International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **2(4),** 15-20, April **(2013)** *Int. Res. J. Environment Sci.*

Prolonged Gas Flaring and Water Quality in Obiakpu Egbema, IMO State, Nigeria

Egwurugwu J.N.[1*], Nwafor A.[2], Olorunfemi O.J.[2], Nwankpa P.[3] and Okwara J.E.[4]
[1]Department of Human Physiology, College of Medicine and Health Sciences, Imo State University, Owerri, NIGERIA
[2]Department of Human Physiology, College of Health Sciences, University of Port Harcourt, Choba, NIGERIA
[3]Department of Medical Biochemistry, College of Medicine and Health Sciences, Imo State University, Owerri, NIGERIA
[4]Department of Chemical Pathology, College of Medicine, Nnamdi Azikiwe University, Awka, NIGERIA

Available online at: www.isca.in
Received 26th February 2013, revised 14th March 2013, accepted 8th April 2013

Abstract

Water is essential for life, though human activities have made some water sources unsuitable for human comsumption. This study evaluated the effects of gas flaring on the physico-chemical characteristics of water sources at Obiakpu, Egbema , Nigeria. Surface and ground water samples from the area were compared with samples from Alaoma Owerre-Ebeiri, a non gas flared community. Both water sources were then compared with WHO standards for drinking water. The results revealed that water sources from the gas flared area have raised levels of conductivity, total dissolved solids, total hardness, temperature, dissolved oxygen, chemical oxygen demand,chloride, nitrate, nitrites, magnesium, manganese, sulphates, cadmium, lead, copper, calcium, potassium and zinc when compared with water from non-gas flared sources. In conclusion, gas flaring can pollute water sources within oil and gas facilities, thereby making them unsuitable for human consumption. Oil and gas industries should therefore treat water sources within their areas of operations in addition to other remediation measures as part of their social responsibility.

Keywords: Prolonged gas flaring, water pollution, heavy metals, physical, chemical.

Introduction

Water is vital for life. Water is the largest component of the human body, making up to 50 to 70% of the body's weight. An adult can survive for up to 8 weeks without food but only a few days without water because there is no storage site for water[1]. Water is usually added to the body by two main sources, namely: firstly and majorly, ingestion in form of liquids or water in the food, and secondly, it is synthesized in the body as a result of oxidation of carbohydrates[2]. The various uses of water include drinking and household needs, recreation, agriculture, industry and commerce, thermoelectricity/energy and medicine (e.g. hydrotherapy, dialysis, etc)[3]. Water also serves as a medium for chemical reactions, temperature regulation, removal of waste products, maintenance of homeostasis and lubrication[1]. Water is a prime natural resource, a basic human need and a very important national asset, therefore, its use needs appropriate planning, development and management[4]. Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all[5].

Man needs water in right quantity and quality and the water has to be exempt from toxic substances and from excessive quantity of minerals or organic minerals[6,7]. Water is the source of life as well as the source of death when it is contaminated by chemicals and organic substances[8,9]. Various regulatory agencies such as WHO and NAFDAC (National agency for food and drug administration and control) have been emphasizing on the need to provide an unpolluted water to the populace. Water pollution is the contamination of water bodies and their substrates, when pollution exceeds their self-purification capacity, or their sink capacity for pollutants[10].

Pollution not only makes fresh water undrinkable but also unsuitable for industrial and agricultural purposes[6].

Nigeria is the 6th largest producer of oil in the world and it is endowed with more gas reserves than oil[11,12]. In 2011, a total of 2,400.40 Billion Standard Cubic Feet(BSCF) of Natural Gas was produced by the sixteen oil companies; of the quantity produced, 1,781.37 BSCF (74%) was utilized, while 619.03BSCF (26%) flared[12]. There are many processes in the oil and gas industry operations such as exploration, drilling, refining and distribution to final consumers. In the course of most of these activities, wastes either in solid, liquid or gaseous form are generated and discharged into the environment[13]. Flared gas is one of the generated wastes in the oil and gas industry.

Gas Flaring is a common practice in the oil and gas industry, of burning off unwanted, flammable gases via combustion in an open atmosphere, non-premixed flame[14]. Gas flaring is one anthropogenic activity defined as the "wasteful emission of greenhouse gases (GHGs) that cause global warming, disequilibrium of the earth, unpredictable weather changes and major natural disasters because it emits a cocktail of benzene and other toxic substances that are harmful to humans, animals, plants and the entire physical environment"[15].

According to the World Bank[16] global gas flaring has increased from 138 to 140 billion cubic meter in 2011 and Russia is the largest gas flaring country, followed by Nigeria, Iran and Iraq. Nigeria flared 14.6 bcm of natural gas in 2011 and most of this occur in the Niger Delta region. During gas flaring, incomplete combustion emits various compounds such as methane, propane, and hazardous air pollutants such as volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and soot[17]; these volatile organic compounds have various potential health effects[18].

Nigerian crude oil is known to contain heavy metals such as Al, Zn, As, Ba, Fe, Pb, Co, Cu, Cr, Mn, Ga, Sb, Ni and V[19]. Nwankwo and Ogagaure[20] have noted that surface and underground waters in gas flared environments tend to have more concentrations of heavy metals such as lead, barium, cadmium, selenium and copper than non-gas flared area.

The pollution of water sources by heavy metals, such as lead(Pb), cadmium(Cd), arsenic (As), copper (Cu) and zinc (Zn) occurs when their concentrations in water exceeds their tolerance limits and such pollution has been reported to cause deleterious effects in biosystems[21,8]. Cd is a metal toxin of continuing worldwide concern, daily intake/exposure, albeit in small quantities, over a period of time, is associated with a number of adverse health effects, attributable to distinct pathological changes in a variety of tissues and organs and systems[22-24] reflecting the multiplicity of Cd targets and toxicities[25]. Cadmium exposure has been implicated in hypertension and atherosclerosis[26-28,23-24].

Trace metals and bio-exchangeable cations are required for the normal physiological functioning of the body. Iron is the central metal ion for haemoglobin, its toxicity can lead to hemochromatosis and possible damage to organs, especially the heart, liver, endocrine system, pancreas[29,30]. Zinc is important for male reproduction, its toxicity can cause lethargy, liver and kidney failure and anaemia[31-33]. Magnesium is an important electrolyte constituent that helps in ensuring electrical neutrality, maintain osmotic pressure relationships, and serves as buffer[34]. Calcium is an important element for the formation of strong bones and teeth[35]. Ca deficiency can cause defective bone formation.

There is paucity of literature on the effects gas flaring on the physico-chemical features of water in areas of Imo State with oil and gas industries. This study was therefore aimed at investigating the effects of prolonged exposure to gas flares on water sources in gas flared area of Obiakpu Egbema.

Material and Methods

Study areas: Water was collected from two different communities, with very similar characteristic features, in the Imo East Senatorial zone of Nigeria. Imo State is one of the nine states in the Niger Delta region of Nigeria. Egbema, an oil and gas producing community with active gas flaring by shell petroleum development company (SPDC) for more than 40 years, constitute the test community. This community is also located in between many other active oil and gas flaring sites such as Ossu, Oguta and Izombe oil and gas fields operated by Addax and Akri and Ebocha oil and gas fields run by Nigeria Agip Oil Company. Alaoma Owerre-Ebeiri autonomous community, a non oil and gas producing area, constitute the control community. The residents of both communities were mainly farmers, traders and civil servants and share many common characteristics.

Collection of water samples: Water samples were abstracted from two drinking water sources from each of the communities. These include two underground water sources (commercial bore holes water sources) and two surface water sources (streams). Specifically, the samples were Alaoma Owerre ebeiri bore hole (A) and Mgbee stream (B), Obiakpu bore hole (C) and Oloshi stream (D). Samples A and B were from the control community while samples C and D were from the test community. The samples were collected in the month of June, 2012, in clean polyethylene bottles and labeled for identification and then preserved at room temperature. Three representative samples were collected from each source and the results presented were the means of the three readings.

Sample analyses: Chemical oxygen demand(COD) and biochemical oxygen demand (BOD) samples were analyzed the same day, according standard methods[36] Fabuss and Fabuss[37] method was used to analyze for colour and odor. Colour was determined by visual observation after matching the samples against white background, while the odor was determined by organoleptic method of smelling. The pH of the samples were evaluated with a pH meter(LABTECH), which was first standardized using acetate and phosphate buffers at ph 4 and 9.2 respectively. Conductivity was determined with a conductivity meter (HANNA EC 215), which was first standardize using KCI (0.01 M and 0.0005). Chloride was determined by titration[37,38] Phosphate was determined by the Molybdate Blue method, and the transmittance was measured at 465 nm; while nitrate was determined by Phenoldisulphonic acid method, and the UV absorbance was measured at 550 nm[38] using UV spectrophotometer (Pharmacia LKB-Ultrospec 111). The biochemical oxygen demand (BOD) was determined as BOD_s using DO meter (Horiba 10), after incubating the water samples in BOD bottles at 20^oC for 5 days, while the chemical oxygen demand (COD) was obtained by dichromate method. The trace metals were determined according to Udedi S.S.[39] and Kanu I et al[40] with the aid of an atomic absorption spectrophotometer (UNICAM SOLAR 969).

Results and Discussion

Water quality is very essential for it is a measure of the environmental quality, a reflection of human health, economic well being and health of the ecosystem.

The results of the various parameters studied from different water sources are shown in tables 1 and 2. The results are compared with WHO standards.

pH is a measure of acidity or alkalinity of a solution. pH of all the water samples are acidic and the values are below the WHO range of 6.5-8.5. pH of water beyond permissible range can affect mucous membrane of cells and cause corrosiveness in water supply system[41]. This acidic nature of the samples, especially that from Oloshi stream (5.69) can be due to the presence of CO_2 from gas flares in the environment. It could also be due to the presence of humic acid from the decomposition of vegetable matter[42].

Table-1
Physicochemical parameters of the water samples

Parameters studied	Water Samples				WHO Standard
	A	B	C	D	
Colour	15.00	17.00	50.00	77.00	15.0-85.0
Odor	NO	NO	NO	NO	-
Taste	Inoffensive	Inoffensive	inoffensive	Offensive	Inoffensive
Alkalinity	50	70	10	10	500
pH at 29^{o}C	6.05	6.10	6.19	5.69	6.5-8.5
Conductivity at 29^{o}C(μS/cm)	22.00	23.00	40.4	30.90	-
Total Hardness (mg/dl)	5.5	6.8	11.60	8.1	-
Turbidity (NTU)	1.60	3.95	20	15	25.00
Temperature(^{0}C)	25.1	27.2	29.2	28.80	-
DO(mg/l)	2.30	3.90	5.1	4.9	-
BOD_5 (mg/l)	1.26	1.23	0.7	1.2	2.00
COD (mg/l)	12.20	11.80	20.00	21.3	196.00
Total dissolved solids(mg/l)	3.78	4.10	18.60	9.60	-

DO=Dissolved oxygen; BOD = Biochemical oxygen demand, COD = Chemical oxygen demand.

Table-2
Concentrations (mg/dl) of anions and trace elements in water samples

Parameter	Water Samples				WHO Standard
	A	B	C	D	
Arsenic	<0.0001	<0.0001	<0.0001	<0.0001	0.01
Barium	<0.0001	<0.0001	<0.0001	<0.0001	0.7
Cadmium	<0.0001	<0.0001	<0.0001	0.1127	0.003
Chloride	6.15	6.50	20.20	15.30	-
Chromium	<0.0001	<0.0001	<0.0001	0.0127	0.05
Copper	0.70	0.15	0.6722	2.5401	2.00
Iron	0.24	0.41	0.0039	0.1488	1.00
Lead	<0.0001	<0.0001	<0.0001	0.1102	0.01
Manganese	0.001	0.003	0.0109	2.1044	-
Magnesium	<0.0001	0.05	1.1664	2.1562	50.00
Nitrate	0.25	0.20	29.00	37.7	50
Nitrite	0.45	0.32	6.6	8.5	3
Phosphate	0.04	0.06	1.37	1.64	-
Potassium	<0.0001	<0.0001	1.3198	<0.0001	-
Selenium	<0.0001	<0.0001	<0.0001	<0.0001	0.04
Sodium	<0.0001	<0.0001	<0.0001	<0.0001	50
Sulphate,	1.25	2.46	10.20	3.62	400
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	0.006
Calcium	1.18	2.54	2.9621	3.2490	50
Zinc	0.08	0.06	1.6020	3.1293	5.00

Temperature: Plays a crucial role in the dissociation of salts, in the increase of chemical activity and the determination of electric conductivity[42,43]). It also governs to a large extent the biological species present and their rates of activity[44]. The temperature range of the control community water sources was 25.1-27.2°C compared with 28.80-29.3°C of the gas flared test community. The increase in temperature in the gas flared area may be due to climatic changes in the environment. Oseji[45] has noted increase in temperature in gas flared community in Nigeria. The rise of temperature or acidity of the water in the gas flared water sources may increase the accumulation of heavy metals.

Taste and Odor: The water samples (C and D) from gas flared area have objectionable taste compared with those (A and B) from non gas flared community. Water sample D, had offensive odor when compared with samples A to C. These observations could be due to contamination from constituents of gas fares. The results agree with those of Nwankwo et al[20].

Colour: The color range of samples A and B, was 15-17 while that for samples C and D was 50-77. All the water sources had color values within the WHO range of 15-85Hu. The higher values in the gas flared community water sources may be due to contamination.

Conductivity: is the numerical expression of the ability of an aqueous solution to carry an electric current. Electric conductivity is connected to the presence of ionic species in solution[42,43]. This study showed the gas flared water sources had a range of 30.90-40.40 compared with 22.00-23.00 µS/cm of the non gas flared sources. The observed high conductivity values from water sources in the gas flared community indicates the water is in contact with inorganic constituents probably originating from the emissions of the flared gas[46]. Again, the geology of the area has been observed to be underlain mainly by the Benin Formation, known for high hydraulic conductance and transmissivity values[47,48].

Total Hardness: Hardness is the concentration of multivalent metallic cations in solution. Dissolved calcium and magnesium ions are the major sources of hardness in water whereas minor contribution is made by the ions of aluminium, barium, manganese, iron, zinc, etc. Hardness values range of 5.50-6.80 mg/l was gotten from non gas flared environment compared with 8.10- 11.60mg/l of water sources from gas flared community. Thus, water sources from gas flared community are harder than those from non gas flared community. The increased hardness can decrease lather formation of soaps and increase of scale formation on hot water[20].

Alkalinity: Alkaninity is a measure of the ability of water to neutralize acids. The alkalinity of all the water samples were well below the permissible threshold concentration.

Total Dissolved Solids (TDS): Generally, the quantity of TDS is proportional to the degree of pollution[44]. The increased TDS in the gas flared water sources compared with the non gas flared sources in this study may be due to increased pollution to the water bodies from the activities of oil and gas companies operating in the area. Furthermore, high amount of TDS have been noted due to industrial pollution[49].

Dissolved Oxygen (DO): DO is very important for many chemical and biological processes taking place in water. A stream must have a minimum of about 2mg/l of dissolved oxygen to maintain higher life forms[44]. The DO of all the water samples in this study are within permissible limit. DO can decrease in water due to microbial activity, respiratory and organic decay and its value tend to depict an inverse relationship with water temperature[50]. The observed low values of DO in the test water samples compared with the control may be due to high decomposition of organic matter, which can also indicate high pollution load in the water following many years continuous gas flaring in the environment. The deficiency of oxygen in the water can be a shelter for bacteria and other pathogens, which are anaerobic and injurious to human health[51].

Biochemical Oxygen Demand (BOD): BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. It is widely used as an indication of the organic quality of water[52]. The BOD of all the water samples in this study were within WHO limits.

Chemical Oxygen Demand (COD): COD is commonly used to indirectly measure the amount of organic compounds in water. The result of a chemical oxygen demand test indicates the amount of water-dissolved oxygen (expressed as parts_per million or milligrams per liter of water) consumed by the contaminants, during two hours of decomposition from a solution of boiling potassium dichromate. The higher the chemical oxygen demand, the higher the amount of pollution in the test sample. The water sources from gas flared environment had COD range of 20.00 to 21.30mg/l compared with 11.80 to 12.20mg/l of the non gas flared water sources. The increased COD can is an indication of high pollution due to gas flaring.

The following trace metals: arsenic, barium, selenium, sodium and mercury were not detectable in the water samples studied. The absence of barium from the water samples from gas flared area is contrary to the findings of Nwankwo et al[20]. They found very high levels of barium in a gas flared water sources in Delta State, Nigeria. The water levels of zinc, calcium, sulphate, phosphate, nitrate, potassium, chloride, cupper, manganese, and magnesium, though lower than WHO standards, were higher in the gas flared water sources than non-gas flared ones. However, no cadmium, chromium and lead were seen in the water sources from non-gas flared environment compared levels above WHO limits in the water sources from gas flared areas.The presence of these heavy metals could be from the gas flares in the environment.

Conclusion

In conclusion, the water sources from gas flared environment were polluted by the constituents of gas flares, making them unsuitable for human use. The water sources within oil and gas facilities need to be treated by standard techniques to make them potable and drinkable by the residents of their host communities.

References

1. Wardlaw G.M. and Kessel M., Perspectives in Nutrition, 5th Edition, McGraw Hill, New York (**2002**)
2. Guyton A.C. and Hall J.E., Textbook of Medical Physiology, 11th Ed. Gopsons Papers Ltd, Nolda, India (**2010**)
3. CDC (2013) Uses and types of water Centers for Disease Control and Prevention1600 Clifton RdAtlanta, GA 30333 **(2013)** accessed on 14/2/13 **(2013)**
4. Yadav J., Pathak R.K. and Khan E., Analysis of water quality using Physico-Chemical parameters, Satak Reservoir in Khargone District, MP, India, *Int. Res.J.Environ. Sci*., **2**(**1**), 9-11 **(2013)**
5. WHO (World Health Organization), International drinking water standards. 4th edition, Geneva **(2011)**
6. Kumar M. and Padhy P.K. Climate Change, water resources and food production: some highlights from India's standpoint, *Int. Res. J.Environ. Sci.,* **2**(**1**), 79-87 **(2013)**
7. Edorh P., Gnandi K., Elegbede B. Enonhedo F. Et Boko M., Qualite de l'eau des nappes et son impact sur la santé des populations a Kerou, Revue scientique semestriel, LECREDE, Cotonou, 12 **(2007)**
8. Egwurugwu J.N., Duruibe J.O., Abanobi O.C., Ufearo C.S., Nwokocha C.R. and Mounmbegna P.P.E., Physico-chemical and microbial characteristics of drinking and potable water in suburban Orlu, Imo State, Nigeria, *Int. J.Nat. Appl. Sci.,* **3(3),** 339-343 **(2007)**
9. Kinsielounon Gilles E., Edorh Patrick A., Guedenon Patient, Deguenon Yvette, Sossou Bernard, Dougnon Victorien, Loko Frederick, Boko Michel (2013): Risks of drinking water contaminated by chemical and organic substances in the Lakeside City of So-Ava in Benin Republic, *Int. Res. J. Envirobnent Sci.,* **2**(**1**), 49-57 **(2013)**
10. Kraemer R.A., Choudhury K. and Kampa E., Protecting water resources: Pollution and Prevention, In: International Conference on Freshwater, Bonn, Germany, 18 **(2001)**
11. Aston-Jones N., The Human Ecosystem of the Niger Delta: An Era Handbook, Environmental Rights Action, Lagos, Nigeria, 136-138 **(1998)**
12. NNPC (Nigerian National Petroleum Corporation), Draft Annual Statistical Bulletin, (**2011**) www.nnpcgroup.com, Accessed on August 12, **(2012)**
13. Gobo A.E., Richard G. and Ubong I.U., Health Impact of Gas Flares on Igwuruta/Umuechem Communities in Rivers State, *J.Appl.Sci.Environ.Manage.,* **13(3),** 27-33 (**2009**)
14. McEwen J.D.N. and Johnson M.R., Black carbon particulate matter emission factors for buoyancy driven associated gas flares, *J.Air Waste Manage.Assoc.,* **62**(**3**), 307-321 **(2010)**
15. World Bank, Defining and Environmental Strategy for the Niger Delta, West Central Africa Department, World Bank, Washington DC, 150 **(1995)**
16. World Bank, World Bank sees warning sign in gas flaring Increase. Press Release No. 2013/005/SDN, Geneva **(2012)** Accessed: July 3 **(2012)**
17. Kindzierski W.D., Importance of Human environmental exposure to Hazardous air pollutants from Gas flares, *Environ. Rev.* **8**, 41-62 **(2000)**
18. USEPA, United States Environmental Protection Agency (USEPA) Volatile organic compounds, http://www.epa.gov/volatile organic compounds. Washington DC **(2004)**
19. Idodo-Umeh G. and Ogbeibu A.E., Bioaccumulation of the Heavy Metals in Cassava Tubers and Plantain Fruits Grown in Soils Impacted with Petroleum and Non-Petroleum Activities, *Res. J. Environ. Sc.,* **4**, 33-41 **(2010)**
20. Nwankwo C.N. and Ogagarue D.O., Effects of gas flaring on surface and ground waters in Delta State Nigeria, *J.Geol.Mining Res.,* **3(5),** 131-136 (**2011**)
21. Duruibe J.O., Ogwuegbu M.O.C. and Egwurugwu J.N., Heavy metal pollution and human biotoxic effects, *Int. J. Phys. Sci.,* **2**(**5**), 112-118 **(2007)**
22. ATSDR (Agency for Toxic Substances and Disease Registry) Toxicological Profile for Cadmium (update), US Department of Health and Human Services, Atlanta, Georgia, 205-1999-00024, 1-305 **(2008)**
23. Satarug S., Nisho M., Lasker J.M., Edwards R.J. and Moore M.R., Kidney dysfunction and hypertension: Role for Cadmium, P450 and Heme Oxygenases? Tohoku, *J. Exp. Med.,* **208**, 179-202 **(2006)**
24. Swaddiwudhipong W., Mahasakpan P., Limpatanachote P. and Krintratun S., Correlations of urinary cadmium with hypertension and diabetes in persons living in Cd contaminated villages in Northwest Thailand: a population study, *Environ. Res.,* **110**, 612-616 **(2010)**
25. Satarug S. and Moore M.R. Adverse health effects of chronic exposure to low- level cadmium in foodstuffs and cigarette smoke. Environ, *Health Perspect.,* **112**, 1099-1103 **(2004)**

26. Revis N.W., Zinsmeister A.R. and Bull R., Atherosclerosis and hypertension induction by lead and cadmium ions: an effect prevented by calcium ion, Proc. Natl.Acad.Sc. USA, **78**, 6494-6498 **(1981)**

27. Ross R., The pathogenesis of atherosclerosis: a perspective for the 1990's, *Nature* (*London),* **362**, 801-809 (**1993**)

28. Washington B., Williams S., Armstrong P., Mtsshali P., Robinson J.T. and Myles E.L., Cadmium toxicity on arterioles vascular smooth muscle cells of spontaneously hypertensive rats, *Int.J.Environ.Res.Public Health,* **3(4),** 323-328 **(2006)**

29. Ganong W.F., Review of Medical Physiology, 22nd Edition, McGraw-Hill Co. Inc. New York **(2005)**

30. Hoffbrand A.V., Pettit J.E. and Moss P.A.H., Essential Haematology, 4th Edition, Blackwell Publishing Co., Massachusetts **(2004)**

31. Fosmire G.J., Zinc toxicity, *Am. J.Orthomol.Psychiatry*, **12(4),** 27-82 (**1990**)

32. Nolan K., Copper toxicity syndrome, *J. Orthomol.Psych,* **12(4**), 270-282 **(2003)**

33. Ogwuegbu M.O.C. and Duruibe J.O., Environmental pollution and biotoxicity of certain heavy metals, In: International Conference of the Chemical Society of Nigeria; Chemistry and the Nigerian Economy, Yerwa, Maiduguri, Nigeria, 285-288 **(2005)**

34. Holum J.R., Elements of general and biological chemistry , 6th Edition, John Wiley and Sons, New York **(1983)**

35. Esonwune A.A. and Amasiatu G.I., Diploma Chemistry for Colleges and Polytechnics.- Edition, Catholic Institute for Development, Justice and Peace Publishing, Enugu, Nigeria **(2002)**

36. APHA (American Public Health Association). Standard methods for the examination of water and wastewater, 20th Edition, Washington DC **(1998)**

37. Fabbus M.A. and Fabbus B.M., Water, encyclopaedia of industrial chemical analysis **(1974)**

38. Nwokedi G.I., Obodo G.A. and Nwankwo S.I., Pollution Chemistry of the River Niger and its tributaries: characteristic of industrial waste effluents, *Bull. Environ. Contamination and Toxicol.,* **48**, 441-448 **(1992)**

39. Udedi S.S., From guinea worm scourge to metal toxicity in Ebonyi State, *Chemistry in Nigeria,* **2(2),** 13-14 (**2003**)

40. Kanu I., Achi G.K., Ezereonye O.U. and Anyanwu E.C., Seasonal Variation in bacterial heavy metal biosorption in water samples from Eziama River near soap and brewery industries and the environmental health implications, *Int. J.Environ. Sci.Tech.,* **3(1),** 95-102 **(2006)**

41. Course manual for Chemists and Bacteriologists of PHED Laboratories under National Drinking Water Quality Monitoring and Surveillance Programme, Public Health Department, West Bengal (**2010**)

42. Maliki E., Hydrogeologique du littoral beninois dans la region de cotonou (.AO.), These de doctoral du seme cycle Univ. C.A. Diop de Dakar, Senegal, 135 **(1993)**

43. Boukari M., Reactualisation des connaissances hydrogeologique relatives au Bassin sedimentaire Cotier du Benin, Cotonou, 134 **(1998)**

44. Shivayogimath C.B., Kalburgi P.B., Deshannavar U.B. and Virupakshaiah D.B.M., Water quality evaluation of river Ghataprabha, India, *Int. Res.J.Environ. Sci.,* **1(1),** 12-18 **(2012)**

45. Oseji O.J., Environmental impact of gas flaring within Umutu-Ebedei gas plant in Delta State, Nigeria, *Arch. Appl.Sc.Res.,* **3 (6),** 272-279 **(2011)**

46. Etu-Efeotor J.O., Hydrochemical analysis of surface and groundwaters of Gwagwalada area of Central Nigeria, *Global J. Pure Appl. Sci.,* **4(2),** 153–162 (**1998**)

47. Ekine AS, Iheonunekwu E.N. Geoelectric survey for groundwater in Mbaitolu Local Government Area, Imo State, Nigeria, *Sci. Afri.* **6(1**), 39-48 **(2007)**

48. Ehirim C.N. and Nwankwo C.N., Evaluation of aquifer characteristics and groundwater quality using geoelectric method in Choba, Port Harcourt, *Arch. Appl. Sci. Res.,* **2(2**), 396-403 **(2010)**

49. Khare S.K. and Unni K.S., Changes in physic-chemical factors and distribution of periphyton in Pollar river, Proc. All India Seminar on Water Quality around urban ecosystems, Ed. K.S. Unni, (**1986)**

50. Koul N., Lokahande, R.S. and Dhar J.K., Physico-Chemical, Bacteriological and Pesticide analysis of Tap water in Millennium City Gurgoan, Haryana, India, *Int. Res. J.Environ. Sci.,* **1(2**), 1-7 **(2012)**

51. Radha K.R., Dharmaraji K. and Ranjitha K.B.D., A comparative study on the physicochemical and bacterial analysis of drinking borehole and sewage in three different places of Sivakasi, *J.Environ.Biol*., **28(1),** 105-108 (**2007**)

52. Clair N. Sawyer, Perry L. McCarty, Gene F., Parkin *Chemistry for Environmental Engineering and Science* (5th ed.), New York: McGraw-Hill (**2003**)