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A PRELIMINARY ANALYSIS OF GROUNDWATER CHEMISTRY IN SHALLOW BOREHOLES, UGHELLI, NIGERIA

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Groundwater samples collected from 25 shallow boreholes in Ughelli, western Niger Delta, Nigeria, have been analyzed to determine major ion chemistry, and to compare the chemistry with that of the eastern Niger Delta. Preliminary results showed that major ions such as Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-} occurred in relatively significant quantities in all the samples. The concentrations of these ions are below the standards for drinking water as recommended by the World Health Organization (WHO). As with the landward side of the eastern Niger Delta, the concentration of Ca^{2+} was found to be higher than Mg^{2+} in all the samples. Chloride occurs in concentrations less than 14 ppm in 50 percent of the samples. Chloride concentration is higher in the remaining 50 percent of the samples, becoming greater than 40 ppm, which may indicate minor saltwater encroachment. However, only 20 percent of the samples have Na/Cl ratios that are below the values for seawater and freshwater. The results suggest that shallow groundwater in Ughelli is far enough inland to be beyond the influence of seawater from the Atlantic Ocean. As with the eastern Niger Delta, 60 percent of the samples analyzed had iron concentrations higher than the acceptable WHO standard of 0.3 ppm. As the source of the iron in the Niger Delta is not completely understood, further research is recommended in this area.

INTRODUCTION

Increase in population growth rate, urban drift, agricultural and industrial development in Nigeria has led to increased demand for water supply. As the government has been unable to meet the rapidly increasing demand for water in the last few decades, communities and individuals have turned to alternative sources such as surface streams, shallow wells and boreholes (Azzeez, 1972; Löhnert, 1981). In the Niger Delta where oil and gas exploration has polluted most of the surface streams, groundwater is an important resource. Despite the common use of groundwater, several studies have shown that geologic and geochemical considerations are rarely or inadequately incorporated into the location and design of boreholes in the Niger Delta (Amajor, 1989). Most domestic boreholes in the Niger Delta are shallow, ranging in depth from 10 to 30 m. They are drilled either manually or by rotary drilling with little attention paid to the geochemical characteristics of the water and its suitability for domestic consumption.

It is well known that the quality of groundwater depends on the characteristics of the geologic media through which it flows (Raji and Alagbe, 1997). The water chemistry is controlled by factors such as the mineralogical composition of the aquifers, the location and nature of recharge, the drainage area, and the hydraulic properties of the rocks. The effects of these factors on water chemistry for different uses is controlled by chemical standards that are set by various bodies (e.g. World Health Organization (WHO), 1984; Nigerian Standards, 1971). In the past few years, several of these factors have been assessed for water resources purposes in different parts of Nigeria (Amajor, 1991; Tijani, 1994; Olayinka et al., 1999; Ezeonu et al., 2002), and in the Niger Delta (BRGM, 1979; Etu-Efeotor, 1981; Ceffa et al., 1983; Okagbue, 1989; Amadi et al., 1989; Amajor and Gbadebo, 1992). Most of these studies have been sited on the eastern Niger Delta. Although the hydrological environment (topography, climate, geology) of the eastern and western Niger Delta is basically the same, our knowledge of the hydrochemistry of the Niger Delta will be more complete with more investigations in the western parts.

A consideration of the widespread use of shallow boreholes, an appreciation of possible health hazards, and the need to harmonize conclusions of the hydrochemistry across the Niger Delta is the main focus of this study. The specific objective was to perform a preliminary assessment of the water quality from shallow boreholes in the western Niger Delta and to compare this quality with that of water from a site in the eastern part of the delta.

Twenty-five domestic water supply wells were sampled in the town of Ughelli in the Niger Delta. Typical major ions (Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-}) were analyzed to determine the water quality. These ion concentrations were then briefly compared to those obtained from a similar site in the eastern Niger Delta.

LOCATION AND GEOLOGIC SETTING

The study site, the town of Ughelli, is located at approximately latitude 5° 30' N and longitude 6° E. It covers an area of about 20 km^2 in the western Niger Delta (Figure 1). The site is part of a low-lying plain with land elevation generally under 50 m above mean sea level (Aweto, 2002), and with no marked imposing hills that rise above the general land surface. The climate is humid subequatorial with a long wet season which lasts from March to October, alternating with a shorter dry season that lasts from November to February. The annual rainfall is 2800 mm, and is usually marked by intense thunderstorms and prolonged gentle showers that may last for several hours or a few days. The annual temperature averages 27°C with a small range that rarely exceeds 3°C. This

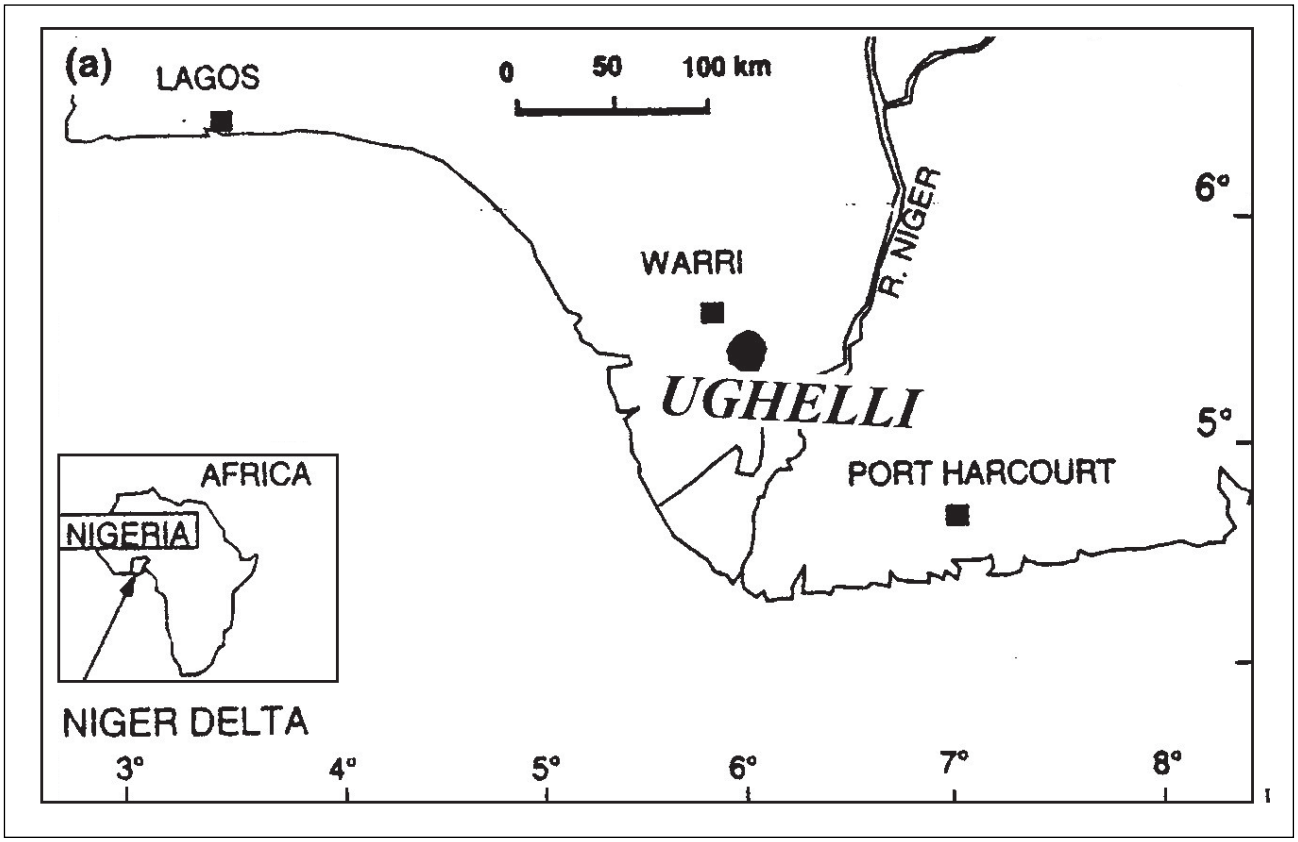

Figure 1. Location map of the study site, Ughelli, in the Niger Delta.

combination of temperature and high rainfall, in conjunction with the underlying unconsolidated sediments, produces a shallow groundwater table that promotes the use of shallow wells by the local inhabitants. More than 50 percent of the population of over 60,000 depends on shallow groundwater for domestic purposes.

Geologically, the site is part of the modern day Niger Delta that is underlain by three major lithostratigraphic units that characterize three main depositional cycles in the region (Short and Stauble, 1967; Azzeez, 1976; Kogbe, 1976; Agagu, 1979; Ofoegbu, 1985; Doust and Omatsola, 1989; Koledoye et al., 2003). The uppermost unit, the Benin Formation, consists of coarse gravely sandstone with minor intercalations of shale. It is the continental sedimentary facies of the Niger Delta, with a thickness in excess of 180 m, and of Miocene to Recent age. Groundwater studies to date in the Niger Delta have been restricted to this unit.

The Benin Formation is underlain by the Agbada Formation, which is Eocene to Pliocene in age. It is made up of sandstones and shales of fluvial origin, having a thickness of up to 450 m. The Akata Formation, of Eocene to Recent age, underlies the Agbada Formation. It is a marine deposit of shales, interbedded with sands and siltstones of thickness in the range of 6000 m.

Freshwater aquifers in the Niger Delta have been summarized to occur in three main zones (Amajor and Okagbue, 1989; Amadi et al., 1989): (1) a northern zone of shallow sand and gravel aquifers, generally less than 100 m deep, (2) a more southern zone of shallow to deep sand aquifers mixed with clay, and (3) a coastal zone of deep sand bars and beach aquifers, with depth in excess of 200 m. Aquifers in the study area appear to fall in the shallow category of the second zone above. For such aquifers, Amadi (1986) has reported transmissivities in the range of 60 m^2/d to 1460 m^2/d, and yields of 40.8 m^3/d to 4363.2 m^3/d. In the absence of geochemical limitations, these aquifers are considered to be desirable for water supply.

HYDROCHEMISTRY

Groundwater samples were collected from 25 shallow boreholes (Figure 2) in the town of Ughelli in the western Niger Delta in January 2006. The water samples were collected in 50 mL polyethylene plastic bottles. The electrical conductivity and pH of the samples were measured in the field. The samples were then acidified for preservation, and the covers were tightly fitted for transportation to the geochemistry laboratory of Montclair State University, Upper Montclair, New Jersey, USA. The samples were analyzed for major ions, and a few minor and trace constituents. Analysis for the cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe, Si, Sr and Cu was carried out using an Industrial Coupled Plasma (ICP-OES) equipment. The anions HCO_3^-, Cl^-, NO_3^{2-}, SO_4^{2-}, Br, Fl, on the other hand, were analyzed with an Ion Chromatograph (IC).

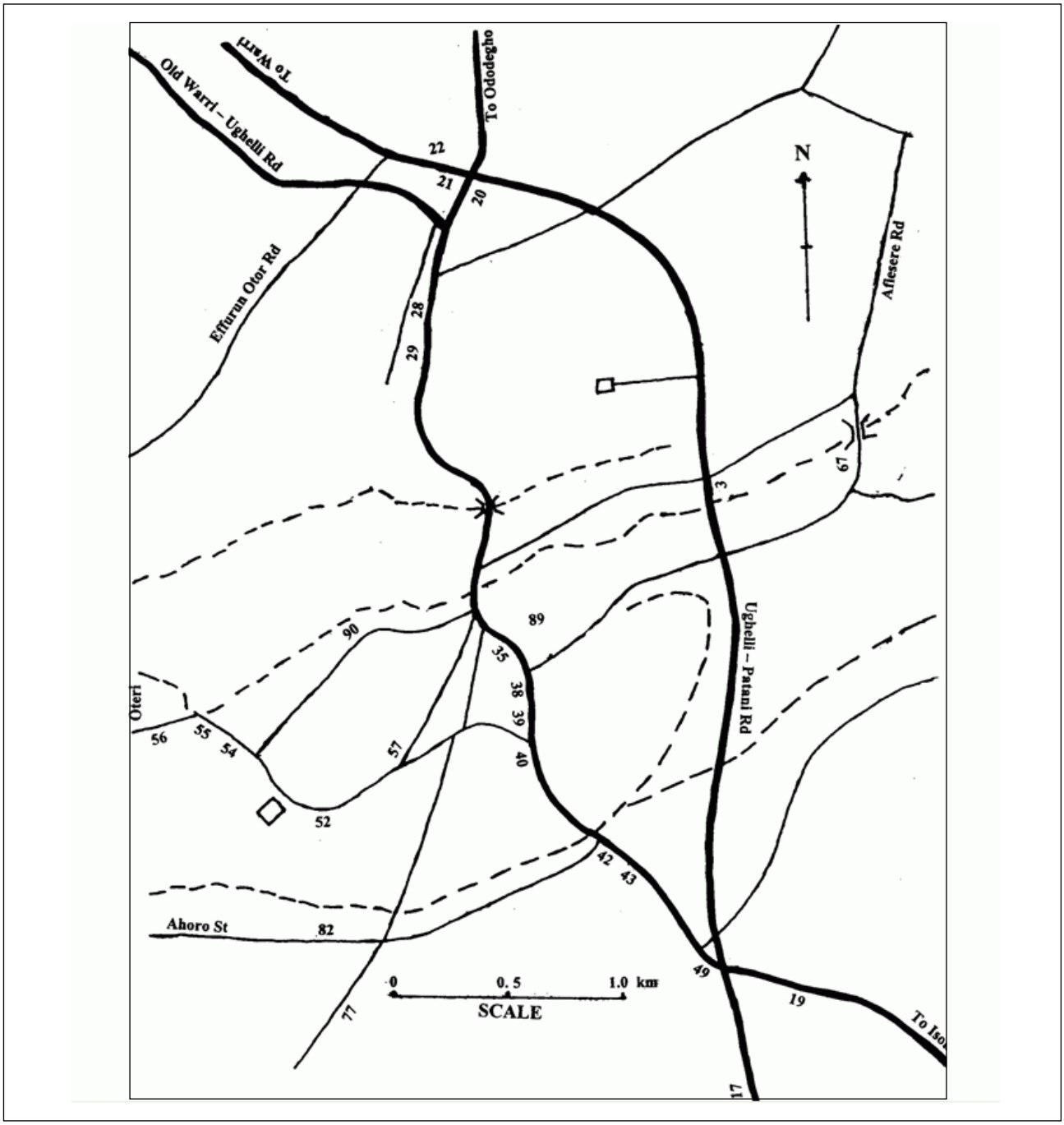

Figure 2. Map of study site, showing water sampling locations (dashed lines are streams).

RESULTS AND DISCUSSION

The concentrations of some selected ions (Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-} and Fe) in groundwater samples are presented in Tables 1 and 2. These ions were selected for a preliminary discussion, and for easy comparison with those that were reported by Amadi et al. (1989) for groundwater from the eastern Niger Delta. Tables 1 and 2 show that, but for Fe, the groundwater in the study area is chemically potable and suitable for domestic purposes (drinking and household uses) as the various ionic concentrations are within the maximum acceptable limits of WHO standards. This conclusion is similar to findings in the eastern Niger Delta (Amajor and Okagbue, 1989; Amadi et al., 1989), and in other parts of Nigeria (Tijani, 1994). Table 1 reveals, however, that 60 percent of the samples analyzed had iron concentrations higher than the acceptable level of 0.3 ppm (WHO 1984, Nigerian Standards 1971). The 60 percent is relatively less than 95 percent of samples with iron in excess of the acceptable level that was reported for a site in the eastern Niger Delta (Amadi et al., 1989). The source of iron in the Niger Delta is not completely understood, but it may be related to the weathering and dissolution processes to produce iron oxides alongside with clay minerals, or to corrosion of well construction materials and pipelines. It is also possible that the active

Table 1. Ion concentrations in shallow groundwater samples (ppm).

Sample Location	Ca^{2+}	Mg^{2+}	Na^{+}	Fe	Cl^{-}
3	1.1	0.2	2.5	0.2	0.5
17	20.1	0.2	4.7	0.9	4.3
19	0.9	0.2	4.9	1.1	0.6
20	34.6	4.7	36.5	0.8	54.3
21	2.0	0.3	14.5	0.5	2.4
22	*	*	2.3	0.6	0.6
28	15.7	1.6	9.3	0.8	12.4
29	12.3	0.3	3.0	1.1	1.0
35	38.3	4.2	41.2	0.4	73.3
38	43.3	5.1	49.2	*	3.1
39	3.0	1.0	7.0	0.4	7.2
40	35.1	2.1	33.0	0.3	56.0
42	5.4	1.5	6.2	0.2	9.3
43	18.6	3.0	13.4	0.3	66.1
49	7.2	2.2	13.2	0.3	24.6
52	17.7	0.3	1.5	0.4	2.0
54	0.7	0.1	3.0	0.4	20.7
55	0.9	0.4	3.1	0.3	39.7
56	7.0	0.2	1.0	*	1.5
57	19.0	0.3	40.0	0.4	31.8
67	0.5	0.1	2.6	0.6	0.9
77	3.4	0.6	4.7	*	12.1
82	16.0	1.5	42.0	3.0	73.3
89	8.3	1.3	19.1	1.1	32.5
90	34.7	3.6	73.7	1.4	108.0

* below detection limit

Table 2. Range of ion concentrations in shallow groundwater samples (ppm).

Total Fe	* - 3.0
Ca^{2+}	* - 43.3
Mg^{2+}	* - 5.1
Na^{+}	1.0 - 73.3
Cl^{-}	0.5 - 108.0

* below detection limit

shallow and open nature of groundwater flow systems in the Niger Delta may cause oxygenated recharge water to oxidize iron minerals and move iron into solution. This is the subject of a future study.

Sodium and calcium ions occur in significantly higher concentrations than magnesium as opposed to the relatively equal concentrations observed by Amadi et al. (1989) in the eastern Niger Delta. In particular, calcium concentration is in excess of magnesium in all the samples. This might indicate the absence of seawater intrusion, as Ughelli is far from the coast of the Atlantic Ocean. These cations are probably derived from the chemical weathering of feldspars and micas from alluvial deposits of sedimentary, igneous and metamorphic rocks.

Chloride, a conservative ion, occurs in concentrations less than 14 ppm in 50 percent of the samples. Such concentrations were observed in landward locations in the eastern Niger Delta (Amadi et al., 1989). Higher concentrations of Cl^- in the remaining 50 percent of the samples were also observed in the coastal parts of the eastern Niger Delta. These higher concentrations have been interpreted to indicate saline water intrusion (Lusczynski and Swarzenski, 1966; Tremblay et al., 1973). Thus, there appears to be some indication of salt water encroachment in shallow boreholes at the study site. In order to investigate this possibility further, Na/Cl and Ca/Cl ratios were calculated as shown in Table 3. Using the argument of Mercado (1985) that Na/Cl ratios less than 1 or 0.86 indicate freshwater or seawater respectively, only 20 percent of the samples indicate saltwater encroachment. Furthermore, the fact that Ca^{2+} concentration is constantly higher than Mg^{2+} is an indication that seawater encroachment is minimal (Davis and DeWiest, 1966). This finding is reasonable because the town of Ughelli is far from the Atlantic coast.

Table 3. Ion concentrations in shallow groundwater samples (meq/L).

Sample Location	Ca^{2+}	Mg^{2+}	Na^+	Fe	Cl^-	Ca/Cl	Na/Cl
3	0.06	0.02	0.11	0.01	0.02	3.0	5.5
17	1.0	0.02	0.21	0.04	0.12	8.33	1.75
19	0.05	0.02	0.21	0.04	0.02	2.5	10.5
20	1.73	0.39	1.59	0.03	1.53	1.13	1.04
21	0.1	0.03	0.63	0.02	0.07	1.42	9.0
22	*	*	0.1	0.02	0.02	*	5.0
28	0.79	0.13	0.41	0.03	0.35	2.26	1.17
29	0.62	0.03	0.13	0.04	0.03	20.67	4.33
35	1.92	0.35	1.79	0.02	2.07	0.93	0.86
38	2.17	0.43	2.14	*	0.09	24.11	23.78
39	0.15	0.08	0.31	0.02	0.20	0.75	1.55
40	1.76	0.18	1.43	0.01	1.58	1.12	0.91
42	0.27	0.13	0.27	0.01	0.26	1.04	1.04
43	0.93	0.25	0.58	0.01	1.86	0.51	0.31
49	0.36	0.18	0.57	0.01	0.69	0.52	0.83
52	0.89	0.03	0.07	0.02	0.06	14.83	1.17
54	0.04	0.01	0.13	0.02	0.58	0.07	0.23
55	0.05	0.03	0.13	0.01	1.12	0.04	0.12
56	0.35	0.02	1.04	*	0.04	0.75	1.0
57	0.95	0.03	1.74	0.02	0.09	1.06	1.93
67	0.03	0.01	0.11	0.02	0.03	1.0	3.67
77	0.17	0.05	0.20	*	0.34	0.5	0.59
82	0.8	0.13	1.83	0.12	2.07	0.39	0.88
89	0.42	0.11	0.83	0.04	0.92	0.46	0.90
90	1.74	0.3	3.21	0.05	3.04	0.57	1.06

* below detection limit

CONCLUSION

Groundwater samples were collected from 25 shallow boreholes in the town of Ughelli in the western Niger Delta. The samples were treated for preservation and transported to a geochemical laboratory in Montclair State University, Upper Montclair, New Jersey, USA for analysis. Major cations, minor and trace constituents were analyzed using an ICP-OES equipment, whereas the anions were analyzed using an IC. Only the results of few constituents were discussed in order to compare the basic hydrochemistry of the eastern and western Niger Delta.

Results obtained show a striking similarity in the occurrence and distribution of major ions in both the eastern and western parts of the Niger Delta. Major ions such as Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-} occurred in all the samples. However, the concentrations of these constituents are well below the acceptable concentration standards recommended by the World Health Organization (WHO). But for high Fe concentrations in about 60 percent of the samples, the shallow groundwater at the site is potable. The exceedingly high concentrations of Fe deserve a more detailed study. There is hardly any evidence of sea water encroachment at the site except for high concentrations of Cl^{-} in more than 50 percent of the samples. Furthermore, with higher Ca^{2+} than Mg^{2+} concentrations in all the samples, and only 20 percent of the samples having Na/Cl ratios less than that for freshwater (< 1) or sea water (< 0.86), the results suggest the absence of saline water encroachment.

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