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GROUNDWATER QUALITY ASPECTS OF DUG WELLS IN SOUTHERN NIGERIA

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ABSTRACT

A case study is presented on dug well waters in an urban environment of SW Nigeria. Chemical contamination varies widely in two selected town districts, depending upon local hydrogeological conditions. The operating recharge to shallow groundwater from rain or streams positively effects well water availability and quality.

LOCATION AND METHOD OF STUDY

This study was conducted in Ile-Ife+, renowned as the cradle of the Yoruba and located in Oyo State of southwestern Nigeria. The town is a typical densely populated African settlement grown over centuries with an estimated current population of more than 150.000. Pipe-borne water is available from a dam approximately 50 kilometres distant. However, domestic water supply is unreliable and somewhat intermittent.

Over one thousand hand-dug wells are still in use in the City of Ife, approximately one hundred of them were hydrogeologically surveyed by students of the University of Ife in fulfilment of the requirement of their B.Sc. degree in Geology (refs. 1-5). These projects included well inventories, repeated water level measurements, sampling between November 1978 - February 1979, and chemical analyses. The results are summarized and interpreted in this paper.

Two areas in the heart of Ife town were selected for groundwater quality studies, respectively south of the Lagere and of the Obalufon Roads which are part of the Ibadan-Ilesha main road.

(i) The Sabo district, occupied mainly by Hausa people includes the new Odo-Ogbe market, and is situated along the main topographic divide crossing Ife in a North-South direction. The Ooni's palace is built on this divide.

(ii) The Akarabata district is located 1-2 kilometres west of the divide being a residential area populated mainly by Yorubas.

+Lat. 7° 28.5' N, long. 4° 33.5' E, elevation approximately 250-290 metres a.s.l.

Privately owned dug wells in the areas under consideration are mostly circular in shape, 0.7-1.2 metres in diameter, 1-9 metres deep and unlined. Their sanitary protection is rather poor; only a few are protected by concrete rings or wooden covers over the top. Pit latrines are frequently located nearby. Other possible sources of pollution are indiscriminate excrement and rubbish scattered all over the areas.

PHYSICAL ENVIRONMENT

For a description of the general physical setting the reader is referred to a publication by L.O. Asseez (ref. 6). The area of Ile-Ife belongs to the Pre-Cambrian Basement Complex. Rock outcrops in town are, however, scarce due to the weathering cover, commonly termed laterite, the properties of which are determined by the underlying parent rock types. In the case of Ile-Ife "Schists, undifferentiated; includes some gneiss" prevail while towards the South and East pegmatites and pegmatised schists occur (ref. 7). North of Ife town the University Campus is dominated by gneiss inselbergs.

Ile-Ife lies in the well-drained head water area of the River Shasha and River Owena which take their course southward to the Atlantic. Local drainage in the Sabo district is to the Ogbe stream which is non-perennial while the Agbara stream in the Akarabata district is perennial. The valley of the latter is frequently flooded after heavy storms during the wet season lasting from early March to early November interrupted by the "little dry season" in August. Annual precipitation amounts to 1288 mm (10-year mean 1969-78) with September and October being the wettest months. Monthly maximum temperatures range between 27-37°C and minimum temperatures between 20-22°C (ref. 8).

HYDROGEOLOGY

It is the lateritic overburden that possesses modest aquifer properties. Sometimes the water level is reported to rise when hard rock is being approached while digging a well. We are dealing, nevertheless, with a more or less unconfined aquifer system with varying permeability. Recharge was assumed to be due mainly to rain infiltration. In fact, most of the wells water levels respond to rain events in a characteristic way. During the dry season the water table drops regularly. However, when scrutinizing the two test areas, marked differences come to light.

Sabo. Groundwater flow is directed towards the Ogbe stream; hydraulic gradients become steeper in the valley especially by the end of the dry season. Hydrographs display a relatively regular shape and small seasonal fluctuations of the water table except at greater depth (closer to the groundwater divide wells commonly run dry). The response to the first heavy rains in March is delayed by 2-3 weeks.

Akarabata. Both, flow nets and hydrographs are of a somewhat unsteady pattern and only a few wells show a similar pattern to Sabo wells. The seasonal water

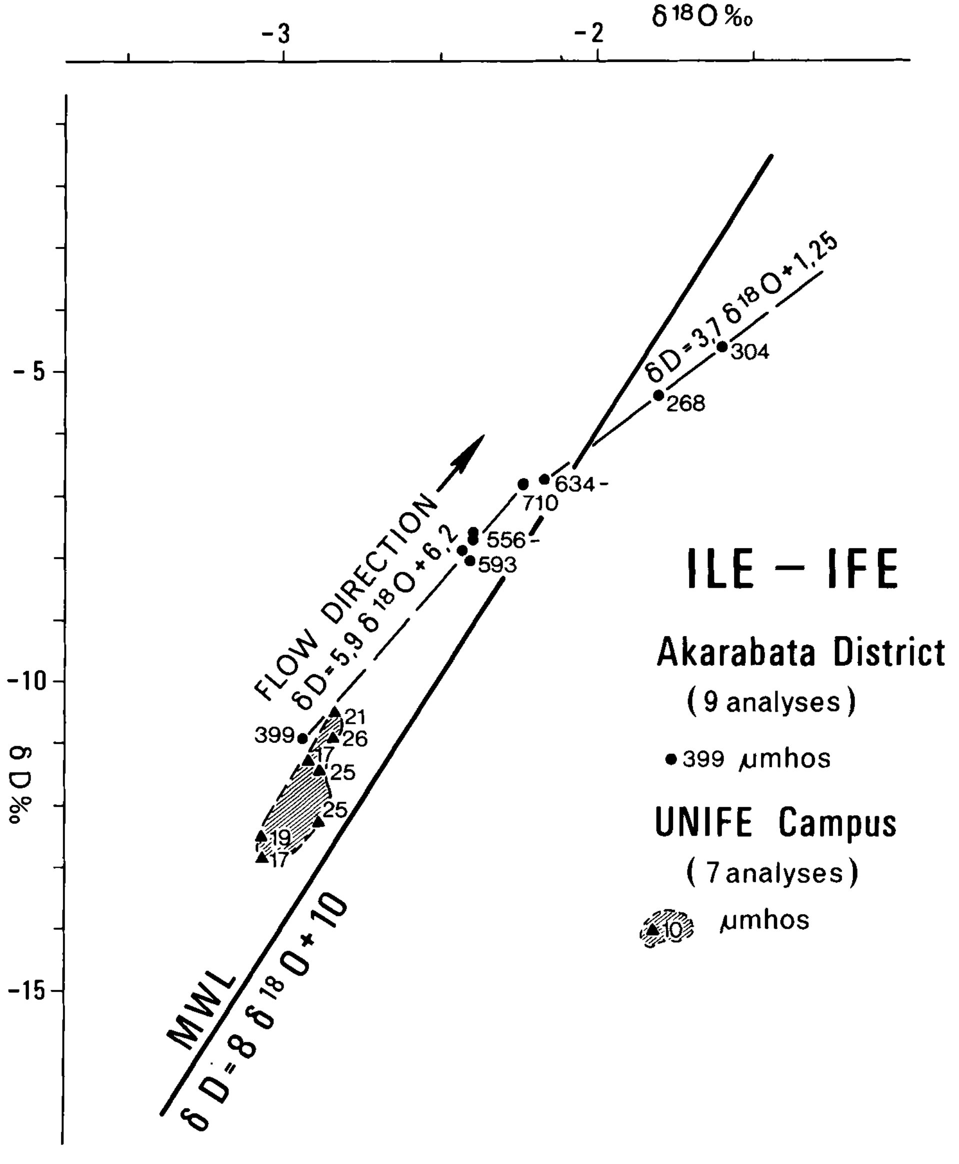

Fig. 1. Diagram showing $\delta D-\delta^{18}O$-relationship of shallow groundwaters in Ife town (Akarabata District) and the University of Ife Campus. MWL = Meteoric Water Line.

table fluctuation is generally high due to peaks at the end and the start of the rain period. Some short water table recoveries in January may be attributed to rainfall in the mountainous surroundings of Ile-Ife. Hence stream discharge is increased and groundwater recharge induced. In addition, infiltration of surface water has been proved by stable isotopes deuterium and oxygen-18 (refs. 9, 10). When plotted in a diagram (Fig. 1) δ-values follow straight lines with flatter slopes (5.9 and 3.7 respectively) as compared with the Meteoric Water Line (8) which suggests surface water and soil moisture[+] contributing to recharge is subjected to evaporation before replenishing the aquifer.

Direct recharge from rain can also be identified as shallow groundwater of interflow nature as sampled several times in the UNIFE campus test well. There is hardly any variation in the stable isotope composition to be noticed (Fig. 1). In this particular case it was possible to roughly quantify the annual recharge rate as being, surprisingly, only in the order of 20 mm (ref. 11).

QUALITY OF GROUNDWATER

Chemical data were obtained from different methods. Electrical conductivity (corrected for 25°C) and pH values were measured in the lab employing standard instruments. The major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) were determined using an Atomic Absorption Spectrophotometer (Model Perkin-Elmer 305B) with air-acetylene flame. Two anions, Cl^- and HCO_3^-, were determined by titration (0.1N $AgNO_3$ with K_2CrO_4 indicator and 0.1N HCl with methyl-orange indicator respectively). From the balance of equivalent cations versus anions, the remaining major anions SO_4^{2-} + NO_3^- were calculated. In agreement with analytical data published by Asseez (ref. 6), nitrate ist most likely to occur in negligible amounts although might theoretically amount to 340 mg/l. in the Sabo district.

Results of chemical analyses are presented in two sorts of diagrams (Figs. 2, 3):

- in the "hardness triangle" total hardness (meq/l. Ca^{2+} + Mg^{2+}) is plotted against carbonate hardness (meq/l. HCO_3^-),
- to plot major ions in the "Piper diagram" meq/l. values have to be expressed in terms of percentages of each cations and anions, the difference of the latter against total cations is assumed to be made up of SO_4^{2-} + NO_3^-.

pH of waters in the Sabo district range between 6.3-6.8 while pH values vary between 4.6-7.8 in the Akarabata district.

The general chemical water composition of the two areas differs significantly.

[+]The evaporation loss is calculated by physicist Dr. C. Sonntag to be approximately 10%.

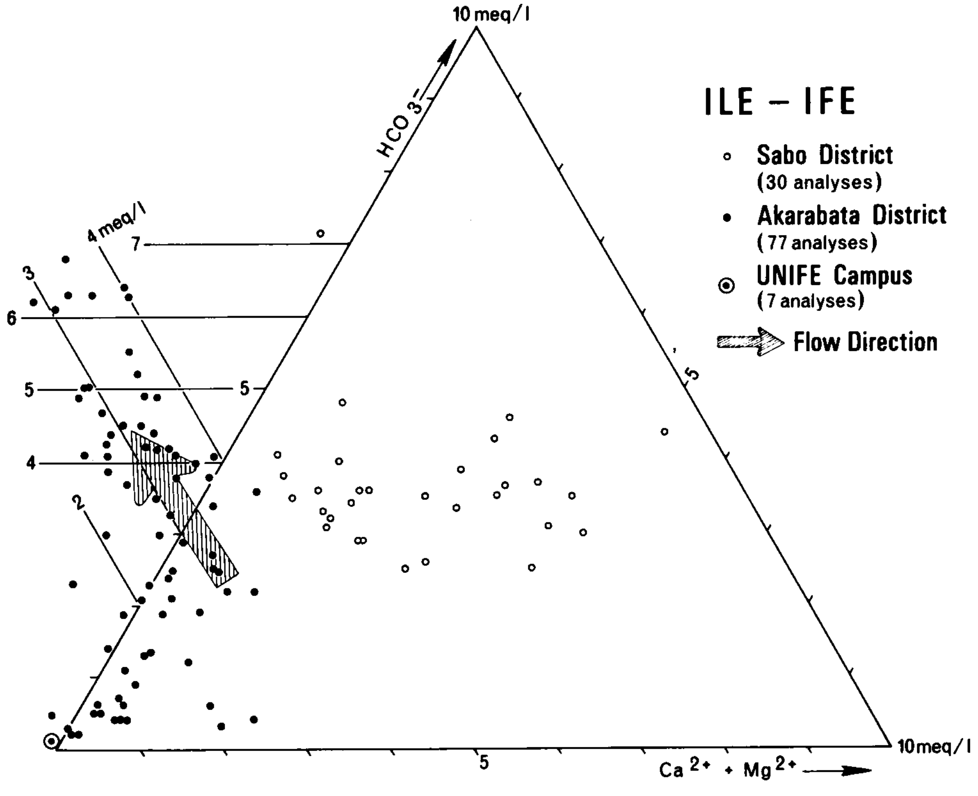

Fig. 2. Hardness triangle. Variation of Total and Carbonate Hardness in shallow groundwaters of Ile-Ife.

Sabo. Conductivity of 600-1000µS (25°C) and total hardness above 4.5 meq/l. hints at contamination. Hardness is equal in the first two sets of samples but is doubled in the third set. Carbonate hardness remains unchanged in single wells. as can be deduced from the Piper diagram, total hardness rises along with calcium at the expense of magnesium. Ca^{2+} dominance (up to 85%) in the hardest water suggests association with SO_4^{2-} (and possibly NO_3^-) as well as Cl^-. It is in these wells that the water table had risen slightly when the third set of samples was taken.

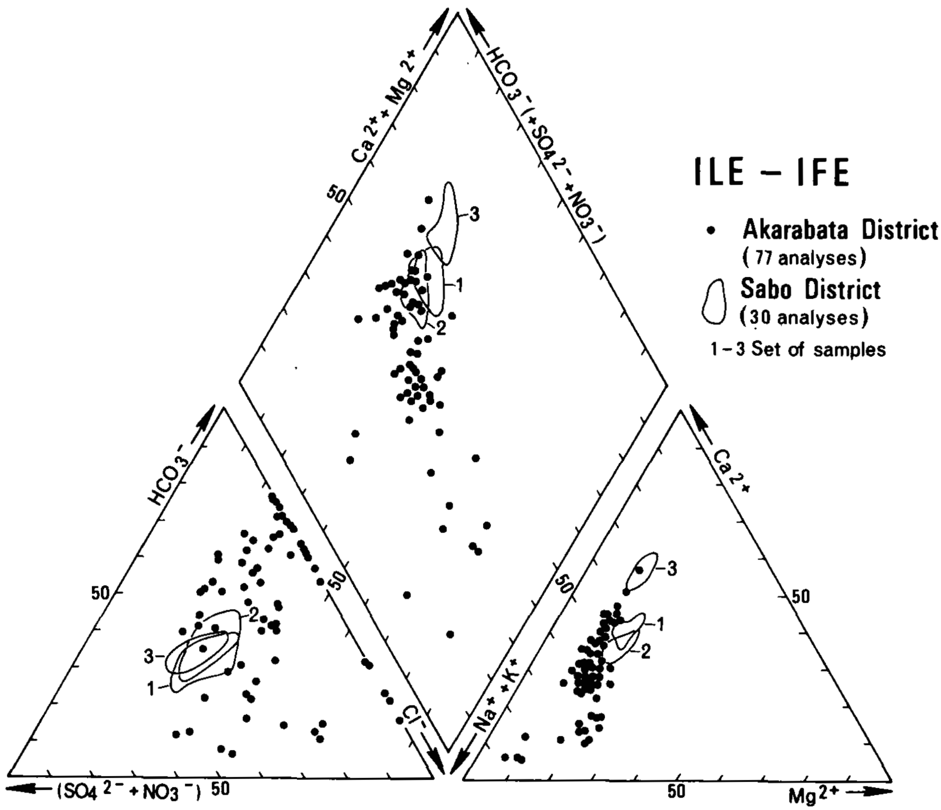

Fig. 3. Piper diagram. Variation of milli-equivalent percentages of major ions in shallow groundwaters of Ife town. Sets 1-3 taken in November, December 1978 and January 1979.

Akarabata. Groundwaters contain less dissolved solids (conductivity 200-800 µS) and are lower in hardness (maximum 4 meq/l.) than in Sabo, some being very soft. A peculiarity occurs at shallow depth to the water table in the hard range waters between 2.5-4 meq/l.: HCO_3^- exceeds Ca^{2+} + Mg^{2+} considerably which points to the presence of dissolved sodium bicarbonate. These waters plot outside (left) the hardness triangle and are relatively enriched in Na^+ (Fig. 3). This type of water is commonly believed to originate from cation exchange processes. Certain soil types in the study area seem to be capable of releasing Na^{+} into solution and absorbing equivalent Ca^{2+} ions. The arrow on figures 1 and 2 hints schematically at a direction of groundwater movement away from recharge areas as identified by isotopes and from the flow net. The same method reveals infiltration water in the Agbara valley to be relatively enriched in Mg^{2+} while Cl^{-} prevails among the anions (Fig. 3).

CONCLUSIONS

The water chemistry depicted in the two diagrams (Figs. 2, 3) seem to reflect

- overall distribution of contamination due to limited groundwater replenishment and poor, uniform aquifer conditions, with a few local polluting sources in the Sabo district,
- only local contamination sources in the Akarabata district the impact of which is diminished by recharge and natural purification processes underground.

Sabo's groundwater appears somehow more stable while Akarabata's is in a steady state of alternation, hydraulically and chemically.

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