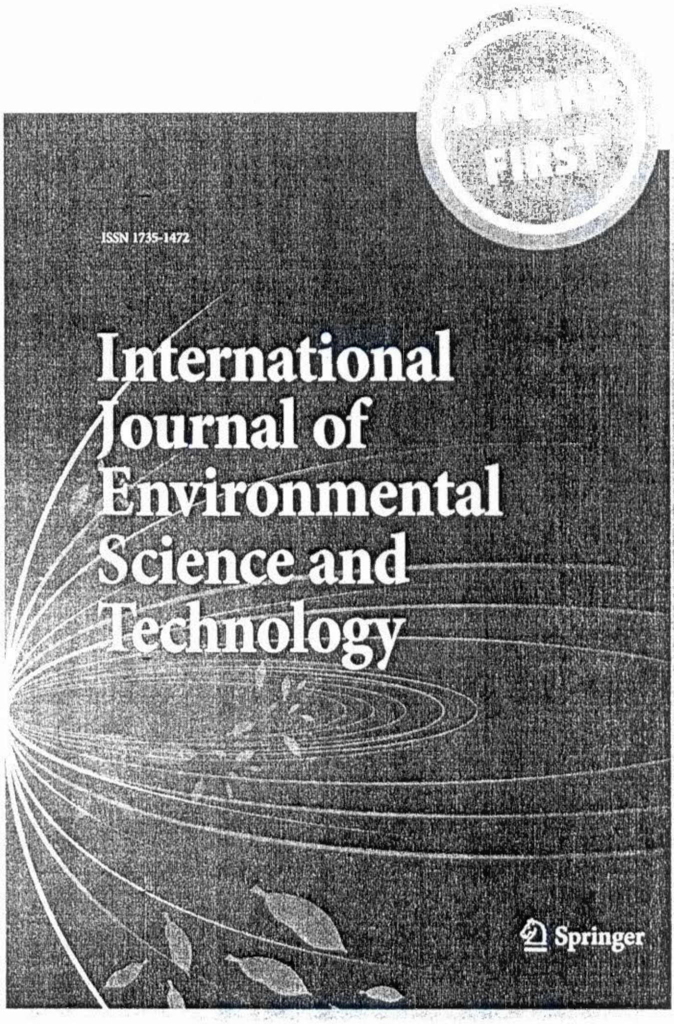
Geochemical and quality assessment of groundwater in some Nigerian basement complex

A. M. Odukoya

International Journal of Environmental Science and Technology

ISSN 1735-1472

Int. J. Environ. Sci. Technol.
DOI 10.1007/s13762-015-0789-y



Springer

Table 5 SAR hazard of irrigation water

	SAR	Notes
None	<3.0	No restriction on the use of recycled water
Slight to moderate	3.0–9.0	From 3 to 6 care should be taken to sensitive crops
		From 6 to 8 gypsum should be used. Not sensitive crops
		Soils should be sampled and tested every 1 or 2 years to determine whether the water is causing a sodium increase
Acute	>9.0	Severe damage. Unsuitable

Table 6 Summary of trace elements in groundwater

Trace elements (ppb)	Min	Max	Mean	SD	Median	EPA (2012)		WHO (2012)	% above standard
						MCLG	MCL		
As	<0.5	9.4	2.97	2.97	1	0	10	10	
B	<5	413	25.72	73.86	8			2400	
Ba	5.48	909.76	79.32	153.29	37.26		700	700	2
Be	<0.05	0.37	0.2	0.21	0.12			12	
Cd	<0.05	0.56	0.17	0.16	0.1	5	5	3	
Ce	<0.01	7.5	1.37	2.08	0.44				
Co	<0.02	5.17	1.01	1.13	0.6				
Cr	<0.5	30.8	5.32	6.39	2.4		50	50	
Cu	[illegible]	86.6	10.07	17.58	1.65	1300	1000	2000	
La	<1	6.5	1.38	1.06	1				
Mn	<0.05	356.1	59.8	86.01	28.64		50		12
Mo	<0.1	24.8	3.45	7.25	0.2			70	
Ni	<0.2	15.7	2.15	3.23	1			20[a]	2
Pb	<0.1	20.5	4.15	5.38	1.4	0	10	10	12
Sb	0.11	7.78	0.94	1.29	0.77	6	6	6	2
Se	<0.5	20.9	5.65	7.66	2.24	50	50	40	
Tl	<0.01	0.14	0.03	0.03	0.02				
U	<0.02	1.85	0.16	0.32	0.05			30	
V	<0.2	15.3	1.27	2.55	0.6				
W	<0.02	2.27	0.62	1.1	0.09				
Zn	1.8	302.9	39.17	53.26	17.8		5000	1000	

[a] National primary drinking water standard

Goering 1993). The inorganic compounds are more toxic than the organic compounds (Stemmer 1976). Soluble antimony salts can cause gastrointestinal mucosa and trigger sustained vomiting after oral uptake. Other effects include abdominal cramps, diarrhea and cardiac toxicity (Elinder and Friberg 1986).

Barium is not considered to be an essential element for human nutrition (Schroeder et al. 1972). At high concentrations, barium causes vasoconstriction by its direct stimulation of arterial muscle, peristalsis as a result of the violent stimulation of smooth muscles and convulsions and paralysis following stimulation of the central nervous system (Stockinger 1981). The prevalence of dental caries has also been linked to high dose of barium. Death may occur in a few hours or a few days depending on the dose and solubility of the barium salt. The health effect of excess nickel in water includes skin irritation and hypersensitivity. It can also be carcinogenic (WHO 2005).

Manganese is an essential element for man. Excess intake of Mn in water can lead to neurological effects (Canavanet et al. 1934; Cook et al. 1974; Roels et al. 1999; ATSDR 2000). Exposure to high levels of manganese can also lead to a disease called manganism which is characterized by a Parkinson-like syndrome including weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless masklike facial expression and slow clumsy movement of limbs.

The pollution index was used in this study to evaluate the degree of trace metal contamination in water samples (Subramani et al. 2010; Todd 1980; U.S. Environmental

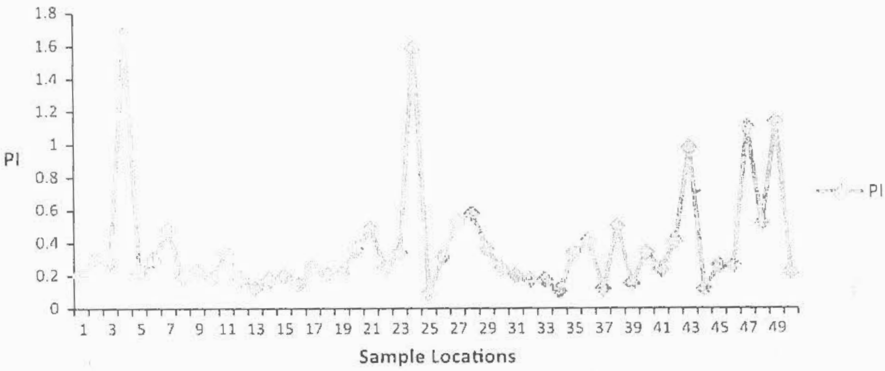


Fig. 7 Plots of pollution index against sample locations

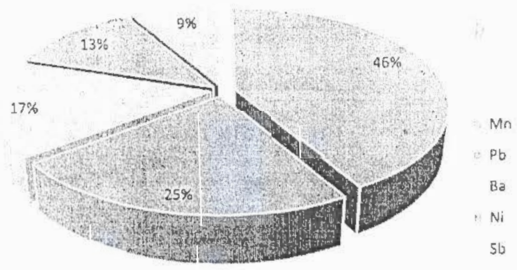


Fig. 8 Percentage of contaminated trace elements

Protection Agency 2002, 2008, 2009). The tolerable level is the element concentration in the water considered safe for human consumption. The tolerable level given by Wilcox (1948) and U.S. Environmental Protection Agency (2012) was used for water, and the pollution index can be calculated by the formulae:

$$PI = (\text{Heavy metal concentration in water}/\text{Tolerable level})/\text{Number of heavy metals}. \quad (4)$$

The PI among all sites varied from 0.09 to 1.76 with a mean value of 0.37 (Fig. 7). Water sample with pollution index >1 is regarded as being contaminated although the water is generally contaminated as much as there is any kind of contamination in it. Eight percentage of the water samples which include W4, W24, W47 and W49 showed pollution index above 1 (Fig. 7).

Mn contributed the highest percentage (46 %) to the pollution index. This was followed closely by Pb which contributed 25 %. Ba, Ni and Sb contributed 17, 13 and 9 %, respectively (Fig. 8). These trace elements just like major elements were from both geogenic and anthropogenic origin.

Conclusion

Fifty samples from hand dug wells and boreholes were collected within Ijebu Igbo and its environs, southwestern Nigeria. The purpose was to establish preliminary baselines for constituents in the groundwater and also to determine the quality for both drinking and irrigation purposes.

The pH and TDS of groundwater showed that the water varied within slightly acidic to basic and fresh, respectively. Ca, Mg, Si and S were all within recommended standard for both drinking and irrigation purposes. Al, Fe, Na, K and P were above the EPA 2012 recommended standard for drinking water in 79, 23, 3, 37 and 6 % of the water samples, respectively.

There is involvement of silicate weathering in the geochemical processes, which contributed mainly calcium, magnesium and potassium ions to the groundwater. $Na^+ + K^+$ contributed more to water chemistry than $Ca^+ + Mg^+$. The high concentration of Fe, Al, Na, K and P which were above recommended standards could also be linked to anthropogenic sources which include waste dumpsites, agricultural activities and sewage that are common in the study area.

SAR in water samples ranged from 0.12 to 10.43 and can be classified as excellent and good for irrigation. MAR varied between 0.89 and 87.94 %. The values obtained in only 22 % of the water samples were <50 % considered suitable with no hazardous effects to the soil. The values obtained for the SSP parameter ranged between 62.79 and 90.32 %. Seventy-eight percentage of the water samples fall within fair classification of 80 %, and the remaining samples fall within poor (>80 %) for the purpose of irrigation. Kellys ratio (KR) obtained for the water samples was 0.008–0.08 meq/L. The values obtained were lower than the permissible limit of 1.0 for all the samples. Water samples were also above 15 % recommended standard for irrigation water based on Na%.

Trace element analysis showed that the concentration of Te and Ti was below detection limit for all the samples. As, B, Cd, Cr, Cu, Mo, Ni, U and Zn though present in water were below recommended standards for all the samples. Ni and Sb exceeded recommended standard only in sample W24, and Ba exceeded recommended standard in W20 with value as high as 909.76 ppb. Mn and Pb were higher than recommended standard in 12 % of the samples. The pollution index varied from 0.09 to 1.66 with 8 % of the water samples showing pollution index above 1.

Generally, groundwater in the study area is suitable for both domestic and irrigation uses except samples W4, W24, W47 and W49. However, since heavy metals are not biodegradable, they tend to bioaccumulate and biomagnify in the body and eventually become harmful to human health.

Acknowledgments This is to appreciate the effort of Mr. Olagbaju, a senior technologist of the Department of Geosciences, University of Lagos, Nigeria, who help in some of the laboratory analysis of the samples.

References

Abulude FO, Obidiran GO, Orunghemi S (2007) Determination of physicochemical parameter and trace metal contents of drinking water samples in Akure. EJEAF Chem 6(8):2297–2303

Aaebo BA, Adetoyinbo AA (2009) Assessment of groundwater quality in unconsolidated sedimentary coastal aquifer in Lagos State, Nigeria. Sci Res Essay 4(4):314–319

Adediji A, Ajibade LT (2005) Quality of well water in Ede Area, southwestern Nigeria. J Hum Ecol 17(3):223–228

Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB (2007) Assessment of groundwater quality in a typical rural settlement in southwest Nigeria. Int J Environ Res Public Health 4(4):307–318

Ahiarakwem CA, Ejimadu OG (2002) Geochemical properties of groundwater in Orlu area of Imo State, Southeastern Nigeria. Water Res 13:19–22

Ajayi O (1998) Quality of groundwater in the Agbabu oil sands area of the Ondo State, Nigeria. J Afr Earth Sci 27(2):299–305

Ajayi O, Obot AU (1998) Quality of groundwater in the Coastal Plain Sands Aquifer of The Akwa Ibom State, Nigeria. J Afr Earth Sci 27(2):259–275

Alagbe SA (2006) Preliminary evaluation of hydrochemistry of the Kalambaina Formation, Sokoto Basin, Nigeria. Environ Geol 51:39–45

ATSDR (2000) Toxicological profile for manganese. United States Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA

Ayers RS, Westcot DW (1985) Water quality for agriculture FAO irrigation and drain. 29(1):1–109

Bartarya SK (1993) Hydrochemistry and rock weathering in a sub-tropical lesser Himalayan river basin in Kumaun, India. J Hydrol 146:149–174

Boboye OA (2008) Hydrogeochemical assessment of groundwater in Iddo area, southwestern Nigeria. J Min Geol 44(2):183–201

Bowman CA, Bobrowsky PT, Selinus O (2003) Medical geology: new relevance in the earth sciences. Episodes 26(4):270–278

Bryan G, Donald A, Robert G, Jason W, Dan M (2007) Managing irrigation water quality for crop production in the Pacific Northwest. A Pacific Northwest Extension publication

Bullen TD, Krabbenhoft DP, Kendall C (1996) Kinetic and mineralogic controls on the evolution of ground-water chemistry and 87Sr/86Sr in a sandy silicate aquifer, northern Wisconsin. Geochim Cosmochim Acta 60:1807–1821

Canavanet MM, Cobb S, Srinker C (1934) Chronic manganese poisoning. Arch Neurol Psychiatry 32:501–512

Cardona A, Rivera JJC, Alvarez RH, Castro EG (2004) Salinization in coastal aquifers of arid zones: an example from Santo Domingo, Baja California Sur, Mexico. Environ Geol 45:350–366

Cederstorm DJ (1946) Genesis of groundwater in the coastal plain of Virginia. Environ Geol 41:218–245

Chae GT, Kim K, Yun ST, Kim KH, Kim SO, Choi BY, Kim HS, Rhee CW (2004) Hydrogeochemistry of alluvial groundwaters in an agricultural area: an implication for groundwater contamination susceptibility. Chemosphere 55:369–378

Chukwu GU (2008) Water quality assessment of boreholes in Umuahia South Local Government Area of Abia State, Nigeria. Pac J Sci Technol 9(2):592–598

Cook DG, Fahn S, Brait KA (1974) Chronic manganese intoxication. Arch Neurol 30:59–64

Dash JR, Dash PC, Patra HK (2006) A correlation and regression study on the ground water quality in rural areas around Angul Talcher industrial zone. Indian J Environ Prot 26(6):550–558

Delleur JD (1999) The handbook of groundwater engineering. CRC Press/Springer, New York

Edet AE (1993) Groundwater quality assessment in parts of eastern Niger delta. Niger Geol 22:41–46

Edet E, Okereke CS (2002) Delineation of shallow groundwater aquifers in the coastal plain sand of Calabar Area using surface resistivity and hydro-geological. J Afr Earth Sc 35(3):433–441 doi:10.1016/S0899-5362(02)00148-3

Edet AE, Worden RH, Mohammed EA, Preston MR (2011) Hydrogeochemical processes in a populated shallow Coastal Plain Sand Aquifer southeastern Nigeria. Environ Earth Sci. doi:10.1007/s12665-011-1175-9

Efe SI, Ogban FE, Horsfall M, Akporhonor EE (2005) Seasonal variations of physico-chemical characteristics in water resources quality in western Niger Delta region, Nigeria. J Appl Sci Environ Manag 9(1):191–195

Elinder CG, Friberg L (1986) Antimony. In: Friberg L, Nordberg GF, Vouk VB (eds) Handbook on the toxicology of metals. Elsevier, Amsterdam, pp 26–42

Erah PO, Akujieze CN, Oteze GE (2002) The quality of groundwater in Benin City: a baseline study on inorganic chemicals and microbial contaminants of health importance in boreholes and open wells. Trop J Pharma Res 1(2):75–82

Ezeigbo HI (1989) Geological and hydrogeological influences on the Nigeria Environment. Water Resour 1(1):37–44

Fakir Y, Mernissi ME, Kreuser T, Berjami B (2002) Natural tracer approach to characterize groundwater in the coastal Sahel of Oualidia (Morocco). Environ Geol 43:197–202

Fowler BA, Goering PL (1991) Antimony. In: Merian E (ed) Metals and their compounds in the environment: occurrence, analysis, and biological relevance. Weinheim, New York, pp 743–750

Frape SK, Fritz P, McNutt RH (1984) Water–rock interaction and chemistry of groundwaters from the Canadian Shield. Geochim Cosmochim Acta 48:1617–1627

Freeze RA, Cherry JA (1979) Groundwater. Prentice Hall, Englewood Cliffs

Garrels RM, Mackenzie FT (1967) Origin of the chemical composition of some springs and lakes. In: Gould RF (ed) Equilibrium concepts in natural water systems, Advances in Chemistry Series, vol 67. Amer. Chem. Soc., Washington, pp 222–242

Harivandi MA (1999) Interpreting turfgrass irrigation water test results. Publication 8009. Regents of the University of California. Division of Agriculture and Natural Resources

Hem JD (1985) Study and interpretation of the chemical characteristics of natural water, 3rd edn. US Geol. Surv. Water Suppl. Pap 2254, p 263

Jacks G (1973) Chemistry of groundwater in a district in Southern India. J Hydrol 18:185–200

32

Jatau BS, Bajeh I (2007) Hydrogeological appraisal of parts of Jema Local Government, North Central Kaduna State, Nigeria. Res J Appl Sci 2(11):1174–1181

Jones HA, Hockey RD (1964) The geology of part of Southwestern Nigeria. Geological Survey of Nigeria. Bull., 1964, pp. 31, 87

Joshi DM, Kumar A, Agrawal N (2009) Assessment of the irrigation water quality of River Ganga in Haridwar District India. RASAYAN J Chem 2(2):285–292

Juang DF, Lee CH, Hsueh SC (2009) Chlorinated volatile organic compounds found near the water surface of heavily polluted rivers. Int J Environ Sci Technol 6(4):545–556

Kenoyer GJ, Bowser CJ (1992) Groundwater chemical evolution in a sandy silicate aquifer in northern Wisconsin: 1. Patterns and rates of change. Water Resour Res 28:579–589

Kim K (2002) Plagioclase weathering in the groundwater system of a sandy, silicate aquifer. Hydrol Process 16:1793–1806

Kim K (2003) Long-term disturbance of ground water chemistry following well installation. Ground Water 41:780–789

Longe EO, Malomo S, Olorunniwo MA (1987) Hydrogeology of Lagos metropolis. J Afr Earth Sci 6(2):163–174

Lowrance R, Altier LS, Newbold JD, Schnabel RR, Groffman PM, Denver JM, Correll DL, Gilliam JW, Robinson JL, Brinsfield RB, Staver KW, Lucas W, Todd AH (1997) Water quality functions of Riparian forest buffers in Chesapeake Bay watersheds. Environ Manag 21:687–712

Nagarajan R (2010) Hydrogeochemistry in parts of Ariyalur region, Precambrian district, Tamilnadu, India. J Appl Geochem 12(2):253–260

Nganje TN, Adamu CI, Ugbaja AN, Amah AE (2010) Evaluation of hydrogeochemical characteristics of groundwater in parts of Lower Benue Trough, Nigeria. Chin J Geochem 29:398–406

Nkotagu H (1996) Origins of high nitrate in groundwater in Tanzania. J Afr Earth Sci 21:471–478

Nordstrom DK, Ball JW, Donahoe RJ, Whittemore D (1989) Groundwater chemistry and water–rock interactions at Stripa. Geochim Cosmochim Acta 53:1727–1740

Obiefuna GI, Sheriff A (2011) Assessment of shallow ground water quality of Pindig Gombe Area, Yola Area, NE, Nigeria for irrigation and domestic purposes. Res J Environ Earth Sci 3(2):131–141

Odukoya AM, Abimbola AF (2010) Contamination assessment of surface and groundwater within and around two dumpsites. Int J Environ Sci Technol 7(2):367–376

Ofoma AE, Omologbe DA, Aigberua P (2005) Physico-chemical quality of groundwater in parts of Port Harcourt City, eastern Niger Delta, Nigeria. Water Res 16:18–24

Ogunbanjo MI (2004) The geochemical evolution of water resources in and around Ijebu-Ode Town, southwestern Nigeria and its environmental implications. Water Res 15:20–25

Oladeji OS, Adewoye AO, Adegbola AA (2012) Suitability assessment of groundwater resources for irrigation around Otte Village, Kwara State, Nigeria. Int J Appl Sci Eng Res 1(3):437–445. doi:10.6088/ijaser.0020101044

Olarewaju VO, Olorunfemi MO, Alade O (1997) Chemical characteristics of groundwater from some parts of the basement complex of central Nigeria. J Min Geol 33(2):135–139

Olobaniyi SB, Efe SI (2007) Comparative assessment of rainwater and groundwater quality in an oil producing area of Nigeria: environmental and health implications. J Environ Health Res 6(2):111–118

Olobaniyi SB, Owoyemi FB (2004) Quality of groundwater in the Deltaic Plain Sands aquifer of Warri and environs, Delta State, Nigeria. Water Resour 15:38–44

Olorunfemi MO (1990) The hydrogeological implication of topographic variation with overburden thickness in basement area of S.W Nigeria. J Min Geol 26(1):145–152

Otezie GE (1991) Potability of groundwater from the Rima Group aquifer in the Sokoto Basin. J Min Geol 27(1):17–24

Ozoko DC (2004) Geochemical and microbiological studies of the natural water systems in Agila, Benue State, Nigeria. Water Res 15:60–65

Perez JMS, Antiguedad I, Arrate I, Linares CG, Morelld I (2003) The influence of nitrate leaching through unsaturated soil on groundwater pollution in an agricultural area of the Basque country: a case study. Sci Total Environ 317:173–187

Qiu J (2010) China faces up to groundwater crises. Nature 466:308

Rahaman MA (1976) Review of the basement geology of southwestern Nigeria. In Kogbe CA (ed) Geology of Nigeria. Elizabethan Publishing Company, Lagos, Nigeria, pp 41–58

Richards LA (1954) Diagnosis and improvement of saline and alkali soil. Agricultural Handbook 60. USDA, Washington

Roels HA et al (1999) Prospective study on the reversibility of neurobehavioral effects in workers exposed to manganese dioxide. NeuroToxicology 20:255–271

Rogers RJ (1987) Geochemical evolution of groundwater in stratified drift and arkosic bedrock aquifer in north central Connecticut. Water Resour Res 23:1531–1545

Sarin MM, Krishnaswamy S, Dilli K, Somayajulu BLK, Moore WS (1989) Major ion chemistry of the Ganga-Brahmaputra river system: weathering process and fluxes to the Bay of Bengal. Geochim Cosmochim Acta 53:997–1009. doi:10.1016/0016-7037(89)90205-6

Schoeller H (1965) Qualitative evaluation of groundwater resources. In: Methods and techniques of groundwater investigations and development an international guide for research and practice. UNESCO, pp 54–83

Schoeller H (1967) Geochemistry of groundwater—an international guide for research and practice, Chap. 15, pp 1–18. UNESCO

Schroeder HA, Tipton IH, Nason P (1972) Trace metals in man: strontium and barium. J Chronic Dis 25:491–517

Sekabira K, Oryem Origa H, Basamba TA, Mutumba G, Kakudidi E (2010) Assessment of heavy metal pollution in the urban stream sediments and its tributaries. Int J Environ Sci Technol 7(3):435–446

Stallard RF, Edmond JM (1983) Geochemistry of the Amazon, the influence of geology and weathering environment on the dissolved load. J Geophys Res 88:9671–9688. doi:10.1029/JC088iC14p09671

Stemmer KL (1976) Pharmacology and toxicology of heavy metals: antimony. Pharmacol Therapeut Part A 1:157–160

Stigter TY, Ooijen SPJV, Post VEA, Appello CAJ, Dill AMMC (1998) A hydrogeological and hydrochemical explanation of the groundwater composition under irrigated land in a Mediterranean environment, Algarve, Portugal. J Hydrol 208:262–279

Stockinger HE (1981) The metals. In: Clayton GD, Clayton FE (eds) Patty's industrial hygiene and toxicology, vol 2A, 3rd edn. Wiley, New York, pp 1493–2060

Subramani T, Rajmohan N, Elango L (2010) Groundwater geochemistry and identification of hydrogeochemical processes in a hard rock region, Southern India. Environ Monit Assess 162:123–137

Todd DK (1980) Groundwater hydrology, 2nd edn. Willey, New York

Udom GJ, Esu EO, Ekwere SJ (1998) Quality status of groundwater in Calabar Municipality, southeastern Nigeria. Global J Pure Appl Sci 4(2):163–168

Udom GJ, Ushie FA, Esu EO (2004) A geochemical survey of groundwater in Khana and Gokana Local Government Areas of Rivers State, Nigeria. J Appl Sci Environ Manag 6(1):53–59

UNDP (1971) Groundwater investigations in Tamil Nadu (phase I) United Nations Tech Rep, New York

UNESCO (2007) UNESCO water portal newsletter no 161: water-related disease

U.S. Environmental Protection Agency (2002) Proposed radon in drinking water rule: Washington, D.C., Office of Water. http://www.epa.gov/safewater/radon/proposal.html. Accessed Jan 2009

U.S. Environmental Protection Agency (2008) U.S. EPA's 2008 Report on the Environment (Final Report). U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-07/045F (NTIS PB2008 112484)

U.S. Environmental Protection Agency (2009) National primary drinking water standards and national secondary drinking water standards. Washington, D.C., Office of Water, EPA 816–F–09–0004, 6 p. http://www.epa.gov/safewater/consumer/pdf/mcl.pdf

U.S. Environmental Protection Agency (2012) Drinking-water advisory-consumer acceptability advice and health effects analysis on sodium. Washington, D.C., Office of Water, EPA 822–R–02–032, 34 p

Vetrimurugan E, Elango L, Rajmohan N (2012) Sources of contaminants and groundwater quality in the coastal part of a river delta. J Environ Sci Technol, Int. doi:10.1007/s13762-012-0138-3

WHO (World Health Organization) (1993) Guidelines for drinking water quality, vol 1 Recommendations, Geneva, Switzerland

WHO (2005) Nickel in drinking-water. Background document for development of World Health Organisation Guidelines for Drinking-water Quality

WHO (2012) Guidelines for drinking water quality, recommendations, 4th edn. World Health Organization library cataloguing in publication data. http://www.int

Wilcox LV (1948) The quality of water for irrigation use. US Department of Agriculture Technology Washington DC Bulletin 962, 40 pp

Zilberbrand M, Rosenthal E, Shachnai E (2001) Impact of urbanization on hydrochemical evolution of groundwater and on unsaturated-zone gas composition in the coastal city and on unsaturated-zone gas composition in the coastal city of Tel Aviv, Israel. J Contam Hydrol 50:175–208