

Assessment of the groundwater quality status and vulnerability of the coastal aquifer systems of Benin, Nigeria and Togo (West Africa)

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ABSTRACT

The coastal sedimentary transboundary aquifer of west Africa is partly shared by three countries including Benin Republic, Nigeria and Togo. The groundwater resources in the area are mainly for domestic water supply in both urban and rural areas. However, with the pressure on groundwater some problems exist which include but not limited to overexploitation, contamination and pollution from poor waste disposal and intrusion of sea water. The present work entails the identification of aquifers, determination of the quality status of the groundwater and assessment of the coastal aquifer vulnerability to pollution. The results showed that within the coastal area, seven (7) aquifers were identified as follows: Lower and Upper aquifers (Benin Republic), Deltaic and Benin Aquifers (Nigeria) and Continental Terminal (CT), Eo-Paleocene (Eo-Pa) and Maestrichtian (Ma) aquifers in Togo. The average physicochemical compositions are generally within the levels of portability. The mean concentration of nitrate however, exceeded 10mg/l in all the aquifers except the Deltaic Aquifer (mean 2.82mg/l) in Nigeria and Eo-Pa Aquifer in Togo (mean 7.88mg/l). The major factors controlling the water chemistry in the study area are sea water intrusion (enhanced Cl), carbonate dissolution/weathering (enhanced concentration of Ca & HCO₃) and human activities (enhanced concentration of NO₃). Vulnerability assessment according to GOD method indicates that the aquifer systems are lowly (Upper, Eo-Pa & Ma aquifers) through moderately (Deltaic Aquifer & CT aquifers) to highly (Lower & Benin Aquifers) vulnerable. Management of the groundwater resource will include mainly legislation towards construction and use of shallow wells/boreholes and regulation of abstraction to reduce saline contamination and proper waste management ate to reduce the concentration of nitrate as is presently done in Nigeria.

Keywords: Aquifer, hydrochemical, pollution, transboundary, vulnerability

1. INTRODUCTION

The coastal sedimentary basin of West Africa straddles several countries including Benin, Nigeria and Togo (Fig. 1). Almost all communities in the coastal area depends on groundwater for drinking and domestic purposes. However, despite the urbanization in the west coast of Africa, natural processes and indiscriminate disposal of waste forms a major threat to these aquifers.

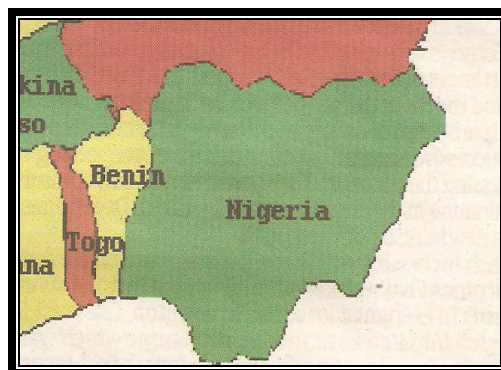


Fig. 1 Map of West Africa including Benin, Nigeria and Togo.

1.1 Objectives

The main objective of the present work therefore is to identify the major aquifers in the coastal parts of Benin Republic, Nigeria and Togo; determine the quality status of groundwater and assess the vulnerability of the aquifers to pollution as a basis of identifying major threats to the different aquiferous layers to enable proper management of the groundwater resource. The climatic and geological conditions for these areas are presented in Table 1.

Table 1 Area characteristics and vulnerability of aquifers in Benin, Togo and Nigeria

Country	Age	Aquifer	Lithology (Geology)	Climatic Conditions	Temp °C	Rainfall mm	Vulnerability Class
Benin	Quaternary	Upper	Sand and clay	Sub-equatorial type			High vulnerability
	Miocene-Pleistocene	Lower	Sand, gravel and clay	Two rainy and two dry seasons			Low vulnerability
Nigeria	Quaternary	Deltaic	Sand, silt, clay and peaty materials	Tropical rainforest	27	2400-4800	High vulnerability
	Tertiary	Benin	Sand and clay	One rainy and one dry season			Medium vulnerability
Togo	Quaternary	CT	Sand, gravel and clay	Guinea equatorial type			Medium vulnerability
	Eocene	Eo-Pa	Limestone and marl	Two rainy and two dry seasons	24-30	800-1400	Low vulnerability
	Maestrichtian	Ma	Sand and clay				Low vulnerability

1.2 Data

The hydrochemical data for coastal sedimentary of Benin was adapted from Boukari *et al.* (2008); Edet (2008) and some recently acquired data for Nigeria and from the work of Akouvi *et al.* (2008) for Togo.

2. GROUNDWATER QUALITY

2.1 Statistical assessment

The basic properties of groundwater are listed in Table 2. The mean values of the parameters in the groundwater samples for all the aquifers fall within the safe limits prescribed by WHO (1993) for drinking water. The only exception was pH for the Ma aquifer in Togo.

Table 2 Mean values of physicochemical Parameters for the different aquifers

Country	Aquifer	SEC μS/cm	TDS mg/l	pH	Na ⁺ mg/l	K ⁺ mg/l	Ca ²⁺ mg/l	Mg ²⁺ mg/l	Cl ⁻ mg/l	HCO ₃ ⁻ mg/l	SO ₄ ²⁻ mg/l	NO ₃ ⁻ mg/l	Hardness mg/l	Na Hazard	RSC	SAR
Benin	Upper	543.94	362.12	7.27	56.68	20.55	28.82	7.06	65.06	96.76	37.92	46.36	100.998	62.417	-0.443	3.172
	Lower	583.46	416.62	7.19	48.12	26.47	49.33	4.79	55.72	141.12	28.83	57.93	142.969	49.593	-0.552	1.803
Nigeria	Deltaic	272.49	150.50	6.56	33.16	5.55	28.13	4.29	80.60	56.93	7.19	2.82	87.938	48.036	-0.831	1.663
	Benin	228.58	117.40	6.30	18.94	2.30	2.22	0.46	10.84	44.81	2.82	27.55	7.465	87.608	0.585	3.631
Togo	CT	728.00	466.67	5.37	90.21	2.80	26.52	17.32	143.45	166.13	16.02	15.83	137.307	60.648	-0.046	3.335
	Eo-Pa	1099.00	704.49	7.55	68.90	7.83	110.34	37.99	105.58	581.54	50.19	7.88	431.610	28.126	0.851	1.534
	Ma	156.67	100.43	5.30	9.12	1.60	14.47	4.12	14.34	68.84	4.64	14.05	53.059	36.700	0.062	0.636
<i>Standards</i>	<i>WHO (1993)</i>	1400	1000	6.5-8.5	250	10	200	100	250		250	10				
Maximum value		Eo-Pa	Eo-Pa	Eo-Pa	CT	Lower	Eo-Pa	Eo-Pa	CT	Eo-Pa	Eo-Pa	Lower	Eo-Pa	Benin	Eo-Pa	Upper
Minimum value		Ma	Ma	Ma	Ma	Ma	Benin	Benin	Benin	Benin	Benin	Deltaic	Benin	Eo-Pa	Deltaic	Ma

CT-Continental Terminal; Eo-Pa-Eocene-Paleocene; Ma-Maestrichtian

Strong correlations exist between Na and Cl; Ca and HCO₃ and K and NO₃. These relationships identify sea water intrusion, carbonate dissolution and anthropogenic input as the main elements contributing to groundwater chemistry in these areas.

The R-mode factor analysis indicated three factors accounting for 85.516% of the variance in the data set. Factor 1 (56.473%) has high loadings for HCO₃ and Ca is interpreted as mainly due to carbonate weathering. This is attributed to the limestones and marls of the Eo–Pa Aquifer (Togo). Factor 2 (16.152%) indicates the effect of anthropogenic input given the high loading for K and NO₃ as in the Lower and Upper Aquifers in Benin (Boukari et al., 1996). Factor 3 (12.891%) with high loaders for Na and Cl is as a result of seawater contamination in Benin, Nigeria and Togo.

2.2 Quality Status and vulnerability of aquifers

Based on the %Na the groundwaters were classified as very good to good for irrigation. On individual basis only few samples for the Lower and Upper Aquifers (Benin Republic), CT and Eo–Pa Aquifers (Togo) were grouped as good to permissible and doubtful to unsuitable. The sodium adsorption ratio (SAR) indicates that the groundwater is satisfactorily for irrigation use in almost all soil types. In addition, the Residual Sodium Carbonate (RSC) values ranged of between –0.831 and 0.661 mg/l which is < 1.25 mg/l and thus safe for irrigation (Richards, 1954).

Vulnerability of the different aquifers in the area was based on Groundwater occurrence (aquifer type), Overall aquifer class (lithology and porosity) and Depth to water table (GDD, Table 1) designed by Foster (1987). The data show that the aquifers are lowly (Upper, Eo-Pa & Ma Aquifers) through moderately (Benin & CT Aquifers) to highly (Lower & Benin Aquifers) vulnerable.

4. MANAGEMENT ISSUES AND CONCLUSIONS

The study demonstrates that three main factors control the groundwater quality in coastal parts of West Africa namely:

- (i) sea water intrusion due to elevated concentration of Cl⁻; (All aquifers except Benin aquifer in Nigeria and Ma Aquifer in Togo).
 - For the purpose of management, wells/shallow boreholes should be encouraged and abstraction regulated.
- (ii) anthropogenic as a result of enhanced concentration of NO₃⁻ (as in Benin)
 - In order to safe guard the resources, proper management of waste should be put in place (as presently seen in most cities in Nigeria).
- (iii) carbonate dissolution due to high concentration of Ca²⁺, Mg²⁺ and HCO₃⁻ (especially, in Eo-Pa Aquifer in Togo)
 - These waters will require some form of treatment. However, detailed studies will guide the siting of boreholes in areas of relatively soft water.

Generally, proper site investigation should be carried out in these areas before a waste dump or landfill is sited due to high vulnerability of some of the aquifers.

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