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SPATIAL VARIATION IN GROUNDWATER GEOCHEMISTRY AND WATER QUALITY INDEX IN PORT HARCOURT

Taiwo Ayodele Bolaji, and *Akaha Celestine Tse
Department of Geology, University of Port Harcourt, Nigeria
*Corresponding Author: e-mail: akacelts@yahoo.com

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ABSTRACT
The aim of this work is to convert the complex chemical quality data of groundwater in Port Harcourt area into a Water Quality Index, WQI, determine the 0perating geochemical processes and produce a map reflecting the spatial distribution of the water quality. Results of the physicochemical analysis of the groundwater from 71 boreholes show that 21% of the boreholes are low in pH indicating acidic water. Elevated electrical conductivity values in some of the water samples suggest pollution by sea water. Iron concentration is above the World Health Organization guide value in 9% of the boreholes studied, with maximum value up to 0.62mg/L. A high Coliform count in 9% of the wells poses a potential health risk. The water is generally classified as soft and fresh water based on its hardness and TDS. Concentrations of major ions are: $Ca > Mg > Na > K = HCO_3 > Cl > SO_4 > NO_3$ in the order of abundance. Ca-Mg-HCO_3 and Ca-Mg-SO_4-Cl are the dominant hydrogeochemical facies. Interpretation of the hydrochemical data suggests that ion exchange; reverse ion exchange and silicate weathering are the prevailing hydrochemical processes responsible for the groundwater chemistry. Hydrochemical indices (Mg/Ca, Cl/HCO_3, and Cation Exchange Value, (CEV) generally indicate low-salt inland water, with minimal marine influence. Using the weighted arithmetic mean method of the Water Quality Index Scheme, the groundwater is classified into five groups: Excellent (59%), Good (30%), Poor (11%), Very poor (4%) and Unsuitable (6%) with respect to human consumption. The general trend on the WQI map reveals that water quality decreases southwestwards suggesting a possible influence of the sea water.

INTRODUCTION
Since the commencement of oil exploitation in the Niger Delta in 1958, the population of Port Harcourt has grown from 179, 563 according to the 1963 population census through 213, 443 (1991 Census) to an estimate of 1.3 million in 2008. These figures show that the city and its region have witnessed an unprecedented growth. This rapid growth has several implications on the carrying capacity of the environment and has resulted in poor sanitary conditions across the city, which portends danger to the availability of safe drinking water arising from increasing sources of private water supply, solid waste generation and poor disposal system from various anthropogenic activities. With the present pace of industrialization and infrastructural development, groundwater resource contamination has become a matter of deep concern. However little or no efforts have been expended in combating these problems. For example, there is no policy regulating the development of private water supply via boreholes, and construction of household sewage disposal systems by septic tanks,

which can be found in every residential plot. This is against the backdrop of reported water quality problems, including the ingress of saline water in boreholes due to over pumping. Several groundwater quality investigations carried out in Port Harcourt metropolis consider the traditional physical, chemical and bacteriological constituents in line with the World Health Organization (WHO's) guide values. These studies have widely reported that iron and chloride concentrations in the Port Harcourt area and indeed, the Niger Delta region are above acceptable limits (Etu-Efeotor, 1981; Etu-Efeotor and Odigi, 1983; Amajor, 1986, 1989; Udom et al, 1999). However, most of these studies emphasize location-specific water quality with respect to individual chemical parameters without an attempt to give a picture of the local or regional water quality and its spatial distribution. This work is an attempt to use the physicochemical results of groundwater analysis to derive the water quality index, identify the chemical processes that control the hydrogeochemistry of the groundwater and produce a map showing the spatial variation of water quality in the study area.

Study area Description

Port Harcourt and its environs, the study area is the capital of Rivers State in the Niger Delta Sedimentary Basin of Southern Nigeria with an area of 924,000 km². Port Harcourt is located within latitudes 04^{0}43'N and 05^{0}00'N and Longitudes 06^{0}45'E and 07^{0}06'E (Fig.1) within the subequatorial region north of the Bight of Biafra. Its geomorphological features consist mainly of fresh water swamp, mangrove swamps, beaches, bars and estuaries (Etu-Efeotor and Odigi, 1983). The closeness of the area to the sea is marked by the localized Saltwater/Mangrove swamp to the extreme South of Port Harcourt, and Northwest of Okrika. The tributaries and creeks of the main Bonny River constitutes the local anatomizing drainage pattern. Generally, elevations ranging between 7 and 16 above sea level were recorded during the field studies, which reveals that the Port Harcourt area is low-lying. A 55 year rainfall data (1950-2006) obtained from the Nigerian Metrological Agency, Lagos, shows that rainfall in the area exhibits a double maxima regime with peaks in July and September and a little dry season in August.

Geologically, the study area lies within the Niger Delta basin which covers an area of over 70,000km^2 and is composed of an overall regressive clastic sequence reaching a thickness of 10,000 to 12,000m composed of Quatenary and Tertiary sedimentary deposits (Table 1). The Tertiary Formations are made up of three principal lithostratigraphic units based on the dominant environment of deposition (Short and Stauble, 1967). The oldest stratigraphic unit is the Akata Formation which is a deep marine pro-delta unit composed of mainly shales deposited during the Paleocence. Shales of the Akata Formation are generally regarded as the hydrocarbon source rocks of the Niger Delta. Overlying the Akata Formation is the paralic Agbada Formation, Eocene to Recent in age and consisting mainly of sequences of sandstones and shales. The sand units constitute the hydrocarbon reservoir while the shales form the seal. The topmost unit is the Benin Formation, Eocene to Recent in age, was deposited in continental fluviatile conditions. It consists mainly of over 90% massive porous sand with localized clay/shale interbeds and constitutes the regional aquifer. These subsurface lithostratigraphic units are overlain by various types of Quaternary deposits) which consist of either a relatively uniform lithology or rapidlly alternating sequences of Recent deltaic sand, silt, clay-

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peat or sand – silt – clay mixtures with the latter becoming increasingly more prominent towards the sea.

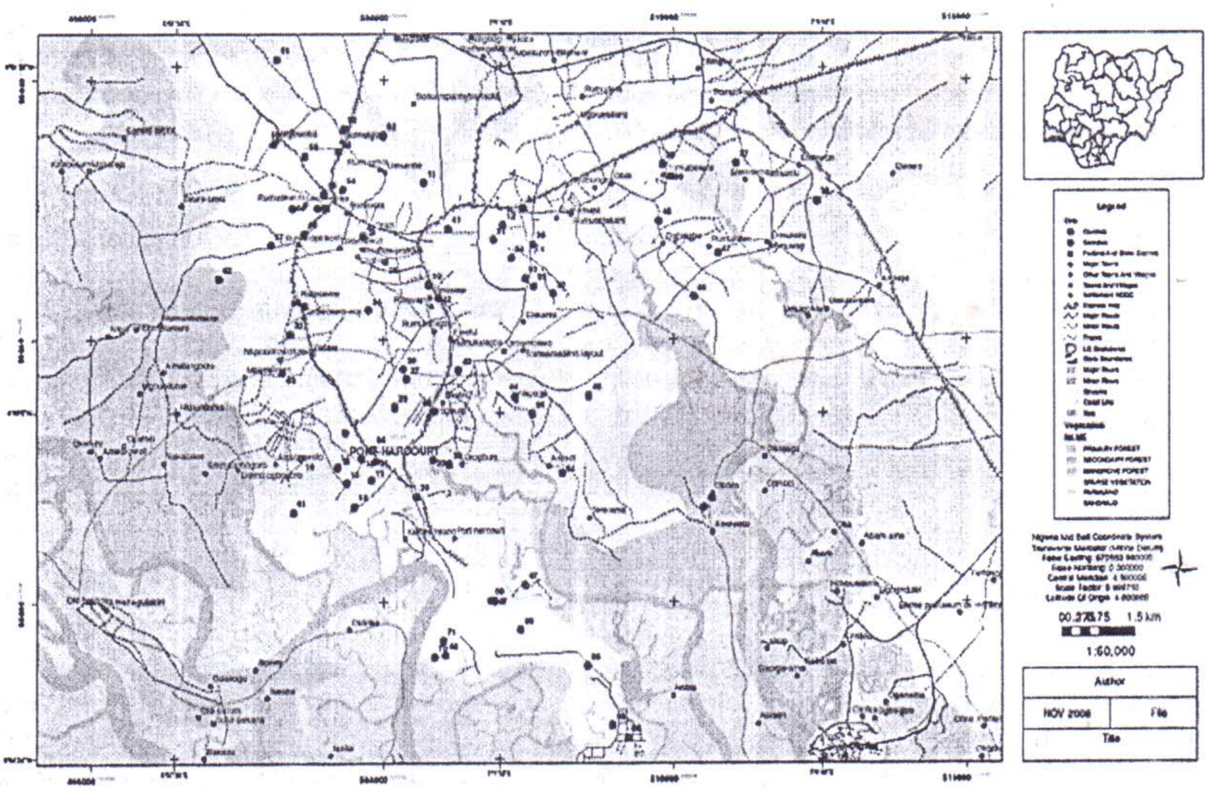

Fig.1: Location map of Port Harcourt, showing sampling points

Table 1.: Geologic units of the Niger Delta (after Short and Stauble, 1967).

Geologic Unit	Lithology	Age
Alluvium (General)	Gravel, sand, clay, silt	
Freshwater Backswamp, Meander belt	Sand, clay, some silt, gravel	
Saltwater Mangrove swamp and backswamp	Medium-fine sands, clay and some silt	Quaternary
Active/abandoned beach ridges	Sand, clay, and some silt	
Sombreiro-Warri deltaic plain	Sand, clay, and some silt	
Benin Formation (Coastal Plain sand)	Coarse to medium sand; subordinate silt and clay lenses	Miocene – Recent
Agbada Formation	Mixture of sand, clay and silt	Eocene – Recent
Akata Formation	Clay	Paleocene