Journal of Environmental Chemistry and Ecotoxicology Vol. 4(2), pp. 29-34, 22 January, 2012
Available online http://www.academicjournals.org/jece
DOI: 10.5897/JECE11.052
ISSN-2141-226X ©2012 Academic Journals

Full Length Research Paper

Radioactivity concentration and heavy metal assessment of soil and water, in and around Imirigin oil field, Bayelsa state, Nigeria

R. K. Meindinyo[1] and E. O. Agbalagba[2]*

[1]Department of Physics, Bayelsa State College of Education, Okpoama, Brass, Nigeria.
[2]Department of Physics, University of Port Harcourt, Rivers state, Nigeria.

Accepted 10 October, 2011

The alpha and beta activity concentration and heavy metal assessment of soil and water in and around Imirigin oil field has been carried out. Study area was subdivided into five locations, Soil and water samples were collected from field undisturbed environment and oil spilled areas. Sample collection and preparation follows standard procedures. *In situ* measurement was conducted for pH and electrical conductivity, heavy metal analysis was carried out using Atomic absorption Spectrophotometer (AAS) and gross alpha and beta activity concentration was by using gas filled proportional counter. Average value for pH and E.C. are 6.5±0.2 and 46.8±1.0 µs/cm respectively for soil and 6.4±0.5 and 406.1±5.2 µs/cm respectively for water. The mean values obtained for ASS analysis for soil are 11.9±1.0, 3.3±0.4, 1.7±0.7, 8.1±0.5, 42.5±1.9, 3.3±0.5, 8.0±0.6, 0.08±0.02 and 79.5±2.2 mg/kg. For Ca, Mg, Zn, Ni, Fe, Cd, Pb, Hg and Cr respectively for water, mean value obtained are 8.3±0.5, 4.2±0.4, 1.6±0.4, 1.5±0.3, 1.3±0.2, 0. 0.06±0.004, 0.07±0.003, 0.05±0.01 and ND mg/l for Ca, Mg, Na, K, Fe, Pb, Cd, Hg and AS respectively. Gross alpha and beta activities mean concentrations for soil are 0.53±0.02 Bq/g and 29.29±0.17 Bq/g respectively, and 4.02±0.01 Bq/l and 54.23±1.76 Bq/l respectively for water. The results show that the level of the various metals obtained differs from location to location. Values obtained in soil are within reported values in the Niger Delta region except Iron level. Heavy metals such as Ca, Fe and Cd exceed the WHO limits for drinking water. The mean values for alpha and beta activity in soil are above reported values in similar environment while mean values obtained in water samples are above WHO recommended maximum permissible limit for drinking water. These values obtained shows that drinking water from sampled locations may pose some long term health hazards to the public users though soil from the area is still safe as construction material for buildings.

Key words: Assessment, radionuclide concentration, heavy metal, oil field.

INTRODUCTION

The advent of oil mineral exploitation and exploration activities resulted in increased pollution of the Niger Delta environment. Some of such problems are increase presence of potentially toxic metals in soil and water bodies of the area and increase in human exposure to ionizing radiation. This contamination and pollution of soil and water has been a great concern to many a person in this region and beyond. This is because if contamination/ pollution occurs, damage may be extensive and effects may be long term and extend over many seasons. Studies have shown that almost all the elements in the periodic table including heavy metals are found in the crude oil matrix (Abison, 2000; Avwiri et al., 2007). Thus, the release of gas through flaring, oil spillage and its derivative has serious radiological and hazardous effects to men and direct impact on the soil (Aroganjo et al., 2004; RRC, 2007). This may also result in surface and ground water pollution (Oyinloye and Jegede, 2004). Moreso, leachate from municipal, oil spill, gas flare, solid, landfills, surface water run-off are potential sources of

*Corresponding author. E-mail: ezek64@yahoo.com.

contamination of both surface and ground water (Odukoye et al., 2002). Pollution of water is on the increase at frightening proportion. Frightening in the region especially in the oil host communities due to gas flare and oil spillage into water bodies and land and other allied factors responsible for environmental degradation (Egila and Techemen, 2004).

The concentration of heavy metals in soil, surface and ground water depends on the human activities distributed through the geological stratification of an area (Bolaji and Tse, 2009). The present of such contaminants in water and soil above recommended standard set by water, soil and environmental regulatory bodies like EPA and WHO may result in serious health hazard (US-EPA, 2002). These perceived consequences of the consumption of foodstuff and vegetables from these polluted soil and the consumption of untreated and unregulated water and the attending radiological burden has triggered various environmental studies especially in the Niger Delta region on soil equality and water aquifer quality and aquatic ecosystem (Akpan and Offen, 1993; Udom et al., 1999; Ekpete, 2002; Oguzie et al., 2007; Egila and Terhemen, 2004; Abam et al., 2007; Nwala et al., 2007; Bolaji and Tse, 2009). But none of these studies have been able to relate the presence of heavy metal (physio-chemical parameters) with natural radioactivity concentration in these studies.

This present study examined the presence heavy metals in the Imiringi Oil field environment which has been characterized by frequent oil spillage due to oil pipe failure and vandalization. The study also evaluates the gross activity concentration and its attending radiological burden on the population living in this environment. Baseline data will be gotten from the analysis since no known similar study have been carried out in the oil field. The study will therefore, be of great benefit to the host communities, operating company and the government.

METHODS

Study area

Imiringi oil and gas field is one of the main oil producing fields onshore of Bayelsa State. It lies within latitudes 04 54N and 05'02N and longitudes 006°, 15E and 006° 24E and is situated in the Southern part of the Niger Delta. Its geomorphological features consist of mainly fresh water swamp and mangroves with table land within the swamp. The study area geology is consistence with the geology of Bayelsa State and that of the Niger Delta Complex as reported elsewhere (Bolaji and Tse, 2009; Manila and Nwachukwu, 2009).

Using lithological and geophysical logs, Etu-Efeotor and Akpokodje (1990) delineate five levels of aquifers in the study area. The region ground water problems include salt water intrusion, pollution of the upper aquifers of the area, high iron content in some of the area horizons, causing encrustation and contamination of surface water pollution with oil spillage as major contributor (Avwiri and Agbalagba, 2009).

Deposition of heavy metals on surface water from gas flare and washing of contaminated soil through surface water run-off into water bodies are other major environmental problems in the region.

Sample collection and preparation

The sampled Imiringi oil field was subdivided into five locations; A– Imiringi Town, B- Around Imiringi Gas Turbine, C– Imiringi Flare and Flow Station, D- Ede-Epie area, Yenagoa and E– Agudama area, Yenagoa) for effective coverage of the study area, four soil and water samples were collected from each of the selected location with the study field.

The bulk soil samples were collected from old oil spill site and undisturbed, uncultivated grass cover level area and in remote location from man-made structures such as roads and buildings to prevent any external influence on this type of samples results (Senthilkumar et al., 2010). Soil samples were collected double for Atomic Absorption spectrophotometer (ASS) and gross alpha and beta analysis in a black polythene bag from an area of approximately 100 cm^2 and in range of 10– 15 cm depth for grass cover and undisturbed area while 2–10 cm depth in oil spilled areas (Senthilkumar et al., 2010). For the heavy metal analysis samples were initially broken into smaller aggregates, de-watered and dried at ambient temperature (20–30°C) for two weeks. They were subsequently grounded in a mortar passed through a 2 mm sieve and stored in a sealed container until needed for analysis (Onwuka and Uzoukwu, 2008). Samples for gross alpha and beta analysis were air dried at room temperature for ten (10) days. Samples were then transfer into a low temperature (50°C) drying cabinet to help accelerate the drying process without loss of radionuclides from the samples (Onoja et al., 2004). The dried samples were grounded with mortar and pestle and allowed to pass through a 100-mesh sieve. Prepared soil samples were pelleted into counting planchette size using the hydraulic compressing machine. Samples were kept in desiccators and store for four weeks to attain a state of secular equilibrium.

Twenty water samples were collected for the study, four each from the five sampling locations. Samples were collected from the location creeks/River water which has direct bearing of the oil and gas activities. One sample of borehole water was collected from each location for comparison and check. Samples collection was carried out according to prescribed sample collection procedure in pre-wash and clean 300ml screw plastic containers and as reported elsewhere (Apha, 2000; ISO, 9697 and 9698 (E), 1992; Juliet, 2006; Bolaji and Tse, 2009).

Samples analysis

The PH and electrical conductivity were measured and recorded *insitu*, this is because the chemistry of soil, surface and under-ground water is sensitive to environmental changes. The analytical methods used in the determination of these heavy metals in water have been reported in Nwala et al. (2007), Bolaji and Tse (2009) and were in accordance with ASTM and ALPHA Standard procedures for the heavy metals in soil samples analysis, a high precision variance spectral unicorn 1969 Atomic Absorption Spectrometer (Perkin Elmer Model 2280) was used in acetylene/air flame after sample preparation.

In the gross alpha and beta analysis, prepared samples were analyzed using the gas filled proportional Counted EURISYS MEASUE IN-20 low background eight channels alpha and beta Counter at the Center for Energy Research and Training Ahamdu Bello University, Zaria, Nigeria. The background measurements, calculation for machine efficiency, plateau test were carried out using Standard Methods (ASTM) follows as reported by Avwiri and Agbalagba (2007).

Table 1. Mean physic-chemical parameters concentration in soil sample (±SD).

S/n	Location code	pH	EC µS/cm	Ca cmol/Kg	Mg cmol/Kg	Zn mg/Kg	Ni mg/Kg	Fe mg/Kg	Cd mg/Kg	Pb mg/Kg	Hg Mg/Kg	Cr Mg/Kg
1.	A	6.7 ± 0.1	0.8 ± 0.2	0.12 ± 0.2	1.6±0.2	0.2±0.1	0.2±0.1	40.1±0.1	1.3±0.3	6.2±0.1	0.2±0.00	161.20±2
2.	B	5.3±0.3	41.6±2.6	0.2±O.1	2.6±0.1	1.3V0.5	4.1±1.0	50.4±2.6	0.8±0.1	5.2±0.5	ND	58.4±1.
3.	C	4.5±0.2	32.5±1.5	56.0±4.0	8.66V0.8	1.1±0.8	31.1±0.9	56.1±0.3	0.5±0.2	3.3±0.7	0.01±0.00	79.9±2.
4.	D	7.5±0.5	34.1±0.3	1.3±0.2	2.4±0.5	3.0±0.6	0.3±0.02	45.1±1.5	14.0±2.1	7.2±1.6	0.12±0.01	40.8±
5.	E	8.6±0.1	45.1±0.2	1.2±0.3	1.3±0.3	2.8±1.2	5.0±0.2	21.0±1.5	ND	8.3±0.4	0.01±0.00	57.2±
	Mean	6.5±0.2	46.8±1.0	11.9±1.0	3.3±0.4	1.7±0.7	8.1±0.5	42.5±1.9	3.3±0.5	6.0±0.7	0.07±0.002	79.5±2.2

Table 2. Physico-chemical parameters concentration in water sample (±SD).

S/n	Location code	pH	MS/CM electrical cond. (EC)	Ca Mg/l	Mg Mg/l	Na Mg/l	K Mg/l	Fe Mg/l	Pb Mg/l	Cd Mg/l	Hg Mg/l	AS Mg/l
1.	A	6.8±0.2	290±5.0	7.1±0.3	7.4±0.3	2.3±0.1	1.3±0.2	1.4±0.02	ND	0.01±0.0	0.07±0.001	ND
2.	B	6.1±0.4	300.0±4.6	14.3±0.8	3.8±0.2	1.76±0.2	1.3±0.4	1.3±0.1	0.2±0.0	0.04±0.0	ND	ND
3.	C	7.6±1.0	246.1±3.3	4.4±0.2	4.4±0.3	1.8±0.02	0.9±0.20	0.8±0.2	0.08±0.0	0.3±0.02	0.02±0.002	ND
4.	D	6.4±0.6	570.4±7.0	8.5±0.6	2.57±0.2	0.9±0.1	2.1±0.5	1.0±0.2	ND	ND	ND	ND
5.	E	5.2±0.2	624.7±6.7	7.1±0.7	3.0±0.4	1.3±0.3	1.6±0.5	1.9±1.4	0.03±0.002	ND	ND	ND
Average Values		6.4±0.5	406.1±5.3	8.3±0.5	4.2±0.4	1.6±1.4	1.5±0.3	1.3±0.2	0.06±0.004	0.07±0.0003	0.054±0.006	0.00
WHO limit		6.5 – 8.5	500	7.5		200	200		0.30	0.01		0.05

RESULTS AND DISCUSSION

The results of the heavy metal (physcio-chemical) analysis of the soil and water samples are presented in Tables 1 and 2. The pH of the soil samples ranged from 4.5 acidic to 8.6 alkaline with an average value of 6.52 ±0.24. Jones (1998) reported that acidic soil/water results in corrosion of Iron and Steel materials. Electrical conductivity mean value is 46.8 ± 1.0 µS/cm. This indicates that the soil contain moderate ionic content hence, the capacity of the soil to conduct or transmit electric current would be moderate. The mean values of Calcium (Ca), Magnesium (Mg), Zinc (Zn), and Nickel (Ni), Iron (Fe) are 11.86±0.96, 3.32±0.38, 1.68±0.64, 8.14±0.48 and 42.54±1.92 mg/kg respectively. All these metals except Iron are well within the values for uncontaminated soil (FUGRO, 2004). The high concentration of Fe may be peculiar characteristics of the area soil.

For heavy metals, Cadmium concentration ranged from ND to 14.0±2.1 mg/kg with mean value of 3.32±0.54 mg/kg. This shows that studied area is Cadmium polluted. This is true because the mean value obtained exceeded the recommended upper limit of Cadmium concentration in soil (FUGRO, 2004). This values obtained are also higher than previous reported values in the Niger Delta (FUGRO, 2004; Uzoukwu and Onomake, 2005; Onwuka and Uzoukwu, 2008). This high value may be attributed to the oil spillages in the environment as seen in location of oil spilled site. The lead content of the soil sample ranged from 5.2 to 13.2 mg/kg with mean value of 8.04±0.64 mg/kg. The possible sources of lead in these samples are crude oil and burnt leaded gasoline. Pollution by high levels of lead could be detrimental not only to soil organisms but also to aquatic organism. This is because run-off water from the soil is discharge into a body of water, but the obtained level of lead in the studied area may not be toxic to organisms. However, if there is long time accumulation of lead due to additional pollution, it could result to adverse effect. High concentration of lead (46-218 mg/kg) in

bioavailable forms could harm soil and aquatic organism (Onwuka and Uzoukwu, 2008). Lead-induced effects include neurological dysfunction in the central nervous system, altered behavior and immune suppression (FUGRO, 2004). The values obtained in the study area agrees with that obtained elsewhere in the Niger Delta prior to the establishment of Exxon oil and gas facilities (FUGRO, 2004) and those obtained by Uzoukwu and Onomake (2003) (11.9±90 mg/kg) and 6.59±2.96 (mg/kg) obtained by Onwuka and Ozoukwu (2008) at the university of Port Harcourt botanic garden. This obtained value of lead is below the USEPA standard 50 mg/kg value.

Mercury (Table 1) value concentration ranged from N.D in location B to 0.2 mg/kg in location A. with a mean value of 0.07±0.002 mg/kg. This shows that Hg level in the study area is near insignificant compared to the 25 mg/kg maximum recommendation value (Adekola et al., 2002). The concentration of Chromium (Cr) in the digested soil samples ranged from 40.9 mg/kg in location D to 161.20 mg/kg in location A with a mean value of 79.5±2.2 mg/kg. The concentration of Chromium in uncontaminated environment (soil and estuarine) are in the range of 50-100 mg/kg (CNL, 2001).

Accordingly, the Chromium level in the studied area was within the acceptable range for unpolluted soil or sediments. Thus the level observed will not cause any toxic effects on soil micro and macro organism nor on man that can consume any flora that is cultivated on the soil.

The results of the physico-chemical analysis of the water samples are presented in Table 2. The pH of the sampled water ranged from 4.5 to 8.6 with a mean value of 6.4±0.5. This range of values obtained is well within the WHO range of 6.5-8.5 for domestic and portable water. The electrical conductivity (EC) value ranged from 290-624 µs/cm with a mean value of 406.1±5.3 µs/cm. This shows that EC level of locations D and E exceeded the permissible limit of 500µs/cm set by WHO.

EC is an indicator of water quality and soil salinity hence the relatively high value observed in some river water samples show high salinity, thus water may not be very suitable for domestic and agricultural use.

Ca^{2+} and Mg^{2+} values obtained for the water samples ranged from 4.4-14.3 mg/l with a mean value of 8.3±0.5 mg/l for Ca^{2+} and 2.6-7.4 mg/l with a mean value of 4.2±0.4 mg/l for Mg^{2+}. The values obtained for Mg^{2+} are well in agreement with values reported by Bolaji and Tse (2009) in Port Harcourt well water, and FUGRO (2004). But Ca^{2+} mean values obtained, is above the WHO recommended limit of 7.5 mg/l for domestic and drinkable water. These values are in deviation from the values reported by Nwale et al. (2007), but agree with the values reported in the Niger Delta Environmental Survey report (NDES, 2000).

Na^{+} concentration in the river water analyzed range from 0.9 to 2.3 mg/l with a mean value of 1.6±0.4 mg/l while K^{+} ranged from 0.9 to 2.1 mg/l with a mean value of 1.5±0.3 mg/l. These observed concentrations for Na^{+} and K^{+} in these samples were well below the WHO recommended limit of 200 mg/l for both. These values obtained agree with those reported by Bolaji and Tse (2009), and has no health implication to the public consuming the water in terms of Na^{+} and K^{+} anions.

Fe^{2+} concentration values in the sampled river water samples ranged from 0.8 to 1.9 mg/l with a mean value of 1.3±0.2 mg/l. This shows that Fe^{2+} concentration in all the five location sampled exceeded the WHO limit of 0.3 mg/l. The relatively high concentration of metallic iron may be attributed to the observed turbid nature of the water and the brownish colouration when allowed to settle. This is due to the oxidation of Fe^{2+} to Fe^{3+} which causes nuisance to laundry and sanitary wares (Aiyesanmi et al., 2004).

Lead ion (Pb) was detected at location B, C and E, though it's mean value of 0.06±0.004 mg/l is bellow the WHO 0.3 mg/l limit for drinking water, the level obtained portends some future health hazard as accumulative effect of these levels may possibly lead to Pb poison (Ademoroti,1996). The Cadmium mean value of 0.07±0.003 mg/l obtained in this study is far above the 0.01mg/l WHO recommended limit. This confirmed the reported value in soil and show that oil spillage has impacted both the soil and water negatively. The mean concentration of other heavy metals in these river water samples (mercury) is 0.05±0.006 mg/l while As is below detection limits. The presence of Hg in some location water sample is another indication of the contamination of the water samples.

This may also be attributed to oil spillage and other anthropogenic activities in the area. The result of the water physico-chemical analysis shows that all the heavy metals analysis where present in the samples except Arsenal. This generally indicated that the water is not total safe for drinking, their present in and consumption may leads to toxic waste in the body and a high accumulative level may lead to water poison.

Table 3 present the result for gross alpha and beta activity concentration in both soil and water. Alpha activity in soil ranged from 0.049 Bq/g in location E to 0.96 Bq/g in location C with a mean value of 0.526±0.02 Bq/g. Beta activity concentration in the soil ranged from 1.52 to 119.91 Bq/g with a mean value of 29.29 Bq/g. These values obtained for activities in the soil are higher than other values reported elsewhere (Arogunjo et al., 2004) in similar environment. The high beta activity value obtained especially at location C is an indication of anthropogenic activity in the area. This confirmed that the present of oil spillage in this environment has elevated or enhances the level of radionuclides in the area.

Alpha activity in water ranged from 0.021 Bq/l in location E to16.950 Bq/l in location A with a mean activity of 4.02±0.09 Bq/l. Beta activity ranged from 5.84 Bq/l in location E to 135.88 Bq/l in location C with a mean

Table 3. Mean gross alpha and beta activity concentration in soil and water samples (±SD).

S/n	Location code	Soil activity conc.(Bg/g)		Water activity conc. (Bg/l)	
		α-activity	β-activity	α-activity	β-activity
1.	A	0.610±0.040	3.992±0.012	16.950±0.032	59.54±0.52
2.	B	0.620±0.015	17.430±0.096	1.240V0.042	15.220±0.25
3.	C	0.960±0.039	119.910±0.469	0.510±0.009	54.680±1.314
4.	D	0.390±0.003	3.600±0.149	1.380±0.124	135.88±6.713
5.	E	0.049±0.003	1.520±0.121	0.021±0.002	5.840±0.03
		0.526±0.020	29.29±0.169	4.02±0.09	54.232±1.763

activity value of 54.232±1.763 Bq/l. The generally low values of activity observe in location E is an indication of unpolluted soil and suitable water. The mean alpha emitters (4.02±0.009 Bq/l) and mean beta emitters (54.232±1.763 Bq/l) are far above the 0.1 Bq/l for alpha and 1.0 Bq/l for beta WHO recommended practical screening levels of radioactivity in drinking water (WHO, 2003). This shows that the activities of oil spillage and gas flare in the environment may have increased the radionuclide levels and concentration of these river water and are therefore not suitable radiologically for drinking as portable water.

A regression analysis on heavy meters and gross activity concentration show a strong correlation between the heavy metals examined and the concentration of alpha and beta activities in water and soil, with a value of 0.633 to 0.892 respectively. This shows that the presence of heavy metals has a direct bearing with the level of radionuclide in the environment.

Conclusion

The survey of radioactivity concentration and heavy metal assessment in soil and water in and around Imirigin oil field has been carried out. The level of the various heavy metals examined differs from location to locations. This is confirmed by the heterogeneity of radionuclide deposits in soil and water samples was mainly of geological origin. The present of some heavy metals especially cadmium in water is an indication of water pollution.

The measured alpha and beta activity in soil are above reported values in similar environment while in water, the values obtained are well above reported values and that of WHO recommended maximum permissible limit for drinking water. The research findings revealed that the water in the oil field is not radoiologically safe for drinking. The values obtained may pose some serious health hazards to the public users of these river waters.

REFERENCES

Abam TKS, Olu AW, Nwankwoala H (2007). Ground water monitoring for environmental liability assessment. J. Nig. Environ. Soc., 4(1): 42-49.

Adekola FA, Eleta OA, Atenda SA (2002). Determination of the level of some heavy metals in urban run-off sediments of Ilorin and Lagos, Nigeria. J. Appl. Sci. Environ. Mgt., 6(2):23-26.

Ademoroti CMA (1996). Standard methods for water and effluent analysis. Foludex Press Ltd. Ibadan, Pp. 145 – 151.

Aiyesanmi AF, Ipinmoroti KO, Oguntimehin II (2004). Impact of automobile workshop on groundwater quality in Akure Metropolis. J. Chem. Soc. Nig. (Supplement to 2004 Proceeding) 420. – 426.

Akpan EH, Offem JO (1993). Seasonal Variation in water quality of the Cross River, Nigeria. Rev. Hydrobiol. Trop., 26(2): 93 – 103.

American Public Health Association (APHA), (2000). American Water works Association and Water Pollution Control Federation. Standard Method for Examination of Water and Wastewater, APHA, AWWA and WPCF, New York.

Aregunjo AM, Farai IP, Fuwape IA (2004). Impact of oil and gas industry on the natural radioactivity distribution in the Delta region of Nigeria. Nig. J. Phys., 16:131-136.

Avwiri GO, Chad-Umoren YE, Enyima PI, Agbalagba EO (2009). Occupational radiation profile of oil and gas facilities during production periods in ughelli, Nigeria. Working and living. Environ. Hot., 6(1):11-19.

Avwiri GO, Agbalagba OE, Enyinna PI (2007). Assessment of natural radioactivity concentration and distribution in river Forcados, Delta State, Nigeria. Sci. Afr., 7(1): 1281-135.

Avwiri GO, Agbalagba EO (2007). Survey of gross alpha and gross beta radionuclide activity in Okpare-Creek Deltal State Nigeria. Asian Network for Scientific information J. Appl. SC., 7(22): 3542-3546.

Bolaji TA, Tse CA (2009). Spatial variation in ground water geochemistry and water quality index in Port Harcourt Scientia Africana, 8(1):134-155.

Chevron Nigeria limited (CNL), (2001). Draft report of the environmental impact assessment of Tubu Field Development. Chevron Nig. Ltd., Lagos Nigeria.

Egila JN, Terhemen A (2004). A preliminary investigation into the Quality surface d water in the environment of Benue cement company Plc Gboko Benue state, Nigeria Int. J. Sci. Tech., 3(1): 12-17.

Ekpete OA (2002). Determination of physico-chemical parameters in borehole water in Odihologboj, Community in Rivers State. Afr. J. interdisciplinary stud., 3(1): 23-27.

Etu- Efeotor JO, Akpokodje EG (1990). Aquifer systems of the Niger Delta . J. min. Geol., 26(2): 279-294.

FUGRO (2004). Environmental Impact assessment of East Area Projects- Additional oil Recovery Project. Procedures FUGRO Quality Assurance. Report No. S-0310.

ISO 9696 (1992). Water Quality-Measurement of gross alpha activity in non saline water (International Organization for Standardization, London), first edition. Pg. 12-14.

ISO 9697 (1992). Water Quality-Measurement of gross beta activity in non saline water (International Organization for Standardization, London), first edition, pg. 12-14.

Jones LW (1998). Corrosion and water technology: Oil and Gas Consultant International Inc., Tulsa Pp. 47 – 51.

Juliet NM (2006). Gross alpha and beta radioactivity in Kaduna River . M.sc. thesis. ABU Zaria.

Niger Delta Environmental Survey (NDES), 2000. Niger Delta Development Priorities and Action Plan. Phase II Report, 2: 156-176.

Nwala CO, Akaninwor JO, Abbey BW (2007). Physico-chemical parameters of mono pumps and well waters in Igbo Etche. J. Nig. Environ. Soc., 4(1): 78-87.
Odukoya OO, Arowolo TA, Bamgbose (2002). Effect of solid waste land fill under-ground and surface water quality at Ring-Road, Ibadan. Global J. Environ. Sci., (22): 235-242.
Oguzie EE, Ayochukwu IB, Offem JO (2007). Groundwater contamination: A simulation study of buried waste. Metallic contaminant penetration through the aquifers. J. chem. Soc. Nig., 27(1): 82-84.
Onoja RA, Akpan TC, Mallam SP, Ibeanu IGE (2004). Characterization of the gross alpha/beta counter in the center for energy research and training; ABU, Zaria . Nig. J. phys., 16: 13-18.
Onwuka OA, Uzoukwu BA (2008). Studies on the Physicochemical properties of soil from the Botanica Garden, University of Port Harcourt, Port Harcourt, Nigeria. Scientia Africana, 7(1): 157-164.
Oyinloye AO, Jegede GO (2004). Geographysical survey, Geo chemical and microbiology investigation of ground well water in Ado-Ekiti North, South western Nigeria. Global J. Geological Sci., 2(2):235-242.
Udom GJ, Etu - Efeotor JO, Esu EO (1999). Hydro-chemical evaluation of ground water in part of Port Harcourt and Tai-Eleme local Government Area, Rivers state. Global J. pure Appl. Sc., 5(5): 545-552.
US-EPA (United States Environmental Protection Agency), 2002. Current drinking water Standard. Office of groundwater and drinking water quality. Government printing office, Washington DC, USA.
Uzoukwu BA, Onomake OR (2003). Physico-chemical studies of soil along the bank of Milli Shallow Stream in Nnewi, Anambra state, Nigria for evidence of industrial pollution. Global J. Pure Appl. Sci., 10(1);111-119.
Uzuokwu BA, Onomake OR (2005). Physicochemical Studies along the bank of Ubu River in Ekwusigo and Nnewi Local government Areas of Anambra State, Nigeria. Annali di Chimca, 95(1&2):95-104.