

Hydrogeochemical Assessment of Groundwater Quality in Parts of the Niger Delta, Nigeria

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ABSTRACT / Detailed hydrogeochemical analysis of several samples of groundwater collected from parts of the Niger Delta, Nigeria has been carried out in an effort to assess the quality of groundwater in the area. Results obtained showed the groundwater in the area to be enriched in Na^+ , Ca^{++} , Mg^{++} , Cl^- , HCO_3^- , and SO_4^{--} . The concentration of these ions as well as such parameters as salinity, total hardness, and TDS are below the World Health Organization (WHO) standards for drinking water. The concentration of Ca^{++} was found to be higher than Mg^{++} except in some areas very close to the coast suggesting the encroachment of saltwater.

This encroachment of saltwater is further indicated by the general increase in Cl^- and a decreased in HCO_3^- content towards the coast and Na/Cl ratios. On the basis of the present hydrogeochemical studies, five groundwater types have been recognized to occur in the area of study. These are (1) Sodium-Calcium-Magnesium-Bicarbonate type (Na-Ca-Mg-5HCO_3), (2) Iron-Calcium-Bicarbonate type (Fe-Ca-4HCO_3), (3) Sodium-Calcium-Magnesium-Sulfate type ($\text{Na-Ca-Mg-}\frac{5}{2}\text{SO}_4$), (4) Iron-Chloride-Bicarbonate (Fe-Cl-HCO_3), and (5) Magnesium-Chloride type (Mg-2Cl). The assemblage of groundwater types in the area shows that both compound and single groundwater types occur. The geochemical characteristics of the groundwaters are thought to be closely related to the peculiar geologic and hydrologic conditions that prevail in the Niger Delta area of Nigeria.

Introduction

The usefulness of groundwater to humans to a great extent depends on its chemistry and based mainly on this chemistry, several bodies have set various standards for water usage (Public Health Service 1962; WHO 1963; Nigerian Standards 1971). The chemistry of groundwater is determined by such hydrologic, climatic, and hydrogeological factors as, the type of aquifer, the mode and source of recharge, the drainage area, and the permeability of the soil cover. Most of these factors have been assessed in the Niger Delta (NEDECO 1961; BRGM 1979; Ceffa and others 1983). Numerous boreholes have been drilled and developed in the area with little attention paid to the geochemical characteristics of the groundwater and its suitability for various purposes. Such information when available is often scanty, doubtful, and therefore unreliable hence making the systematic determination of the quality of groundwater in the Niger Delta difficult.

The present article represents an attempt aimed at the systematic evaluation of the groundwater types in parts of the Niger Delta, Nigeria (Figs. 1 and 2) and their suitability for domestic use. The area covered lies between latitudes $4^{\circ}37'$ and $5^{\circ}08'N$ and longitudes $6^{\circ}00'$ and $6^{\circ}50'E$ and represents one of the areas where freshwater and seawater constantly come in contact with each other.

This constant mixing implies that during both the dry season and the rainy season, the region is drained

by several groundwater types resulting from water mixing. In the present study, only hand-dug wells have been considered and all samples can therefore be ascribed to the same aquifer horizon.

Geology and Hydrology of the Niger Delta

The geology of the Niger Delta has been presented by several authors (Short and Stauble 1967; Agagu 1979; Asseez 1976; Novelli 1974; Kogbe 1976; Hoppers 1965; Ofoegbu 1985; WEC 1985) and the reader is referred to these authors for detailed accounts of the geology of the area. In brief, the modern day Niger Delta is geologically defined by three main lithostratigraphic units that are associated with the three major depositional cycles to which the area was subjected. The upper-most of these is the Benin Formation, which is composed of coarse grained, gravelly sandstone with minor intercalations of shales. It is a continental deposit of Miocene to recent age and has a thickness in excess of 182 m. Typical outcrops of the Benin Formation can be seen around the towns of Benin, Onitsha, and Owerri and almost all hydrogeological activity to date in the Niger Delta has been restricted to this formation.

The Agbada Formation, which lies directly below the Benin Formation, is made up of sandstones and shales and is of fluvial origin. This Formation ranges in age from Eocene in the north to Pliocene in the south. The fluviomarine sands and sandstones and marine shales that make up the Agbada Formation at-

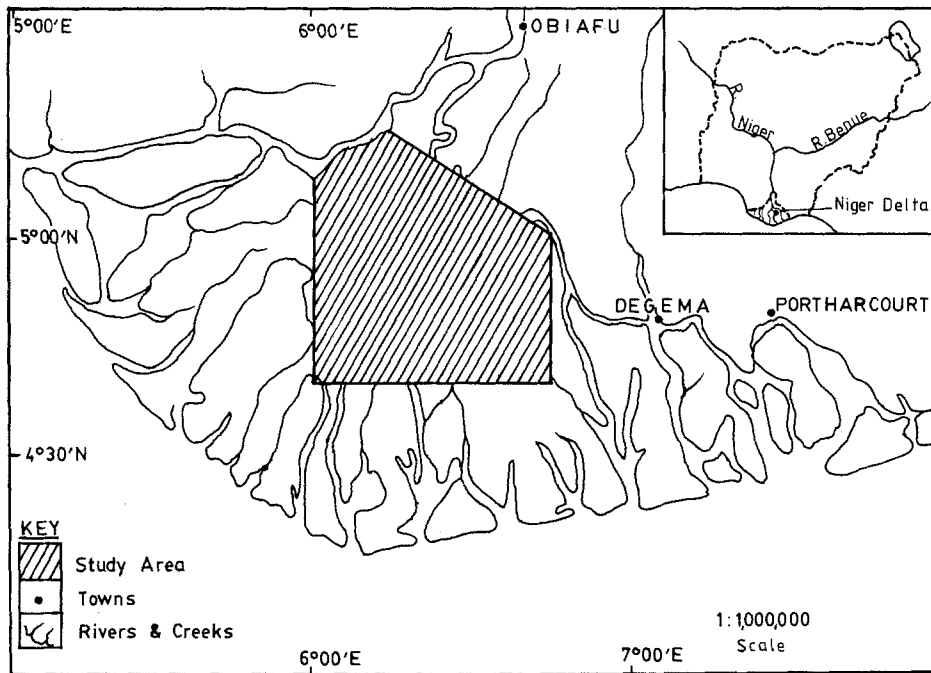


Figure 1. Location map of Niger Delta and study area.

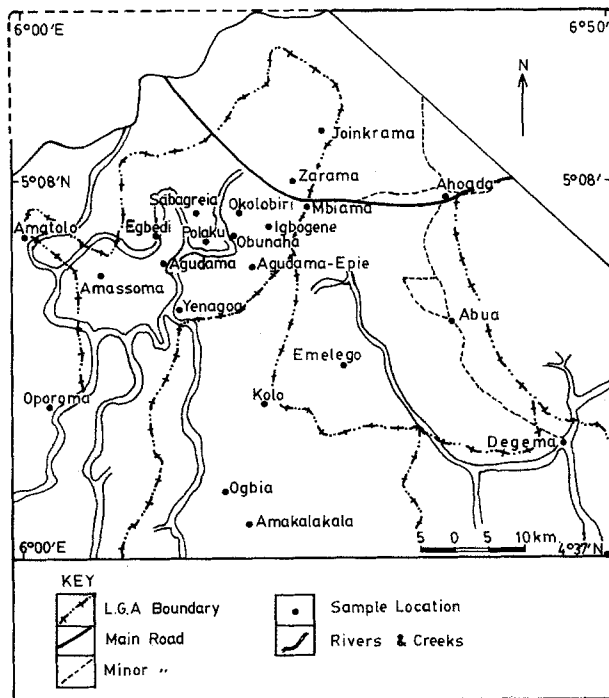


Figure 2. The project area.

tain a thickness of about 457 m. Underneath the Agbada Formation is the Akata Formation of Eocene to recent age, which is made up of shales with local interbedding of sands and siltstones. It was deposited in a typically marine environment with a maximum thick-

ness of about 6100 m (Hospers 1965; Short and Stauble 1967; Kogbe 1976; Ofoegbu 1985).

In the Niger Delta, the drainage system consists of an upper braided belt above Obiafu and meander belt region with distributaries (Fig. 1). These distributaries drain and criss-cross the delta through a network of rivers and creeks with at least 18 major river systems directly connected to the sea. These rivers are mostly turbid during the wet season possibly due to the discharge of clay and silt into the drainage channels during this time. The area experiences a single short dry season and a long rainy season giving rise to abundant rainfall which varies annually from about 3000 mm (118 in.) to 5000 mm (197 in.) (NEDECO 1961). Due to the generally high rainfall in the wet season, the water table is high and levels of concentration of some salts are reduced. During the dry season, however, the water level is lowered as a result of excessive evapotranspiration leading to high concentration levels in some ionic species (Amadi and Amadi 1986; Amadi 1986; Ceffa and others 1983).

The freshwater aquifers in the Niger Delta occur in three zones; (1) a northern zone of shallow aquifers generally less than 100 m deep and made up mainly of continental deposits, (2) a transitional zone of marine and continental deposits located southwards towards the coast, and (3) a third aquifer zone that occurs within the sand bars and beaches of the coastal areas and at depths of 200 m and more. High yields have been reported in the Niger Delta region. Amadi

(1986) has reported yields of about 1.7 m³/h and 181.8 m³/h at Nchia and Obigbo respectively. Aquifer transmissivities have been calculated to range from 60 m²/d to 1460 m²/d in some cases (Amadi 1986).

Hydrogeochemistry of the Niger Delta

Groundwater samples collected from 21 locations in the Niger Delta have been analyzed in the present study. The water samples were collected in clean 100-mL polyethylene plastic bottles with tightly fitting covers. A total of five samples were collected from each of the locations; two were filtered and acidified for cation analysis while three were preserved for anion determination. Electrical conductivity, pH, and temperature of the samples were determined in the field. The pH was estimated by visual comparison with Lovibond and permanent glass color standards using appropriate Livibond comparator with standard indicators.

Analysis for the cations Na⁺, Ca⁺⁺, Mg⁺⁺, and ΣFe was carried out using an atomic absorption spectrophotometer model IL 451. Bicarbonate and chloride ions were estimated by standard titration methods while sulphate ions were estimated turbidimetrically in the form of BaSO₄ using the Bausch and Lomb Spectronic-70 equipment.

Results of the Analysis

The chemical composition of the groundwater samples as obtained from the present analysis is presented in Table 1. The data in Table 1 shows that the samples are fairly enriched in Na⁺, Ca⁺⁺, Mg⁺⁺, ΣFe, Cl⁻, HCO₃⁻, and SO₄⁻. Table 2 shows the range in values of each of these ions. The ionic concentrations in mg/L (Table 1) have been transformed into values in meq/L and these are presented in Table 3 and Figure 3. A look at Table 1 reveals that more than 95 percent of the samples analyzed had iron concentration higher than the maximum permissible level of 0.3 mg/L (Nigerian Standards 1971). Concentration values of calcium are also in excess of magnesium except in a few locations (Amassoma, Agudama, Abua, Oporoma, Kolo, Ogbia, and Amakalakala) where magnesium content becomes enhanced.

Although most of the samples are enriched in sulphate, which ranges from 1.5 mg/L at Joinkrama to 102.5 mg/L at Amassoma these values are within acceptable limits for drinking water (Nigerian Standards 1971). No carbonate ions were detected and all carbonates exist as the bicarbonate, which range in concentration from 3.4 mg/L at Amatolo to 200.1 mg/L at

Polaku. A close look at the results of the chemical analysis shows that a lack of chemical equivalence exists between the cationic and anionic groups. This is thought to be due to some undetermined constituents such as K⁺, NO₃⁻, and CO₃⁼.

Salinity of samples range from 24.6 mg/L at Obun-agma to 181.4 mg/L at Amasoma and based on the salinity chart of Carroll (1962) all groundwater sampled in this work may be regarded as being fresh. Total Dissolved Solids (TDS) values (Table 1) are not near the brackish water range of 1,000–10,000 mg/L and following the hardness classification of Sawyer and McCarty (1967), WHO (1963), and Nigerian Standards (1971) all the groundwaters analyzed are soft and potable.

Discussion

Tables 1 and 2 and Figure 3 show that there are wide ranges in the ionic levels in the groundwaters from this region. The major cations are Na⁺, Ca⁺⁺, and Mg⁺⁺; while the major anions are Cl⁻, HCO₃⁻, and SO₄⁼. The origin of these species including ΣFe and such parameters as salinity and total hardness must be related to the peculiar geologic and hydrologic conditions of the Niger Delta.

Sodium, calcium, and magnesium are species that can be derived from the chemical weathering of feldspars and micas. The sedimentary rocks in the study area contain unconsolidated alluvial deposits with mixed assemblages of minerals derived from sedimentary, igneous, and metamorphic sources. As a result, fine fragments of feldspars occur with the terrigenous alternation of sands, clays, and shales. All three ions, Na⁺, Ca⁺⁺, and Mg⁺⁺ are among the species that are constantly involved in cation exchange processes and interaction with aquifer material (Mercado 1985). This accounts at least in part, for their erratic concentration levels.

Sulfate levels in the area are below the Nigerian Standards for drinking water and therefore poses no groundwater quality problem. These low values could be due to the removal of sulfate from the water by bacteria. The reduction of sulfate ions produces hydrogen sulfide (Freeze and Cherry 1979); the unpleasant odor of which could easily be detected in the swamps of the Niger Delta.

Of all species, it is only the Cl⁻ ion that showed the most consistent trend in its pattern of variation (Fig. 3). It occurs in all samples but with relatively small values around the landward locations where the values rarely exceeded 14 mg/L while being higher towards the coast where values as high as 120 mg/L were recorded. These higher values are indicative of saline

Table 1. Chemical composition of groundwater samples from parts of the Niger Delta, Nigeria.

Location	Fe (mg/L)	pH	Temp (°C)	Sp Conductivity (μ S)	TDS (mg/L)
Joinkrama	6.2	6.3	26.0	400	260
Zarama	4.3	6.5	25.8	351.5	248
Mbiam	5.6	6.6	26.3	141.5	92
Ahoda	5.1	6.1	26.5	16.9	11
Sabagreia	3.0	6.2	26.6	605.8	363.5
Polaku	1.9	6.3	27.6	536.7	322.1
Obunagha	1.4	6.8	26.0	546.6	327.9
Okolobiri	2.0	6.8	26.5	625.4	375.2
Ametolo	0.1	6.2	27.0	675.1	405.1
Amassoma	2.0	6.5	26.0	352.3	229
Egbedi	2.5	6.4	26.0	643.1	418
Agadama	1.5	7.5	26.5	303.0	197
Agudama-Epie	2.4	6.3	26.6	465.0	279
Yenagoa	4.5	6.3	27.6	172.9	112.4
Emelego	5.1	6.4	26.5	405	243
Abua	5.4	6.3	28.0	411.6	264.9
Degema	5.4	7.0	26.5	405.6	243.4
Oporoma	0.5	6.8	27.1	398.6	58.0
Kolo	0.4	6.8	28.5	485.7	291.4
Ogbia	0.4	6.9	28.0	367.4	220.4
Amakalakala	0.9	6.4	27.5	552.6	331.6

water encroachment (Luszczynski and Swarzenski 1966; Tremblay and others 1973). According to Luszczynski and Swarzenski (1966) chloride concentrations of 50 mg/L or more were indicative of saltwater intrusion on Long Island. Tremblay and others (1973) on the other hand considered a chloride content greater than 40 mg/L to be indicative of saltwater contamination of the Summerside area of Prince Edward Island. The present authors' suggestion of saltwater encroachment in the area of study is therefore in agreement with the results obtained by earlier workers in other areas of the world. To further confirm the salinization of the aquifer as one approaches the coast, the authors have studied the variations in the Na/Cl and Ca/Cl ratios (Table 3) and compared these ratios to the values for seawater. A look at Table 3 shows a general decrease of Na/Cl and Ca/Cl ratios as one moves towards the coast. In the Yenagoa, Emelego, Abua, Degema, Oporoma, Kolo, Ogbia, and Amakalakala areas the Na/Cl ratios fall below both freshwater ($\cong 1$) and seawater ($\cong 0.86$) values. Following the results of Mercado (1985) this is indicative of saltwater encroachment. Furthermore, there appears to be marked seaward decrease in the bicarbonate concentrations especially around Oporoma, Kolo, Ogbia, and Amakalakala where values of 0.056, 0.100, 0.082, and 0.061 meq/L respectively were obtained (Table 3). This decrease in the bicarbonate concentration ac-

ording to Mercado (1985) is also indicative of aquifer salinization.

In the coastal region where the samples used in the present study were taken, a common source of the Cl^- would be seawater. The advance of chloride from seawater may be responsible for the general variation in the chloride content. The relatively high Cl^- content recorded at Yenagoa, Emelego, Abua, Degema, Oporoma, Kolo, Ogbia, and Amakalakala as well as the Na/Cl ratios in these areas that fall below values for seawater and freshwater and the general decrease in bicarbonate concentrations recorded in these areas are thought to be caused to a great extent by the encroachment of saltwater. This may be due to either nearness to sea or to excessive pumping or both. Irrespective of its source, the Cl^- ion is conservative. It does not react easily with aquifer materials and tends to be closely associated with water molecules (Mercado 1985) and hence is useful in monitoring water chemistry behavior.

The concentration of iron has been noted to be generally high throughout the study area, with values ranging from 0.1 mg/L to 6.2 mg/L. Most of the waters are clear when first drawn from the well but soon become cloudy and then brown from precipitating ferric hydroxide. Conclusive evidence is lacking as to the exact source of this high iron activity. Important factors that influence iron solubility and consequently

Table 1. *Continued.*

Salinity	Hardness	Ca ⁺⁺ (mg/L)	Mg ⁺⁺ (mg/L)	Na ⁺⁺ (mg/L)	SO ₄ ⁻ (mg/L)	Cl ⁻ (mg/L)	HCO ₃ ⁻ (mg/L)
136.6	13.3	10.5	2.4	4.1	1.5	5.6	68.3
149.9	14	8.6	1.6	3.0	2.6	6.4	43.7
48.9	16	11.3	1.2	3.0	3.5	6.4	65.3
7.9	12.4	7.2	1.5	2.4	4.3	5.9	41.5
92.3	12	11.2	4.9	23.0	2.5	3.3	39.1
89.5	14.5	12.8	5.6	21	2.5	4.1	200.1
24.6	13.8	10	5.7	25	3.5	4.3	78.1
30.4	27.5	11.0	6.0	31	2.7	4.5	56.8
85.9	8.0	3.2	2.0	33	35	5.7	3.4
181.4	11.2	4.5	5.1	39	102.5	4.3	6.1
171.5	22	8.8	5.0	35	52.5	14.2	19.5
68.4	7.5	5.1	6.4	31	96.5	4.4	5.0
163.4	32.0	2.8	12.7	41	78.4	4.5	3.7
49.3	8.0	2.5	1.6	3.0	2.1	48.4	19.5
89.6	9.4	3.0	2.0	2.4	2.6	50.1	21.4
90.5	26.4	3.0	5.1	2.0	3.4	55.6	23.8
96.4	40.0	2.8	2.0	18.0	3.2	56.8	25.4
116.0	25	4.0	10.0	8.8	3.3	108.5	3.4
125.4	14	5.6	8.7	11.4	4.3	111.4	6.1
80.0	9.5	3.8	11.1	6.8	1.5	109.8	5.0
98.6	20.1	2.4	7.9	5.8	4.6	119.0	3.7

Table 2. Range in values of ions (mg/L).

Ion	Range (mg/L)
Total Fe	0.1–6.2
Ca ⁺⁺	2.4–12.8
Mg ⁺⁺	1.2–12.7
Na ⁺	2.0–41.0
Cl ⁻	3.3–119.0
SO ₄ ⁻	1.5–102.5
HCO ₃ ⁻	3.4–200.1

its concentration in groundwater include the local geologic structure, hydrological conditions of the basin, and complex physiochemical and biochemical factors such as the pH and redox potential (Eh), the dissolved carbon dioxide and sulfur species, organic substances with high capacity to form complexes including humic substances, and the content and composition of microflora. Given this complex array of factors, any explanation of high iron content in a given locality must concentrate on those factors known to prevail in the area.

The pH values determined in this work range from 6.1 to 7.5 and support high iron dissolution. Hem (1970) has noted that groundwater with a pH between 6 and 8 can be sufficiently reducing to carry as much as 50 mg/L of ferrous iron at equilibrium where bicarbonate activity does not exceed 61 mg/L. Much of the

bicarbonate measured in this work is less than 60 mg/L hence the relevance of the pH values.

The type of sedimentation in the Niger Delta suggests another source for the iron. The sedimentary rocks in the study area contain unconsolidated alluvial deposits with mixed assemblages of pyroxene amphiboles, biotite, magnetite, and olivine. These are iron-bearing minerals and can be derived from sedimentary, igneous and metamorphic sources. Besides, shales, which are common in the study area, are known to contain high amounts of iron (Davis and DeWiest 1966). The leaching of the Niger Delta shales is a possible source for the iron contamination. The fact that the groundwater occur at shallow depths (less than 20 m) suggests an open system where there is frequent contact between such waters and the atmosphere. Recharge reaching the water table is generally oxygenated owing to this contact and any reduced iron minerals especially pyrite, which the solution contacts will be attacked to yield ferric iron and sulfate. Hem (1970) has attributed high iron contents in groundwater to the oxidation of reduced iron in sedimentary materials (Bouwer 1978). The phenomenon of corrosion cannot be overlooked. Corrosion of well casings and other pipes may also contribute iron to the well-water sampled.

There is evidence of occasional enhancement of one ion concentration relative to others as the coast is

Table 3. Values of ions in meq/L excluding the ratios, which are dimensionless.

Location	Ca	Mg	Na	Fe	SO ₄	Cl	HCO ₃	Na/Ca	Ca/Cl
Joinkrama	0.524	0.197	0.178	0.222	0.031	0.158	1.12	1.127	3.316
Zarama	0.429	0.132	0.131	0.154	0.054	0.181	0.716	0.724	2.370
Mbiana	0.564	0.099	0.131	0.201	0.073	0.181	1.07	0.724	3.116
Ahoad	0.359	0.123	0.104	0.183	0.090	0.166	0.680	0.627	2.163
Sabagreia	0.559	0.403	1.00	0.107	0.052	0.093	0.641	10.753	6.011
Polaku	0.639	0.461	0.914	0.068	0.052	0.116	3.28	7.879	5.509
Obunagha	0.499	0.469	1.09	0.050	0.073	0.121	1.28	9.008	4.124
Okolobiri	0.549	0.494	1.35	0.072	0.056	0.127	0.931	10.630	4.323
Amatolo	0.160	0.165	1.44	0.003	0.729	0.124	0.056	11.613	1.290
Amassoma	0.225	0.420	1.70	0.072	2.13	0.121	0.100	14.049	1.859
Egbedi	0.439	0.411	1.52	0.090	1.09	0.401	0.320	3.791	1.095
Agudama	0.254	0.526	1.35	0.054	2.01	0.124	0.082	10.887	2.048
Agundama-Epic	0.140	1.04	1.78	0.086	1.63	0.127	0.061	14.0167	1.102
Yenagoa	0.125	0.132	0.131	0.161	0.044	1.37	0.320	0.096	0.091
Emelogo	0.150	0.165	0.104	0.183	0.054	1.41	0.351	0.074	0.106
Abua	0.150	0.165	0.870	0.193	0.071	1.57	0.390	0.550	0.096
Degema	0.140	0.165	0.783	0.193	0.069	1.60	0.413	0.489	0.088
Oporoma	0.200	0.823	0.383	0.018	0.067	3.06	0.056	0.125	0.065
Kolo	0.280	0.716	0.500	0.014	0.090	3.14	0.100	0.159	0.089
Ogbia	0.190	0.913	0.296	0.014	0.031	3.10	0.082	0.095	0.061
Amakalakala	0.120	0.650	0.252	0.032	0.096	3.36	0.061	0.075	0.036

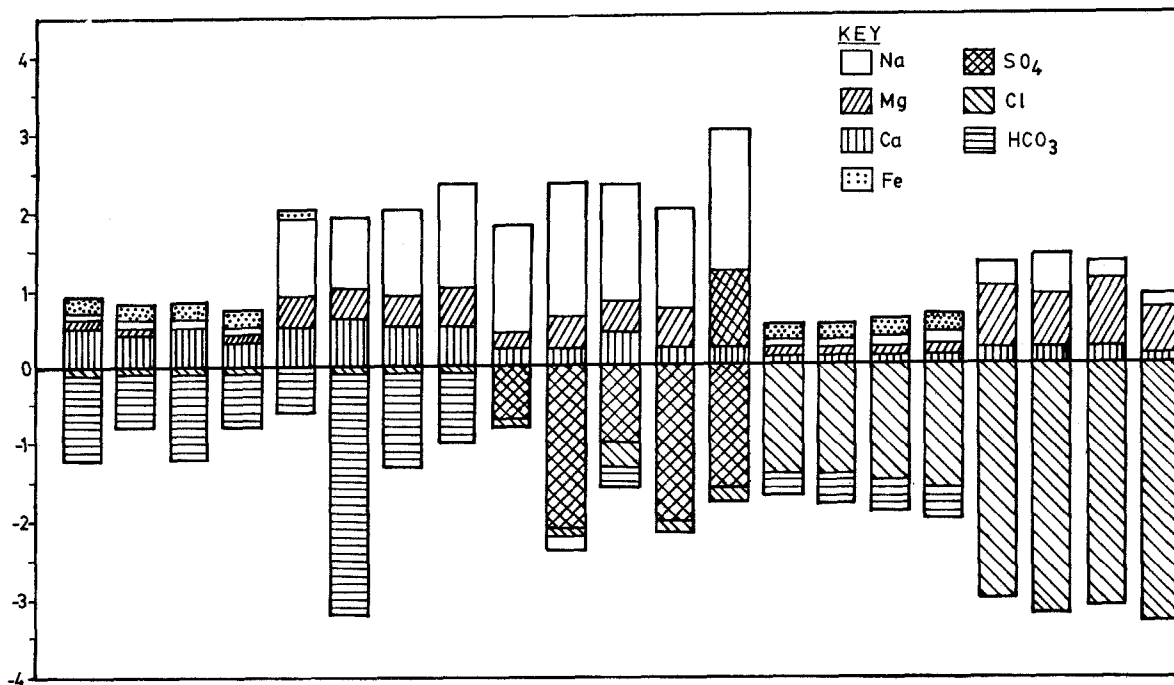


Figure 3. Bar graphs representing analyses in milliequivalents per liter.

approached. For example, Ca⁺⁺ is in excess of Mg⁺⁺ around the landward stations; but around Oporoma, a conspicuous reversal in the trend takes place. An increase in Mg⁺⁺ is an indication of saltwater encroachment, as seawater is known to be more enriched in magnesium than calcium (Davies and DeWiest 1966).

One result of these ionic variations is the existence

of several groundwater types as outlined earlier. The first water encountered is a bicarbonate type with iron and calcium as the main cation components, giving us an iron-calcium-bicarbonate water (Type I), (Fig. 4). Water Type 1 appears to be restricted to Joinkrama, Zarama, Mbiana, and Ahoad areas. The bicarbonate persists along with calcium around Sabagreia, Polaku,

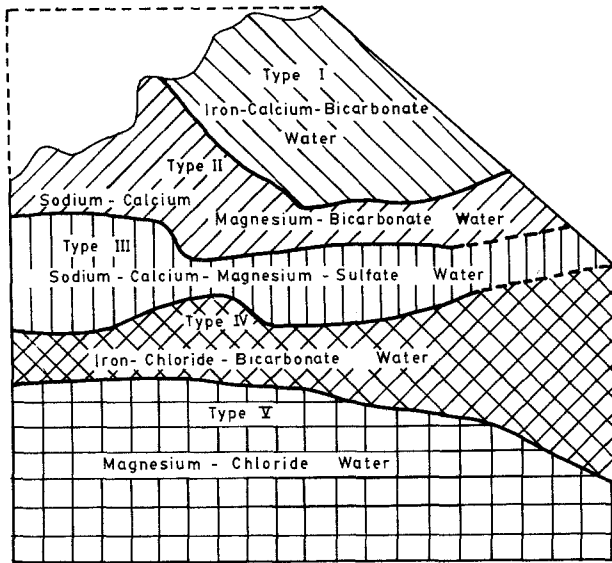


Figure 4. Groundwater map of the area investigated.

Obunagha, and Okolobiri, but with sodium and magnesium as the new enhanced cations. This leaves us with a sodium-calcium-magnesium-bicarbonate water (Type II). This again is essentially a bicarbonate water. Events become altered at Amatolo, Amassoma, Egbedi, Agudama, and Agudama-Epie where we now come in contact with a sulfate-type water. The cations in Type II however persist and the water is named a sodium-calcium-magnesium-sulfate water (Type III). This water is therefore only distinguishable from Type II by its anion contrast. At Yenagoa, Emelego, Abua, and Degema, the Cl^- ion concentration is high; Fe and HCO_3^- reappear and we are left with an iron-chloride-bicarbonate water (Type IV). Again water Type IV is essentially similar to water Type I except that the high calcium in Type I has been overwhelmed by chloride in Type IV. The water encountered at Oporoma, Kolo, Ogbia, and Amakalakala is designated Type V and is a magnesium-chloride type. This is the only simple groundwater type encountered in this work.

The existence of these water types indicates that it is not unreasonable to expect that in many areas, the chemistry of local groundwater exhibits complex spatial patterns that may be difficult to interpret. The evolution of these groundwater facies can however be reasonably explained by the order of encounter proposed by Freeze and Cherry (1979). This theory briefly states that the order in which groundwaters encounter strata of different mineralogical composition can exert an important control on the final water chemistry. As groundwater flows through strata of different mineralogical composition, the water compo-

sition undergoes adjustments caused by imposition of new mineralogically controlled thermodynamic constraints. The water types as defined in this research may even correspond to possible broader classifications, which can further be split.

Conclusion

Chemical analysis of groundwater samples collected from hand-dug wells in parts of the Niger Delta has been carried out. Results obtained show that the waters in the area range from slightly acidic to neutral on account of the pH values which range from 6.1 to 7.5 and relatively enriched in Na^+ , Ca^{++} , Mg^{++} , Cl^- , SO_4^{--} , and HCO_3^- . Increases in Mg^{++} and Cl^- as one approaches the coast is interpreted as being due to saltwater encroachment. This is further confirmed by the Na/Cl ratios, which as one approaches the coast, are below values for seawater and freshwater (Mercado 1985) as well as decreasing bicarbonate concentration towards the coast.

Five groundwater types are delineated and named as follows: Type I—Iron-Calcium-Bicarbonate (Fe-Ca-4HCO_3) water; Type II—Sodium-Calcium-Magnesium-Bicarbonate (Na-Ca-Mg-4HCO_3) water; Type III—Sodium-Calcium-Magnesium-Sulfate ($\text{Na-Ca-Mg-}\frac{5}{2}\text{SO}_4$) water; Type IV—Iron-Chloride-Bicarbonate (Fe-Cl-HCO_3) water; and Type V—Magnesium-Chloride (Mg-2Cl) water. Consequently, a tentative groundwater map of the region showing water types has been developed (Fig. 4). The naming of these waters is based on the dominant cations and anions after transforming values to meq/L. With the exception of water Type V, all the rest are compound groundwater types. The varied types notwithstanding, groundwaters in many of the locations are fresh, soft, and potable but high iron concentrations and seawater encroachment into aquifers present quality problems to groundwater. The evolution of the water types can reasonably be explained by the order of encounter, which is the most important factor in the chemical evolution of groundwaters in mixed and layered assemblages. The water types as defined in this research may correspond to possible broader classifications which can further be split provided they are strongly tied to the geologic, hydrologic, and geochemical conditions prevailing in the Niger Delta.

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