe), physicochemical parameters and bacteriological content in Ground water around the study area and its suitability for irrigation.

MATERIALS AND METHODS

STUDY AREA

The study area is located in Andoni local government area of Rivers State. Andoni lies between latitude 4° 32′ 57″ N and longitude 7° 26′ 47″ E, with total land area of 233km^2 and a population of 211,009 million people (Census, 2006). Andoni is bounded by the Altantic Ocean in the South, the Ogonis in the North, Bonny in the West, and Akwa-Ibom State in the East (Fig.1).

It is characteristically bordered by vegetation comprising 98% Nipa palm and Red mangrove. The climate of the zone is basically that of tropical monsoon with rainfall occurring almost all through the year except the months of December, January and February, which are not completely free from rainfall in some years. (Calmano and Forstner 1996). The zone experiences diurnal ebb and flow of the tides with maximum values obtained during the once a year spring tide (Calmano and Forstner 1996).

SAMPLING SITE SELECTION AND LOCATION

The sampling site was selected based on representative of

most used ground water. Groundwater samples were collected from five stations. The identification and geographical positioning system (GPS) are shown in Table 2.

Table 2: Geographical Location of the Sampling Stations.

Station No.	Station Name	Sample Type	Geographical locations	
			East (longitude)	North (latitude)
1	ASARAMA –IJA	Groundwater	007° 26′ 887″	04° 33′ 228″
2	IWOMA	Groundwater	007° 26′ 893″	04° 33′ 283″
3	IN-YONG-ORONG	Groundwater	007° 27′ 365″	04° 33′ 694″
4	ASARAMA TOWN	Groundwater	007° 27′ 034″	04° 31′ 831″
5	EBUKUMA	Groundwater	007° 28′ 368″	04° 30′ 279″

The water samples were properly labeled and taken to the laboratory in a cool box containing ice block.

SAMPLE COLLECTION AND PREPARATION

The water samples were collected into 1.5 litre plastic containers. Samples for total hydrocarbon (THC) were collected into THC bottles while samples for Heavy metals and microbiology were collected into sterile vials. The containers were rinsed thoroughly with the sample twice before sample collection.

ANALYTICAL METHODS

Physico-Chemical Parameters and Heavy Metals

Winkler solutions I and II were added to the water samples *insitu* for Dissolved oxygen (DO) and kept under laboratory condition at 30°C. Conductivity and salinity were determined using Horiba water checker U-10. Turbidity was determined using LaMotte TC 3000wi, Trimeter 1969 – ISO while Extech Dissolved Oxygen meter (Water proof series) DO 700 was used to determined pH and Total Dissolved solids (TDS).

The chemical analysis was done using standard laboratory methods suggested by the American Public Health Association (APHA, 1995). Nitrate was determined using the Brucine method, Sulphate was determined by the Turbidimetric method, Phosphate was determined using the stannous chloride method, Chloride was determined by the Argentometric methods, Total Alkalinity was determined by Acid-Base Titration method, Dissolved Oxygen and BOD_5 was determined by the modified Azide or Winkler methods, Calcium was determined by the EDTA Titration method and Ammonia was determined by the phenate method. Heavy metals (Fe, Pb, Mg, and Mn) were analyzed using Atomic Absorption Spectrophotometer (AAS) by GBC Avanta Version 2.02.

MICROBIOLOGICAL ANALYSIS

Heterotrophic plate count was performed using the pour plate method. Serial ten-fold dilutions of the samples were prepared using sterile normal saline as diluents. Nine milliliters of normal saline was dispensed into each tube and sterilized using autoclave. After cooling, one milliliter of the water sample was transferred with the aid of a sterile pipette into nine milliliters normal saline to obtain 10^{-1} dilution. This was well mixed manually using the same sterile pipette; 1ml of the mixture (10^{-1} dilution) was transferred into the second tube (10^{-2} dilution). The same procedure was repeated until 10^{-7} dilution was prepared.

An aliquot (0.1) of the suitable dilution 10^{-4} to 10^{-7} was aseptically transferred into sterile Petri dish and cooled sterile nutrient agar was added. The mixture was allowed to solidify and then incubated at 37°C for 48h. Bacterial colonies on each plate was counted and multiplied by the reciprocal of the appropriate dilution.

IRRIGATION INDICES

(a) Sodium Adsorption Ratio (SAR) was calculated by the equation given below (Richards 1954)

$$SAR = \left[Na^{+}\right] / \left\{ \left(\left[Ca^{2+}\right] + \left[Mg^{2+}\right] \right) / 2 \right\}^{\frac{1}{2}}$$

Where, all the ions are expressed in meq/L.

(b) Soluble sodium percentage (SSP) was calculated by the equation of (Todd, 1980):

$$SSP = \left[Na^{+} / \left(Ca^{2+} + Mg^{2+} Na^{+}\right)\right] \times 100$$

Where, all the concentration of Ca^{+2} + Mg^{+2} + Na^{+} are expressed in meq/L.

(C) The Residual Sodium Bicarbonate (RSBC) was calculated according to Gupta and Gupta (1987).

$$RSBC = HCO_3^{-} - Ca^{2+}$$

Where, all RSBC and the concentration of the constituents are expressed in meq/L.

(d) The Permeability Index (PI) was calculated according to the equation given by Doneen (1962).

$$PI = \frac{\left(Na^{+} + \sqrt{HCO_3^{-}}\right) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$$

Where, all the ions are expressed in meq/L.

(e) Magnesium Adsorption Ratio (MAR) was calculated by the equation given by Raghunath (1987).

$$MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}}$$

Where, all the ionic concentrations are expressed in meq/L.

(f) The Kelly's Ratio was calculated using the equation by Kelly (1963)

$$KR = Na^{+} / Ca^{2+} + Mg^{2+}$$

Where, all the ionic concentrations are expressed in meq/L.

RESULTS AND DISCUSSIONS

The results of the levels of the parameters measured in groundwater in the area are presented in Table 3 and Figs 2a-i. Correlation matrixes showing the relationship between the parameters are presented in Table 7.

pH

The pH of groundwater from the study area are slightly acidic at station 2 (Iwoma) 5.4, station 3 (Inyong-Orong) 4.6, station 4 (Asarama) 5.2 and station 5 (Ebukuma) 5.3 with a mean value of 5.58±1.06 which is below the permissible limit (6.5-8.5) by WHO, SON and NAFDAC However, station 1 (Asarama-Ija) pH value is within the limit (Table 3).

pH is an important parameter for determining the quality of drinking water. It indicates the balance between the acids and bases in water and is a measure of the hydrogen ion concentration in solution. As an index of hydrogen ion concentration, a value of 7 indicate a neutral condition; values less than 7 indicate acid condition and values greater than 7 indicates alkaline conditions in water. Surface water generally tends to be alkaline, whereas groundwaters are acidic. (McNeely *et. al.,* 1979). Therefore, the pH of the groundwater at Stations 2, 3,

4, and 5 are acidic and not good for drinking and domestic purposes.

The correlation matrix for groundwater (Table 7) shows that high significant but negative correlation exist between pH and RSBC (r = - 0.9569), and high significant correlation between pH and EC (r = 0.9399), turbidity (0.8304), salinity (r = 0.9562), temperature (r = 0.6227), TDS (r = 0.9400), BOD (r = 0.7227), SO_4^{2-} (r = 0.9562), chloride (r = 0.9472), hardness (r = 0.9549), alkalinity (r = 0.8997), Ca^{2+} (r = 0.9557), Mg^{2+} (r = 0.9543), HCO_3^- (r = 0.8994) and CO_3^{2-} (r = 0.9567).

Table 3: Levels of Physico-chemical parameters in Groundwater Samples from the Study Area

Stations	pH	EC µS/cm	Tub NTU	Sal ‰	Temp °C	TDS mg/l	DO mg/l	BOD mg/l	SO_4^{2-} mg/l	PO_4^{3-} mg/l	NO_3^- mg/l	NH_3^- mg/l	Cl mg/l	TH mg/l	T.Alk mg/l	Ca^{2+} mg/l
ASARAMA-IJA	7.6	254	2.63	0.12	29.3	169	7.3	18.3	23.2	<0.05	<0.05	<0.05	21.7	68.0	24	15.3
IWOMA	5.4	21.8	0.05	0.01	28.5	13.6	5.7	13.7	<1.0	<0.05	<0.05	<0.05	4.0	5.01	8	<0.05
INYONG-ORONG	6.6	34.8	0.09	0.01	27.8	22.2	7.3	8.8	<1.0	<0.05	<0.05	<0.05	4.0	5.01	8	<0.05
ASARAMA	5.2	31.5	1.47	0.01	28.9	19.9	5.7	12	<1.0	<0.05	<0.05	<0.05	5.0	7.66	6	1.5
EBUKUMA	5.1	20.4	0.05	0.01	28.9	12.7	6.5	15.2	<1.0	<0.05	<0.05	<0.05	3.0	5.01	4	<0.05
MINIMUM	4.6	20.4	0.05	0.01	26.9	12.7	5.7	8.8	<1.0	<0.05	<0.05	<0.05	3.0	7.66	4	1.5
MAXIMUM	7.6	254	2.63	0.12	29.3	169	7.3	18.3	23.2	<0.05	<0.05	<0.05	21.7	68.0	24	15.3
AVERAGE	5.6	72.3	0.85	0.05	27.9	17.5	6.3	9.8	5.0	<0.05	<0.05	<0.05	7.14	12.3	9.6	2.36
WHO	6.5-8.5	1200	5.0	-	-	1000	-	-	400	-	50	-	250	500	100	-
SON	6.5-8.5	1000	5.0	-	-	500	-	-	200	-	10	-	100	100	100	75
NAFDAC	6.5-8.5	1000	5.0	-	-	500	-	-	100	-	10	-	100	100	100	75

Stations	Mg^{2+} mg/l	THC mg/l	Mn^{2+} mg/l	Fe^{+} mg/l	Na^{+} mg/l	HCO_3^- mg/l	CO_3^{2-} mg/l	K^{+} mg/l	Pb^{2+} mg/l
ASARAMA-IJA	7.5	<0.02	0.053	<0.001	18.873	23. 939	0.0565	3.183	<0.001
IWOMA	<0.001	0.13	0.041	<0.001	2.864	7.999	$1.88x10^{-4}$	2.054	<0.001
INYONG-ORONG	<0.001	<0.02	0.044	<0.001	4.942	7.999	$2.99x10^{-3}$	2.242	<0.001
ASARAMA	0.9	0.01	0.038	<0.001	12.773	3.999	$5.94x10^{-3}$	2.956	<0.001
EBUKUMA	<0.001	<0.02	<0.001	<0.001	42.392	3.999	$7.48x10^{-5}$	5.245	<0.001
MINIMUM	<0.001	<0.02	<0.001	<0.001	2.864	3.999	$2.99x10^{-5}$	2.054	<0.001
MAXIMUM	0.9	0.13	0.053	<0.001	42.392	23. 939	0.0565	5.245	<0.001
AVERAGE	1.6	0.03	0.035	<0.001	16.368	9.587	0.01137	3.136	<0.001
WHO	20	-	0.4	0.3	200	100	-	10.0	0.01
SON	0.20	-	0.05	0.3	200	-	-	10.0	0.01
NAFDAC	20	-	2.0	0.3	-	-	-	-	0.01

Table 4: Bacteriological Content of Groundwater

Stations	THB (cfu/ml)	TCB (MPN/100ml)	FCB (MPN/100ml)
ASARAMA-IJA	$5.0x10^3$	7	ND
IWOMA	$14.0x10^4$	11	ND
INYONG-ORONG	$2.7x10^2$	ND	ND
ASARAMA	$0.7x10^1$	ND	ND
EBUKUMA	$1.8x10^3$	4	ND
MINIMUM	$0.7x10^1$	4	
MAXIMUM	$14.0x10^4$	11	
AVERAGE	29415.4	7.3	
WHO	<1000	0-10	0

ND: Not Detected

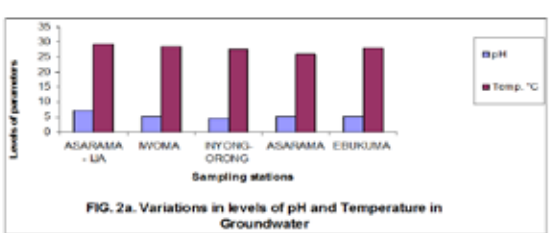


FIG. 2a. Variations in levels of pH and Temperature in Groundwater

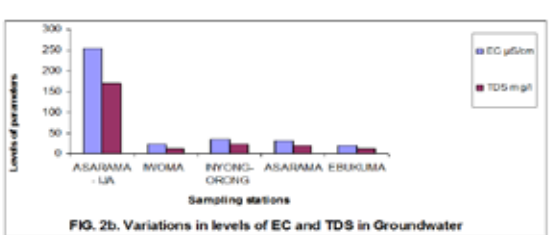


FIG. 2b. Variations in levels of EC and TDS in Groundwater

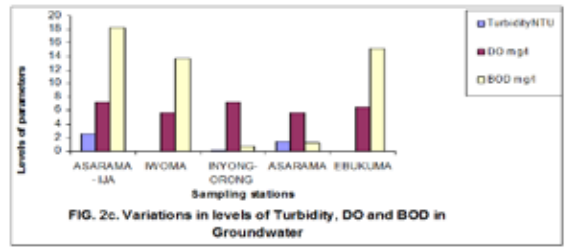


FIG. 2c. Variations in levels of Turbidity, DO and BOD in Groundwater

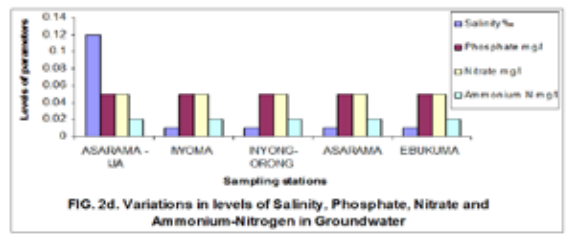


FIG. 2d. Variations in levels of Salinity, Phosphate, Nitrate and Ammonium-Nitrogen in Groundwater

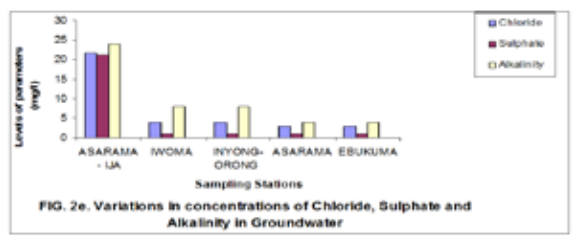


FIG. 2e. Variations in concentrations of Chloride, Sulphate and Alkalinity in Groundwater

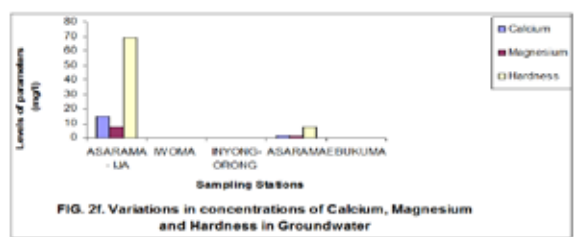


FIG. 2f. Variations in concentrations of Calcium, Magnesium and Hardness in Groundwater

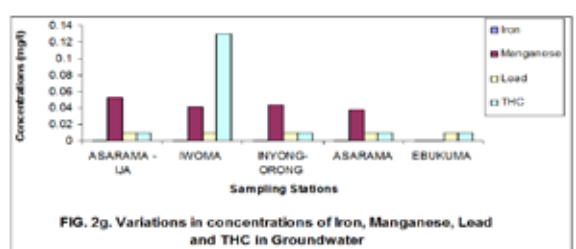


FIG. 2g. Variations in concentrations of Iron, Manganese, Lead and THC in Groundwater

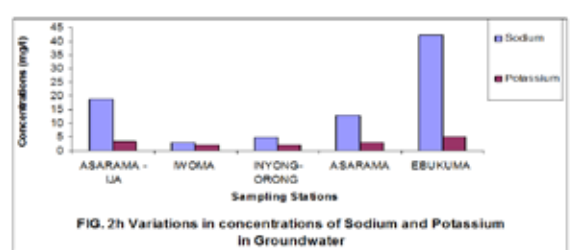


FIG. 2h Variations in concentrations of Sodium and Potassium in Groundwater

ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity is the ability of an object to conduct electric current. It gives the total concentration of the electrolytes; it depends upon the presence of various ionic species. The electrical conductivity of groundwater in this study ranged from 20.6µS/cm at Ebukuma to 254µS/cm at Asarama-ija with a mean of 72.54±101.62. These indicate high content of mineral salts in the water.

Electrical conductivity increase with increase in chloride, Hardness, calcium, magnesium and total dissolved solids. Table 7 shows high significant correlation in groundwater between EC and turbidity (r = 0.8634), salinity (r = 0.9918), temperature (r = 0.6055), TDS (r = 0.9999), SO_4^{2-} (r = 0.9981), Cl^- (r = 0.9969), hardness (r = 0.9948), alkalinity (r = 0.9714), Ca^{2+} (r = 0.9958), Mg^{2+} (r = 0.9940), HCO_3^- (r = 0.99712) and CO_3^{2-} (r = 0.9980). Significant but negative correlation also exist between EC and RSBC (r = - 0.9984).

TURBIDITY

Turbidity of groundwater ranged from 0.03 NTU at Ebukuma to 2.63 NTU at Asarama-ija with a mean of 0.854±1.166. The Turbidity levels were below 5.0 NTU permissible limits recommended by WHO, SON and NAFDAC. Turbidity is a measure of the suspended particles such as silt, clay, organic matter, plankton and microscopic organisms in water which are usually held in suspension by turbulent flow and Brownian movement. (McNeely *et al;* 1979).

Correlation matrix (Table 7) shows high significant correlation between Turbidity and Salinity (r = 0.8511), TDS (r = 0.8630), SO_4^{2-} (r = 0.8511), Cl^- (r = 0.9074), Hardness (r = 0.9036), Alkalinity (r = 0.7557), Ca^{2+} (r = 0.8979), Mg^{2+} (r = 0.9074), HCO_3^- (r = 0.7553), CO_3^{2-} (r = 0.8507), SAR (r = 0.7108), SSP (r = 0.7010), MAR (r = 0.9097), PI (r = 0.7645). High but negative significant correlation exist between Turbidity and RSBC (r = - 0.8637).

SALINITY

The salinity values in groundwater ranged between 0.01‰ at station 2, 3, 4 and 5 and 0.12‰ at station 1 with a mean value of 0.032 ± 0.049‰. The EC of water is a useful and easy indicator of its salinity or total content. The salinity values are less than 1000mg/L set by the World Health Organization (WHO, 1979). This implies that the water is within limit.

The groundwater salinity has high significant but negative correlation with RSBC (r = - 0.9996) and also high significant correlation exist between salinity and temperature (r = 0.6326), TDS (r = 0.9982), Cl^- (r = 0.9981), Hardness (r = 0.9939), Alkalinity (r = 0.9704), Ca^{2+} (r = 0.9953), Mg^{2+} (r = 0.9929), HCO_3^- (r = 0.9703), CO_3^{2-} (r = 0.9999) and SO_4^{2-} (r = 1).

TEMPERATURE

The Temperature of Groundwater in the area ranged from 26.0ºC at Asarama Town to 29.3ºC at Asarama-ija with a mean of 27.9 ± 1.2. Groundwater Temperature tends to exhibit low but more than 25ºC either in a given location or from place to place in agreement with the report of McNeely *et al;* (1979). Public Drinking waters should be of a Temperature that is refreshing to the consumer.

Table 7 shows that high significant but negative correlation exist between Temperature and KR (r = - 0.8015), RSBC (r = - 6141), and high significant correlation exist with TDS (r = 0.6062), BOD (r = 0.7965), Alkalinity (r = 0.7276), SO_4^{2-} (r = 0.6326), Cl^- (r = 0.6603), HCO_3^- (r = 0.7278), CO_3^{2-} (r = 0.6335).

TOTAL DISSOLVED SOLID (TDS)

The Total Dissolved Solids in Groundwater ranged between 12.7mg/l at Ebukuma and 169mg/l at Asarama-ija with a mean value of 47.48±68.05. All the samples were within the permissible limit prescribed by WHO (2006), SON (2007) and NAFDAC (2001). Total Dissolved solids (TDS) are index of the amount of dissolved substances in the water (McNeely *et al;* 1979). In natural water dissolved solids are composed of carbonates, bicarbonates, chlorides, sodium, sulphate magnesium and phosphate. Concentrations of dissolved solids are important parameter in drinking water. The total dissolved solids (TDS) indicate the general nature of salinity of water (Aher and Deshpande, 2011).

TDS showed high significant but negative correlation with RSBC (r = - 0.9985) and TDS also showed high significant correlation with SO_4^{2-} (r = 0.9982), Cl^- (r = 0.9970), Hardness (r = 0.9947), Alkalinity (r = 0.9716), Ca^{2+} (r = 0.9958), Mg^{2+} (r = 0.9939), HCO_3^- (r = 0.9714) and CO_3^{2-} (r = 0.9981).

DISSOLVED OXYGEN (DO)

The DO in groundwater ranged from 5.7mg/l at Iwoma and Asarama Town to 7.3mg/l at Asarama-ija and Inyong-Orong with a mean value of 6.5±0.8. Oxygen is one of the gases that are found dissolved in natural surface water. The amount of dissolved oxygen in natural water varies since it is dependent upon temperature, salinity, turbulence (mixing) of the water and atmospheric pressure (decreasing with altitude). Dissolved oxygen concentrations produce no adverse physiological effect on man; however, adequate amounts of dissolved oxygen must be available for fish and other aquatic organisms. (McNeely *et al;* 1979).

Many aerobic organisms cannot survive below certain levels of dissolved oxygen. Drinking water criteria do not specify any guidelines for dissolved oxygen. However, waters saturated with dissolved oxygen are preferable for drinking as improved palatability results from dissolved oxygen's ability to precipitate substances such as iron and manganese, which produce undesirable tastes. (McNeely *et al*; 1979).

High significant correlation exist between DO and Alkalinity (r = 0.6028) and HCO_3^- (r = 0.6028).

BIOLOGICAL OXYGEN DEMAND (BOD)

BOD values in groundwater was high in station 1 (18.3mg/l), station 5 (15.2mg/l) and station 2 (13.7mg/l) with a mean value of 9.84±8.23. Water with high BOD values may be unsuitable for irrigation purposes, since they may restrict plant growth.

The biochemical oxygen demand of water is the amount of oxygen required to oxidize the organic matter by aerobic microbial decomposition to a stable inorganic form. BOD is usually reported as the amount of oxygen consumed over a specified time period at a specified Incubation temperature. (McNeely *et al*; 1979).

No specific guidelines for BOD have been proposed by WHO, (2006) SON (2007) and NAFDAC (2001), but values in literature show that water with BOD levels less than 4mg/l are deemed reasonably clean. Waters with levels greater than 10mg/l are considered polluted since they contain large amounts of degradable organic materials (McNeely *et al;* 1979).

The value of BOD at stations 1, 2, and 5 were higher than 10mg/l and therefore, considered polluted. BOD showed high significant correlation with Mn (r = 0.9124) in the groundwater.

SULPHATE (SO_4^{2-})

Sulphate is the stable, highly oxidized form of sulphur. It can be produced by bacterial oxidation of reduced sulphur compounds, including metallic sulphides and organo-sulphur compounds; the sulphate ion is readily soluble in water. (McNeely *et al;* 1979). However, the concentrations of Sulphate in the Ground water in the study area were below the permissible limit recommended by WHO (500mg/l), NAFDAC and SON (100mg/l) with a mean value of 5.04±9.03. Sulphate showed high significant correlation with Cl^- (r = 0.9981), Hardness (r = 0.9939), Alkalinity (r = 0.9704), Ca^{2+} (r = 0.9953), Mg^{2+} (r = 0.9929), HCO_3^- (r = 0.9703), CO_3^{2-} (r = 0.9999) and high significant but negative with RSBC (r = - 0.9996) (Table 7).

PHOSPHATE (PO_4^{3-})

Generally, the permissible limit found in literature ranged between 0.05 to 1.0mg/l (Fediran *et al;* 2008). In this study phosphate level was <0.05 in all the samples. This indicates the acceptability of the water for drinking with respect to

phosphate.

Phosphate did not correlate with other parameters in the ground water.

NITRATE (NO_3^-)
The concentration of nitrate in the study area was less than 0.05mg/l. Nitrate is the principal form of combined nitrogen found in natural waters. The consumption of waters with high nitrate concentrations decreases the oxygen-carrying capacity of the blood. (McNeely *et al;* 1979).

Nitrate in the ground water showed no correlation with other parameters in this study.

AMMONIUM - NITROGEN
Ammonia is the most reduced inorganic form of nitrogen in water and it is a non-persistent, non-cumulative toxic substance and its typical low concentrations in water present non physiological detriment to man or livestock. Ammonia-nitrogen in drinking water should not exceed 0.5mg/l (Department of National Health and Welfare, 1969).

In all the stations the concentrations of ammonia was <0.02mg/l. This indicates that the water is not polluted with respect to Ammonia. Correlation matrix shows no correlation between ammonia and other parameters in this study.

CHLORIDE (Cl^-)
Chloride ions are generally present in natural waters and its presence can be attributed to dissolution of salts. The concentration of chloride in Groundwater at the study area ranged from 3.0mg/l at Asarama and Ebukuma to 21.7mg/l at Asarama-ija with a mean of 7.14±8.15.

High significant correlation exist between Cl^- and Hardness (r = 0.9881), Alkalinity (r = 0.9834), Ca^{2+} (r = 0.9900), Mg^{2+} (r = 0.9868), HCO_3^- (r = 0.9833), CO_3^{2-} (r = 0.9981) and high significant but negative correlation with RSBC (r = - 0.9969) in groundwater.

TOTAL HARDNESS (TH)
Total hardness in groundwater was not detected in stations 2, 3 and 5 while in stations 1 and 4 hardness level was 68.97mg/l and 7.66mg/l respectively with a mean value of 15.32±30.17. The hardness levels do not exceed guideline value of 500mg/l set by WHO. Total hardness showed high significant correlation with Alkalinity (r = 0.9493), Ca^{2+} (r = 0.9999), Mg^{2+} (r = 0.9999), HCO_3^- (r = 0.9490), CO_3^{2-} (r = 0.9938), MAR (r = 0.6448), and high significant RSBC (r = - 0.9969) in groundwater.

ALKALINITY
Alkalinity is a measure of the capacity of water to neutralize a strong acid. It indicates the presence of carbonates, bicarbonates, and hydroxides, and less significantly, borates, silicates, phosphates, and organic substances. It is expressed as an equivalent of calcium carbonate ($CaCO_3$). The species composition of alkalinity is affected by pH, mineral composition, temperature, and ionic strength; however, alkalinity is normally interpreted as a function of carbonates, bicarbonate, and hydroxides (McNeely *et al,* 1979).

Total Alkalinity in the study area was low, with mean value of 9.6±8.2. This is much below the standard value of 100mg/l set by WHO (2006). When water with high alkalinity is boiled over an extended time period, either a deposit may be formed or an unpleasant taste is created depending upon the chemical reaction. However, total alkalinity in this study is low and can corrode pipes and plumping.

Alkalinity showed high but negative correlation with RSBC (r = - 0.9667), and high significant correlation with Ca^{2+} (r = 0.9524), Mg^{2+} (r = 0.9470), Mn (r = 0.6150), CO_3^{2-} (r = 0.9706) and HCO_3^- (r = 1) in the groundwater.

CALCIUM (Ca^{2+})
Calcium is a major constituent of most Igneous rock, metamorphic and sedimentary rocks. The principal sources of calcium in groundwater are some members of the silicate minerals such as pyroxenes, amphiboles among igneous and metamorphic rocks, and limestone, dolomite and gypsum among sedimentary rocks.

The concentrations of calcium in groundwater was 15.3mg/l in Asarama-Ija, 1.5mg/l in Asarama Town, <0.01 in Iwoma, Inyong-Orong and Ebukuma with a mean value of 3.36±6.7.

Calcium in groundwater correlated significantly with Mg^{2+} (r = 0.9997), HCO_3^- (r = 0.9522), CO_3^{2-} (r = 0.9952) and MAR (r = 0.6347) and negatively correlated significantly RSBC (r = - 0.9973).

MAGNESIUM (Mg^{2+})
Magnesium, an alkaline-earth metal, is an abundant element and a common constituent of natural water. Natural sources clearly outweigh all cultural inputs of this constituent to the natural environment. Ferromagnesian minerals in igneous rock and dolomitic sedimentary rocks are the principal contributors of magnesium to water. (McNeely *et al;* 1979).

The magnesium values in groundwater ranged from <0.01 at Iwoma, Inyong-Orong and Ebukuma to 7.5mg/l at Asarama-ija with a mean of 1.68±3.27. Groundwater from Asarama-ija and Asarama Town was higher than the limit (0.2mg/l) by SON.

Magnesium in groundwater showed high significant correlation with HCO_3^- (r = 0.9468), CO_3^{2-} (r = 9928), MAR (r = 0.6516) and high significant but negative correlation with RSBC (r = - 0.9955). **TOTAL HYDROCARBON (THC)**

The ingestion of petroleum oils is dangerous to health; these oils cause objectionable tastes and odour at concentrations well below those that constitute health hazard. It is desirable that the oil content of drinking water do not exceed 0.2mg/l (Hart, 1974). Thus, the concentration of Total hydrocarbon in this study is less than 0.2mg/l, with a mean value of 0.034±0.054 in the groundwater indicating that the water is only contaminated with THC.

Correlation matrix shows no high significant correlation between THC and other parameters.

MANGANESE (Mn^{2+})
Manganese values in groundwater ranged from <0.001 at Ebukuma to 0.053mg/l at Asarama-ija with a mean value of 0.035±0.02. The water from the study area are within the permissible limit of (0.4mg/l) by WHO (2006) and (2.0mg/l) by NAFDAC (2001). This is an indication that the ground waters are good.

Manganese is an essential element for the nutrition of both humans and animals. A manganese deficiency may inhibit growth, disrupt the nervous system, and interfere with reproductive function. It is an essential element for plant metabolism (McNeely *et al;* 1979).

Manganese showed high significant but negative correlation with Na (r = - 0.8126), K^+ (r = - 0.8444) and significant correlation with HCO_3^- (r = 0.6154) in groundwater.

TOTAL IRON (Fe)
Iron concentrations in groundwater in all the stations were less than 0.001mg/l. The concentrations of Fe in all the ground water were below NAFDAC, SON and WHO guidelines for Iron (0.3mg/l).

In water, Iron can discolor cloths, plumbing fixtures, and cause scaling which encrusts pipes. Iron is highly objectionable for drinking water because of the stringent taste (Department of National Heath and Welfare, 1969).

Iron in groundwater did not show correlation with other parameters.

SODIUM (Na^+)
The concentrations of sodium in this study were generally low with a mean of 16.36±15.88. The levels are below the limit (200mg/l) set by SON and WHO.

Sodium showed high significant correlation with K^+ (r = 0.9971) in groundwater.

BICARBONATE (HCO_3^-)
The concentrations of bicarbonate in the study area are less than 100mg/l which is the standard set by WHO (2006). Bicarbonate combines with calcium carbonate and sulphate to form heat retarding, pipe clogging scale in boilers and in other heat exchange equipment. The source of bicarbonate ions in groundwater is from the dissolution of carbonate rocks and from carbonate species present and the pH of the water is usually 5 and 7 (Taylor, 1958).

It was observed that below pH 6, especially all dissolved carbonate species are in the form of H_2CO_3 and above 7, the ratio of CO_3^{2-} and H_2CO_3 increase (Drever, 1988). Therefore, the ground water in the study area can be regarded as free from bicarbonate pollution due to low presence of carbonate rocks and species in the area. In groundwater high significant correlation exist between HCO_3^- and CO_3^{2-}(r =0.9705), and high but negative correlation with RSBC(r = -0.9665).

The piper trilinear diagram for critical water samples is shown in Fig. 4. The cation plot in the diagram reveals that majority of critical sample falls in sodium, whereas anion plots indicate the majority of critical water samples fall in Bi-carbonate.

Four water types were identified in this study: Na - Cl (40%), Ca-Mg-Cl (20%), HCO_3^- (20%) and Na-HCO_3^- (20%). The types, Na-Ca-HCO_3^- and Ca-Cl were not recorded.

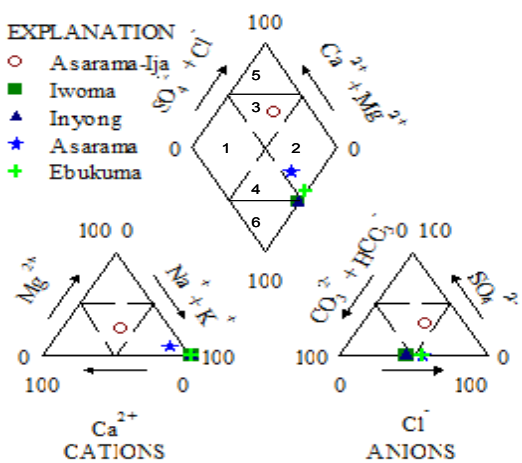


Fig. 3: Piper Trilinear Diagram Showing Chemical Character of Groundwater.

MICROBIOLOGY
Total heterotrophic bacterial in groundwater samples ranged from $2.9x10^2$ to $11.0x10^3$cfu/ml with a mean value of 6078±4421.077. Total coliform bacterial ranged from 4 to 11MPN/100ml in groundwater with no value recorded at Inyong-Orong and Asarama. Faecal coliform result for the groundwater samples had either no coliforms or very low values where present. The water in the study area contained high total heterotrophic bacteria and total coliform bacteria. The presence of these contaminations is an indication that high health risk exists for individuals exposed to the water.

POTASSIUM (K)
The concentrations of potassium in groundwater samples ranged from 2.054mg/l at Iwoma to 5.245mg/l at Ebukuma with a mean value of 3.13 ± 1.27. This is within all standards cited in literature including the value of 10.0mg/l suggested by WHO (2006) as average potassium concentration in drinking-water. This is in agreement with the previous studies by Bashir and Olalekan (2012), who stated that the mean concentration values of potassium in Yola-Jimeta metropolis was within WHO standard.

The low concentrations of potassium recorded in groundwater indicate that the water is good. Although potassium is an essential nutrient for plant and animal life, very high concentrations may be harmful to the human nervous and digestive systems.

The correlation matrix showed no significant correlation between K^+ and other parameters in groundwater.

LEAD (Pb)
Lead is the most significant toxin and if released into the environment can bioaccumulate and enter the food chain. Lead has damaging effects on body nervous system. Lead frequently used in the construction of water supply distribution systems like pipes, brass, bronze fixtures, can contaminate drinking water as a result of the corrosion that takes place when water comes in contact with it (Bakarji and Krajo, 1999).

The concentrations of lead in this study was <0.001mg/l which is below the limit value of 0.01mg/l by WHO, NAFDAC and SON.

ASSESSMENT OF WATER QUALITY FOR IRRIGATION PURPOSE
The ground water of the study area was accessed to determine the suitability for agricultural purposes. Water for this purpose is required to meet certain safety standards that have been set by either WHO or other agencies (Obiefuna and Sheriff, 2011). Water for agricultural purposes should be good for both plant and animals. Good qualities of waters for irrigation are characterized by acceptable range of the following indices: Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR), Kellys Ratio (KR), Total Dissolved Solids (TDS), Permeability Index (PI), Sodium Adsorption Ratio (SAR), and Residual Sodium Bicarbonate (RSBC).

The results of the different irrigation indices for rating irrigation water quality are presented in (Table 5).

Table 5: Different Parameter Indices for Rating Water Quality and their Suitability in Irrigation

S/No	LOCATION	SAR	SSP (%)	MAR (%)	KR (meq/L)	PI (%)	TDS (mg/L)	RSBC (meq/L)	EC (µS/cm)
1.	Asarama-Ija	0.983	37.10	44.96	0.589	65.45	169	-0.373	254
2.	Iwoma	0	0	0	0	0	13.6	0	21.8
3.	In-yong-Orong	0	0	0	0	0	22.2	0	34.8
4.	Asarama	2.025	78.72	50	3.7	115.05	19.9	-0.0094	31.5
5.	Ebukuma	0	0	0	0	0	12.7	0	20.6

SODIUM ADSORPTION RATION (SAR)
The sodium adsorption Ratio is important in evaluating the suitability of water used for agricultural irrigation. This ratio is an estimate of the degree to which sodium will be adsorbed by soil from water. The value is calculated from the ionic concentration of sodium, calcium, and magnesium.

The SAR less than or equal 10 are said to be excellent quality; 10-18 are good, 18 to 26 are fair and about 26 are said to be

unsuitable for irrigation (USDA, 1954). Sodium adsorption ratios of the water in all the stations are less than 10 indicating excellent quality of the water for irrigation (Table 5).

There are significant relationships between SAR values of irrigation water and the extent to which sodium is absorbed by soil. If the water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium (Tatawat and Singh, 2007). The groundwater correlation matrix showed high significant correlation between SAR and KR (r = 0.9453), SSP (r = 0.9999), MAR (r = 0.9386), PI (r = 0.9968).

KELLEY'S RATIO (KR)
A Kelley's Ratio of more than one (1meq/l) indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation (Aher and Deshpande, 2011). The values of Kelley's Ratio in all the stations except Asarama were less than 1 and are suitable for irrigation. The value of KR in groundwater at Asarama (3.7meq/l) is greater than 1meq/l indicating excess level of sodium in the water and may not be suitable for irrigation purposes.

The KR values showed high significant correlation with SSP (r = 0.9497), MAR (r = 0.7749), PI (r = 0.9164).

SOLUBLE SODIUM PERCENTAGE (SSP)
The soluble sodium percentage values less than 50% or equal to 50% indicates good quality water and if it is more than 50% indicates unsuitable water quality for irrigation (Aher and Deshpande, 2011). The soluble sodium percentage values for all stations except station 4 (Asarama Town) were less than 50% and indicate good quality water in agreement with previous studies by Aher and Deshpande, 2011. Station 4 (Asarama Town) groundwater had SSP (78.72%) higher than 50%. This is an indication that the groundwater at Asarama Town is unsuitable for irrigation purpose. High percentage sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability (Joshi *et al*, 2009).

The SSP values showed high significant correlation with MAR (r = 0.9337) and PI (r = 0.9956). **MAGNESIUM ADSORPTION RATIO (MAR)**

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. High magnesium in water will adversely affect crop yields as the soil becomes more saline (Joshi *et al*, 2009).

The values of magnesium adsorption ratio of groundwater in this study varies from 0 to 50% with a mean of 47.5% indicating that they are within the acceptable limit of 50%. The waters are therefore considered suitable for irrigation. This is because low magnesium levels are more or less beneficial for crop growth and soil properties.

The MAR values in groundwater showed high significant correlation with PI (r = 0.9630).

RESIDUAL SODIUM BICARBONATE (RSBC)
The residual sodium bicarbonate values of the ground water samples from the study area was less than 3.0 meq/L and are therefore considered safe for irrigation purposes. This is in agreement with the studies by Talabi *et al* (2013).

The concentration of bicarbonate and carbonate in water influences the suitability of water for irrigation purpose. The water with high RSBC has high pH. Therefore, land irrigation with such water makes the land infertile owing to deposition of sodium carbonate (Eaton, 1950).

PERMEABILITY INDEX (PI)
The soil permeability is affected by long – term use of irrigation water and the influencing constituents are the total dissolved solids, sodium bicarbonate and the soil type. In this study the permeability index values of groundwater ranged from 0 at Iwoma, Inyong-Orong and Ebukuma to 115.05% at Asarama. This shows that groundwater at Asarama-Ija and Asarama falls within class III and unsuitable for irrigation.

TOTAL DISSOLVED SOLID (TDS)
Salts of calcium, magnesium, sodium, potassium present in irrigation water may prove to be injurious to plants. When present in excessive quantities, they reduce the Osmotic activities of the plants and may prevent adequate aeration Obiefuna and Sheriff (2010).

The TDS value of groundwater in the study area ranged from 12.7mg/l to 169mg/l with a mean value of 47.48 ± 68.05. The values are less than 1000mg/l and can be classified as excellent irrigation water in agreement with previous work by Robinove *et al* (1958).

CONCLUSIONS AND RECOMMENDATION
The findings in this study showed that groundwater in the area are acidic (pH 4.6-5.4) except at Asarama-ija. The microbiological contents were high.

Surface water in the study area showed high concentrations of EC, TDS, SO_4^{2-}, Cl^-, Total Hardness, Ca^{2+}, K^+, Mg^{2+} and turbidity at stations 1,2 and 3 exceeded their permissible limits and thus considered to be contaminated and highly mineralized. The contamination of the water can lead to contamination of aquatic lives on which the inhabitants depend. It is therefore concluded that the water in the area is not portable.

The values of irrigation indices showed that the water in the area is suitable for irrigation except the groundwater at Asarama.

This study is presumed the first of its kind in the study area and has provided baseline data and will create awareness in the area.

RECOMMENDATION
Based on the findings of this study, it is recommended that the pH of the groundwater should be raised and the ground water in the area should be monitored regularly to avoid serious pollution problems (epidemics) especially water borne diseases in the area.

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