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PHYSICOCHEMISTRY OF FIVE WATERSHEDS WITHIN THE OIL ABSTRACTION AREAS OF INLAND NIGER DELTA, SOUTHWESTERN NIGERIA

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ABSTRACT

Analyses of selected hydrological set of data were carried out for five watersheds around three major oil fields in the Niger Delta area to evaluate the effect of oil abstraction activities on the physicochemistry of the watersheds. The oil fields include the Afiesere oil field, Kokori oil fields, and Erimu oil fields. The study area was divided into two distinct zones namely, the oil field and non oil field areas. Each zone was analyzed for seasonal (intra-annual) variations in studied physical and chemical parameters. Result of analysis shows that concentrations of physicochemical parameters in the river waters were lower than those obtained from ponds and burrow pits/artificial lakes. Unlike the non-oil producing areas, hydrocarbon was detected, in almost every stream/river and other surface waters sampled in the oil field areas at various levels throughout the year. Mean concentrations of studied parameters show that except manganese in groundwater; manganese and zinc in river waters; Nitrate and ammonia in the soil, most of the studied parameters were highest in the oil field area. The result reported herein suggests a higher pollution status in the oil field area relative to the non oil field area.

KEYWORDS: physicochemistry, watershed, water, soil, Nigeria

INTRODUCTION

The study area falls within the oil producing area of the oil rich Niger Delta region of Nigeria. It lies between latitudes $5^{o}30^{1}$N – $6^{o}00^{1}$N, and longitudes $5^{0}50^{1}$NE – $6^{0}20^{1}$E. Details of the geology of the area is similar to that described by Short and Stauble 1967, Assesz 1989, Kogbe 1975, 1989, Reijers 1996, Stacher 1995, Atakpo and Chukudebelu 1997; Adaikpoh and others, 2000, 2005, Kaizer and Adaikpoh 2006, Kaizer 2007a, and Kaizer 2007b among others. The study area includes oil field host communities and non oil field area for comparison. Borehole, hand dug well, surface water bodies and rainwater monitoring points were located in both up gradient (background) and down gradient locations around oil field facilities. The wells were monitored at regular intervals bimonthly/ quarterly in some cases for a period of one year, based on a series of "indicator parameters". The logic of this sampling technique is that the upgradient water quality represents the background condition for the particular region, and down gradient water quality plus any influence produced by the oil facilities. Because of possible spatial variability within the geologic environment significantly affecting the statistical comparisons, necessary detection programme did not rely on only one background well as a basis for comparison to up gradient wells but on a reasonable number of wells. Thus, the main objective of the water quality detection monitoring programme was to determine if the oil facility is affecting groundwater and surface water. Therefore, this study is expected to provide information on chemical and physical characteristics of the various components of the hydrologic system such as soil/sediments, precipitation, surface and groundwater systems and microclimate (relevant long term details) required in the proper assessment of the response of the oil field areas to heavy abstraction of hydrocarbon.

METHODOLOGY

Method of analysis employed in this study involved a sampling programme based on the objective of establishing the present physical and chemical status of the water resources in the area. Investigation and sampling methods covered both terrestrial and aquatic environment (surface water and groundwater). This method was designed to collect site-specific representative data that truly reflect the existing conditions. Based on the above, the study therefore entails two broad approaches; field study and laboratory studies. The field study involved a detailed survey of the study area and systematic sampling of rainwater, surface water bodies, and ground water from various localities. Studies on the general response characteristics involved a continuous sample monitoring of uncased hand dug water wells, boreholes, rivers/streams, ponds, burrow pits water. Similarly the physical and chemical studies on all surface water were carried out on located sampling points, to provide some general information on the distribution of geochemical characteristics. Identification, evaluation and prediction of potential impacts were based on comparative study of the physical and geochemical analyses of data collected from the oil field areas (OF) and non-oil field area (NOF). All sampling procedures and analytical methods were done following standard techniques outlined by APHA (1995), WHO (2006) and DPR 2001.

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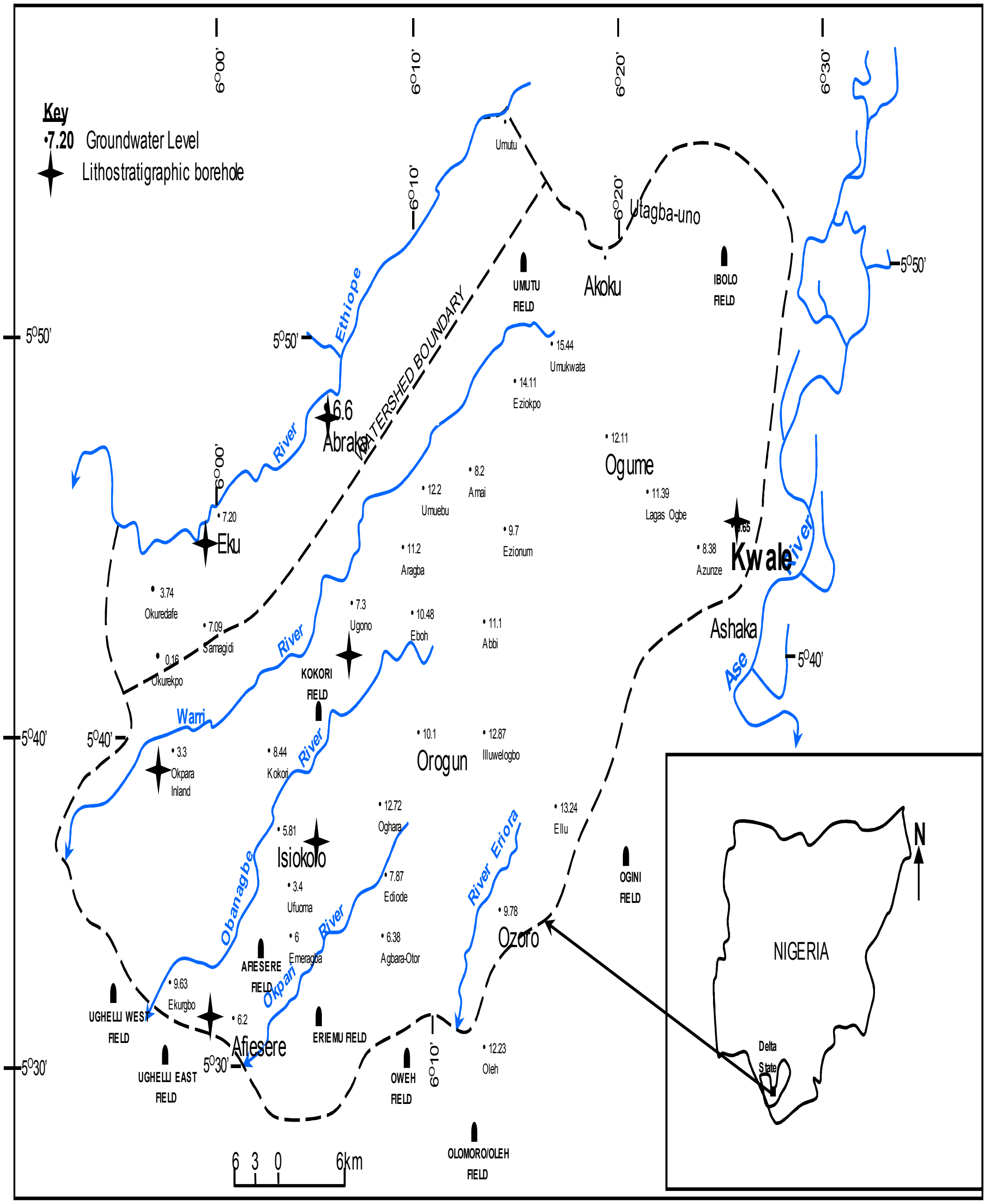


FIGURE 1: MAP OF STUDY AREA

RESULTS AND DISCUSSION

The results of mean physicochemical analysis of the surface water resource samples are presented below (Tables 1 – 6).

TABLE 1: OBANAGBE RIVER WATER - OIL FIELD BI-MONTHLY ANNUAL AVERAGE

PARAMETERS	M1	M2	M3	M4	M5	M6	AVERAGE
pH	5.40	6.23	5.91	5.74	5.65	5.27	**5.70**
Turbidity NTU	10.05	22.76	6.05	3.35	6.35	9.38	**9.66**
Total Solid mg/l	60.55	34.04	53.44	14.65	26.41	26.22	**35.88**
Total Dissolved Solid mg/l	57.68	26.61	36.01	11.65	18.55	19.65	**28.36**
Total Suspended Solid mg/l	2.88	7.43	17.43	3.00	7.87	6.58	**7.53**
Conductivity µΩ/cm	111.18	59.35	81.83	64.94	74.03	85.08	**79.40**
Biochemical Oxygen Demand mg/l	0.38	0.57	1.46	5.20	0.22	4.63	**2.07**
Chemical Oxygen Demand mg/l	1.98	0.16	0.98	3.61	0.13	1.10	**1.33**
Total Hydrocarbon Content mg/l	2.61	0.06	11.88	6.70	3.95	3.15	**4.72**
%Oil	2.57	0.19	2.52	0.65	0.05	10.74	**2.79**
Alkalinity mg/l	9.20	3.51	14.37	9.45	19.55	14.15	**11.70**
Total Hardness mg/l	15.00	5.24	19.13	14.25	24.47	10.80	**14.81**
Calcium (Ca) mg/l	2.29	7.10	8.79	6.40	16.46	6.94	**7.99**
Magnessium (mg) mg/l	6.58	4.02	7.93	5.85	6.64	5.48	**6.08**
Sodium (Na) mg/l	0.56	2.85	5.08	6.57	17.22	9.10	**6.89**
Potassium (K) mg/l	0.35	3.48	6.63	5.61	2.73	11.15	**4.99**
Chloride (Cl) mg/l	18.09	12.54	22.79	30.78	14.40	12.75	**18.56**
Phosphate (PO4) mg/l	1.11	0.05	0.31	1.51	0.70	4.41	**1.35**
Sulphate (SO4) mg/l	0.66	0.02	0.05	0.13	2.38	3.31	**1.09**
Nitrate NO3 mg/l	1.23	0.03	0.46	1.59	9.85	1.71	**2.47**
Ammonia (NH4) mg/l	2.45	0.21	1.05	1.69	0.61	15.82	**3.64**
Coliform MPN / 100 ml	22.00	5.00	28.00	16.50	10.50	11.05	**15.51**
Bicarbonate (HCO3) mg/l	5.53	1.85	0.58	2.92	0.63	1.67	**2.19**
Carbonate (CO3) mg/l	1.19	0.05	2.55	0.03	0.06	0.05	**0.65**
Iron (Fe) mg/l	3.74	0.23	0.05	0.05	0.04	0.10	**0.70**
Chromium (Cr) mg/l	0.01	0.01	0.03	0.03	0.14	0.01	**0.02**
Copper (Cu) mg/l	0.02	0.04	0.05	0.64	0.07	0.06	**0.15**
Zinc (Zn) mg/l	0.87	4.00	1.03	1.10	0.05	0.48	**1.25**
Lead (Pb) mg/l	0.03	0.04	0.56	0.10	0.08	0.04	**0.14**
Cadmium (Cd) mg/l	0.01	0.01	0.01	0.03	0.03	0.01	**0.03**
Nickel (Ni) mg/l	0.01	0.01	0.02	0.03	0.03	0.02	**0.02**
Vanadium (V) mg/l	0.01	0.01	0.03	0.04	0.03	0.01	**0.03**
Manganese (Mn) mg/l	0.01	0.02	0.03	0.00	0.03	0.04	**0.03**

TABLE 2: WARRI RIVER WATER- OIL FIELD BI-MONTHLY ANNUAL AVERAGE

PARAMETERS	M1	M2	M3	M4	M5	M6	AVERAGE
pH	5.72	6.00	6.18	5.49	6.19	5.78	**5.89**
Turbidity NTU	6.80	15.50	4.84	1.88	4.42	4.68	**6.35**
Total Solid mg/l	58.47	64.15	38.30	15.00	17.85	18.70	**35.41**
Total Dissolved Solid mg/l	52.10	40.60	30.76	10.80	12.85	14.35	**26.91**
Total Suspended Solid mg/l	6.38	23.55	7.55	4.20	5.00	4.35	**8.50**
Conductivity µΩ/cm	113.71	75.10	21.85	40.12	43.50	56.84	**58.52**
Biochemical Oxygen Demand mg/l	5.35	3.10	3.80	4.11	0.21	3.65	**3.37**
Chemical Oxygen Demand mg/l	0.53	1.20	5.06	3.23	0.66	1.55	**2.04**
Total Hydrocarbon Content mg/l	1.22	16.60	4.92	6.90	4.08	0.76	**5.74**
%Oil	1.05	1.55	0.32	0.67	0.06	7.48	**1.85**
Alkalinity mg/l	8.31	9.13	8.63	7.82	13.23	14.28	**10.23**
Total Hardness mg/l	30.50	27.07	15.58	7.08	12.86	14.28	**17.89**
Calcium (Ca) mg/l	5.25	7.40	3.50	4.75	20.77	11.58	**8.88**
Magnessium (mg) mg/l	9.88	6.06	2.48	4.75	6.08	8.78	**6.34**
Sodium (Na) mg/l	7.25	4.13	6.04	6.33	19.23	6.81	**8.29**
Potassium (K) mg/l	3.30	5.11	5.03	6.60	2.70	6.56	**4.88**
Chloride (Cl) mg/l	21.12	18.58	26.07	31.30	14.74	12.00	**20.63**
Phosphate (PO4) mg/l	1.20	1.10	0.66	0.78	0.27	8.65	**2.11**
Sulphate (SO4) mg/l	1.03	0.41	0.05	0.58	1.65	0.50	**0.70**
Nitrate NO3 mg/l	1.09	0.92	1.37	1.56	12.64	4.20	**3.63**
Ammonia (NH4) mg/l	1.49	0.96	1.68	0.49	0.69	0.57	**0.98**
Coliform MPN / 100 ml	18.50	16.50	34.67	20.00	32.00	32.00	**25.61**
Bicarbonate (HCO3) mg/l	6.17	0.51	1.48	1.65	0.84	2.64	**2.21**
Carbonate (CO3) mg/l	0.81	0.60	0.44	0.03	0.03	0.04	**0.32**

Iron (Fe) mg/l	0.11	0.34	0.57	0.11	0.03	0.16	**0.22**
Chromium (Cr) mg/l	0.01	0.01	0.03	0.02	0.03	0.01	**0.07**
Copper (Cu) mg/l	0.09	0.38	0.38	0.03	0.06	0.04	**0.16**
Zinc (Zn) mg/l	2.62	10.70	1.13	0.36	0.06	1.54	**2.73**
Lead (Pb) mg/l	0.05	0.02	0.48	0.04	0.03	0.06	**0.11**
Cadmium (Cd) mg/l	0.02	0.01	0.02	0.02	0.04	0.01	**0.02**
Nickel (Ni) mg/l	0.01	0.01	0.02	0.02	0.01	0.02	**0.02**
Vanadium (V) mg/l	0.01	0.01	0.02	0.02	0.01	0.01	**0.02**
Manganese (Mn) mg/l	0.03	0.92	0.04	0.02	0.06	0.02	**0.17**

TABLE 3: OKPARI RIVER WATER - OIL FIELD BI-MONTHLY ANNUAL AVERAGE)

PARAMETERS	M1	M2	M3	M4	M5	M6	AVERAGE
pH	5.19	5.35	6.08	5.18	5.63	5.28	**5.45**
Turbidity NTU	17.53	52.10	18.81	6.35	14.03	11.23	**20.01**
Total Solid mg/l	54.51	93.35	80.62	55.13	35.46	41.61	**60.11**
Total Dissolved Solid mg/l	40.80	33.55	75.18	46.25	23.61	29.81	**41.53**
Total Suspended Solid mg/l	8.71	59.80	19.11	8.88	6.85	11.80	**19.19**
Conductivity µΩ/cm	75.50	78.30	44.82	77.65	54.95	78.30	**68.25**
Biochemical Oxygen Demand mg/l	0.81	4.88	4.34	10.03	11.91	9.84	**6.97**
Chemical Oxygen Demand mg/l	8.29	0.50	10.43	15.15	18.60	3.45	**9.40**
Total Hydrocarbon Content mg/l	8.45	10.80	18.85	11.06	25.80	13.70	**14.78**
%Oil	6.98	1.45	17.61	1.09	2.55	20.44	**8.35**
Alkalinity mg/l	6.55	12.58	25.93	17.70	26.68	26.00	**19.24**
Total Hardness mg/l	51.53	12.10	18.65	20.62	25.45	26.00	**25.72**
Calcium (Ca) mg/l	8.24	5.77	4.66	7.66	27.37	19.57	**12.21**
Magnessium (mg) mg/l	15.57	7.10	2.55	8.28	11.10	13.60	**9.70**
Sodium (Na) mg/l	19.77	2.08	6.12	8.15	24.95	12.38	**12.24**
Potassium (K) mg/l	40.27	3.13	4.64	7.22	6.83	17.85	**13.32**
Chloride (Cl) mg/l	40.27	17.58	36.23	39.15	30.16	20.45	**30.64**
Phosphate (PO4) mg/l	2.34	0.52	4.17	3.74	0.14	20.10	**5.17**
Sulphate (SO4) mg/l	1.19	0.24	1.24	1.18	5.04	1.05	**1.66**
Nitrate NO3 mg/l	11.33	1.30	2.48	3.85	29.03	8.48	**9.41**
Ammonia (NH4) mg/l	12.16	0.83	4.78	3.58	1.39	6.18	**4.82**
Coliform MPN / 100 ml	53.00	40.00	44.67	34.00	21.50	26.00	**36.53**
Bicarbonate (HCO3) mg/l	12.48	0.56	2.60	2.37	0.54	10.13	**4.78**
Carbonate (CO3) mg/l	1.52	0.39	0.59	0.05	0.17	0.81	**0.58**
Iron (Fe) mg/l	0.02	0.20	2.31	0.14	0.06	1.10	**0.64**
Chromium (Cr) mg/l	0.02	0.02	0.05	0.07	0.46	0.05	**0.11**
Copper (Cu) mg/l	0.04	0.51	0.57	1.33	1.36	4.65	**1.41**
Zinc (Zn) mg/l	0.38	10.55	2.68	2.47	0.56	22.41	**6.51**
Lead (Pb) mg/l	0.35	0.04	0.06	0.11	0.06	0.47	**0.18**
Cadmium (Cd) mg/l	0.32	0.01	0.04	0.03	0.05	0.27	**0.16**
Nickel (Ni) mg/l	1.14	0.01	0.04	0.10	0.04	0.03	**0.34**
Vanadium (V) mg/l	0.02	0.01	0.04	0.02	0.02	0.05	**0.03**
Manganese (Mn) mg/l	0.35	1.30	0.03	0.15	0.14	0.04	**0.33**

TABLE 4: ETHIOPE RIVER WATER AT ABRAKA –NON OIL FIELD BI-MONTHLY ANNUAL AVERAGE

PARAMETERS	M1	M2	M3	M4	M5	M6	AVERAGE
pH	6.47	6.27	6.87	6.75	6.71	6.53	**6.60**
Turbidity NTU	2.38	1.39	1.17	0.53	0.86	0.51	**1.14**
Total Solid mg/l	30.74	48.13	32.40	12.87	12.59	25.73	**27.08**
Total Dissolved Solid mg/l	28.95	28.67	26.80	12.81	10.60	20.58	**21.40**
Total Suspended Solid mg/l	1.78	16.09	5.60	0.06	1.99	5.15	**5.11**
Conductivity µΩ/cm	39.63	33.34	23.45	11.81	11.57	28.62	**24.74**
Biochemical Oxygen Demand mg/l	0.37	8.52	0.44	2.38	0.07	0.05	**1.97**
Chemical Oxygen Demand mg/l	0.03	16.81	0.64	0.81	0.06	1.13	**3.25**
Total Hydrocarbon Content mg/l	0.01	6.77	0.12	0.13	0.01	0.14	**0.05**
%Oil	0.01	4.78	0.02	0.01	0.01	6.43	**1.08**
Alkalinity mg/l	5.37	18.67	7.05	3.50	10.19	5.67	**8.41**
Total Hardness mg/l	5.57	15.54	8.45	5.07	11.03	5.67	**8.55**
Calcium (Ca) mg/l	8.58	8.58	5.80	4.87	10.14	3.92	**6.98**
Magnessium (mg) mg/l	6.56	4.36	4.26	3.32	6.76	4.59	**4.98**
Sodium (Na) mg/l	3.97	7.23	7.85	4.86	9.53	3.64	**6.18**
Potassium (K) mg/l	5.90	7.90	4.04	4.00	1.54	2.57	**4.33**
Chloride (Cl) mg/l	8.77	30.12	10.37	17.33	8.84	7.79	**13.87**

Phosphate (PO4) mg/l	0.08	0.74	0.03	0.09	0.43	0.05	**0.24**
Sulphate (SO4) mg/l	0.19	0.82	0.09	0.02	0.85	0.02	**0.33**
Nitrate NO3 mg/l	0.03	4.30	0.09	0.14	7.52	0.29	**2.06**
Ammonia (NH4) mg/l	0.07	1.95	0.21	0.39	0.22	0.12	**0.49**
Coliform MPN / 100 ml	3.67	32.33	4.00	3.33	2.33	3.33	**8.17**
Bicarbonate (HCO3) mg/l	1.05	3.95	2.20	1.75	0.04	2.47	**1.91**
Carbonate (CO3) mg/l	0.02	1.21	1.08	0.02	0.01	0.01	**0.35**
Iron (Fe) mg/l	0.04	1.08	0.08	0.02	0.03	0.02	**0.21**
Chromium (Cr) mg/l	0.01	0.02	0.01	0.01	0.02	0.01	**0.01**
Copper (Cu) mg/l	0.04	1.57	0.03	0.01	0.02	0.02	**0.01**
Zinc (Zn) mg/l	1.94	19.35	1.05	0.05	0.38	0.12	**3.82**
Lead (Pb) mg/l	0.03	0.08	0.04	0.04	0.04	0.04	**0.05**
Cadmium (Cd) mg/l	0.01	0.04	0.01	0.01	0.01	0.01	**0.01**
Nickel (Ni) mg/l	0.01	0.03	0.02	0.02	0.01	0.01	**0.01**
Vanadium (V) mg/l	0.01	0.01	0.02	0.01	0.01	0.01	**0.01**
Manganese (Mn) mg/l	0.01	4.30	0.01	0.01	0.02	0.02	**0.01**

TABLE 5: ANNUAL AVERAGE CONCENTRATION OF PARAMETERS IN PONDS /BURROW PIT WATER PONDS/BURROW PIT WATER

PARAMETERS	M1	M2	M3	YR AV.
pH	5.29	5.44	5.95	5.56
Turbidity NTU	2.02	7.88	10.89	6.93
Total Solid mg/l	168.03	123.06	107.21	132.77
Total Dissolved Solid mg/l	143.50	113.47	81.20	112.72
Total Suspended Solid mg/l	24.53	9.59	25.89	20.00
Conductivity µΩ/cm	214.35	83.99	255.52	184.62
Biochemical Oxygen Demand mg/l	6.38	6.15	12.53	8.35
Chemical Oxygen Demand mg/l	6.80	13.71	11.98	10.83
Total Hydrocarbon Content mg/l	12.51	12.98	14.16	13.22
Alkalinity mg/l	8.66	8.18	0.28	5.71
Total Hardness mg/l	39.48	15.00	11.55	22.01
Calcium (Ca) mg/l	14.85	20.76	29.71	21.77
Magnessium (mg) mg/l	9.96	17.81	27.34	18.37
Sodium (Na) mg/l	6.86	7.08	37.46	17.13
Potassium (K) mg/l	6.31	3.46	34.59	14.78
Chloride (Cl) mg/l	28.34	12.89	8.69	16.64
Phosphate ($P0_4$)	4.40	0.56	51.86	18.94
Sulphate (So_4) mg/l	5.26	1.64	4.86	3.92
Nitrate ($No_{3)}$ mg/l	0.67	0.66	0.59	0.64
Ammonia ($NH_{4)}$ mg/l	2.01	2.02	14.32	6.12
Coliform MPN/100ml	334.86	452.88	415.88	401.20
Bicarbonate (HCO_3) mg/l	13.52	11.24	5.40	10.05
Carbonate (CO_3) mg/l	0.01	0.02	2.38	0.80
Iron (Fe) mg/l	0.35	2.31	0.13	0.93
Chromium (Cr) mg/l	0.03	0.35	0.03	0.14
Copper (Cu) mg/l	3.68	1.74	4.19	3.20
Zinc (Zn) mg/l	7.82	4.65	2.99	5.15
Lead (Pb) mg/l	0.10	0.17	0.11	0.13
Cadmium (Cd) mg/l	0.10	0.04	0.05	0.06
Nickel (Ni) mg/l	0.01	0.26	0.06	0.11
Vanadium (V) mg/l	0.02	0.03	0.05	0.03
Manganese (Mu) mg/l	0.06	0.15	1.42	0.54

Impacts of rainfall patterns were divided into two categories - surface water dilution and runoff potentials. While surface water dilution potential affects the ability of nearby surface water to assimilate discharges and consequently reduce parameter concentrations, runoff potential affects the potential transport of materials to surface waters and surrounding land. From studies conducted, the hydrologic conditions in the study area were often extreme. Climatic conditions were broken into two major seasons of dry and wet periods. This was often characterized by months' long drought of little or no rain. During this period, strained water supplies and decline in crop produce is experienced due to the absence of rainfall even when the rivers and streams are sustained throughout the year by groundwater seepage at the uplands. The wet season comes after the dry period with torrential rains and flash floods. Rainfall pattern during the period of intensive sampling did not differ from the general trend in the area. Hydrologic conditions in the study area were influenced by seasonal variations. During the wet season conditions, proportionately more of the stream flow occurs as surface runoff. These runoffs contain excessive nutrients, hydrocarbon, trace elements and other contaminants washed off land surfaces into the stream and rivers. Also, during the dry conditions, stream quality was strongly influenced by the quality of base flow (and wastewater treatment plant discharge). Within the oil fields, several small streams and ponds occurred within the flow station area and much waste pits and burrow pits, which received runoff water mostly in the wet season. Discharge from the saver pits that received oil effluent from the flow station and compressor station to the flare pits also occurs.

TABLE 6A: RAIN WATER CUMMULATIVE MEAN

NON OIL FIELD AREA	pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl
JANUARY/FEBRUARY	6.76	1.79	0.43	0.66	0.32	15.30	4.02	6.05
MARCH/APRIL	6.69	4.24	5.29	8.52	1.08	9.37	9.89	10.97
MAY/JUNE	6.58	2.64	2.08	4.66	4.94	5.45	3.99	7.49
JULY/AUGUST	6.57	3.57	0.49	2.62	2.72	7.77	0.60	13.67
SEPTEMBER/OCTOBER	6.60	2.66	2.80	2.94	1.19	3.98	2.05	3.25
NOVEMBER/DECEMBER	6.57	2.37	3.61	3.64	2.03	6.55	0.36	8.82
CUMM. MEAN (JANUARY-DECEMBER)	**6.63**	**2.88**	**2.45**	**3.84**	**2.05**	**8.07**	**3.48**	**8.38**

TABLE 6B: RAIN WATER CUMMULATIVE MEAN

OIL FIELD AREA	pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl
JANUARY/FEBRUARY	6.07	14.29	2.55	6.63	1.93	36.57	19.45	12.20
MARCH/APRIL	6.10	14.68	7.47	1.84	1.31	36.50	26.71	12.03
MAY/JUNE	5.81	12.78	10.67	1.84	2.33	33.11	45.91	17.62
JULY/AUGUST	5.82	8.29	6.94	6.50	5.68	21.98	42.75	24.11
SEPTEMBER/OCTOBER	5.51	6.96	6.37	2.45	7.34	28.56	38.11	17.71
NOVEMBER/DECEMBER	5.74	9.68	9.70	7.21	7.66	31.22	54.13	16.73
CUMM. MEAN (JANUARY-DECEMBER)	**5.84**	**11.11**	**7.28**	**4.41**	**4.37**	**31.32**	**37.84**	**16.73**

The major climatic factors affecting water quality were seasonal and area distributions of precipitation. The amount of rainfall affected water quality because areas with higher rainfall generally had greater runoff and more infiltration to ground water. However, increased flows also may have helped to dilute concentrations of chemicals in the ground water and surface water. Generally, the distribution of rainfall in the study area was uniform. The significance of rainfall is seen in the levels of nutrients and metal that contributed to concentrations of these substances in surface water (Tables 1-6). The quality of stagnant surface water in the pits showed a relatively high level of oil sheen and THC. However, in the groundwater samples, other parameters had levels close to those of the non- oil producing area except Fe and Zn, which were predominantly anthropogenic in origin (Fig.2). Physico-chemical characteristics of the soils/sediments show that they were acidic with low to moderate nutrient level. However, slightly elevated levels of Pb were observed. All other metals at the study area were comparable to the background values from the reference site. Total hydrocarbon content (THC) was highest in the waste pits and burrow pits respectively. Spatial distribution of THC in the oil fields did not show any discernable trend but were tied to major oil operating facilities (Fig.3). However, lateral distribution of the THC was related to sedimentation and erosional processes during the rainy season.

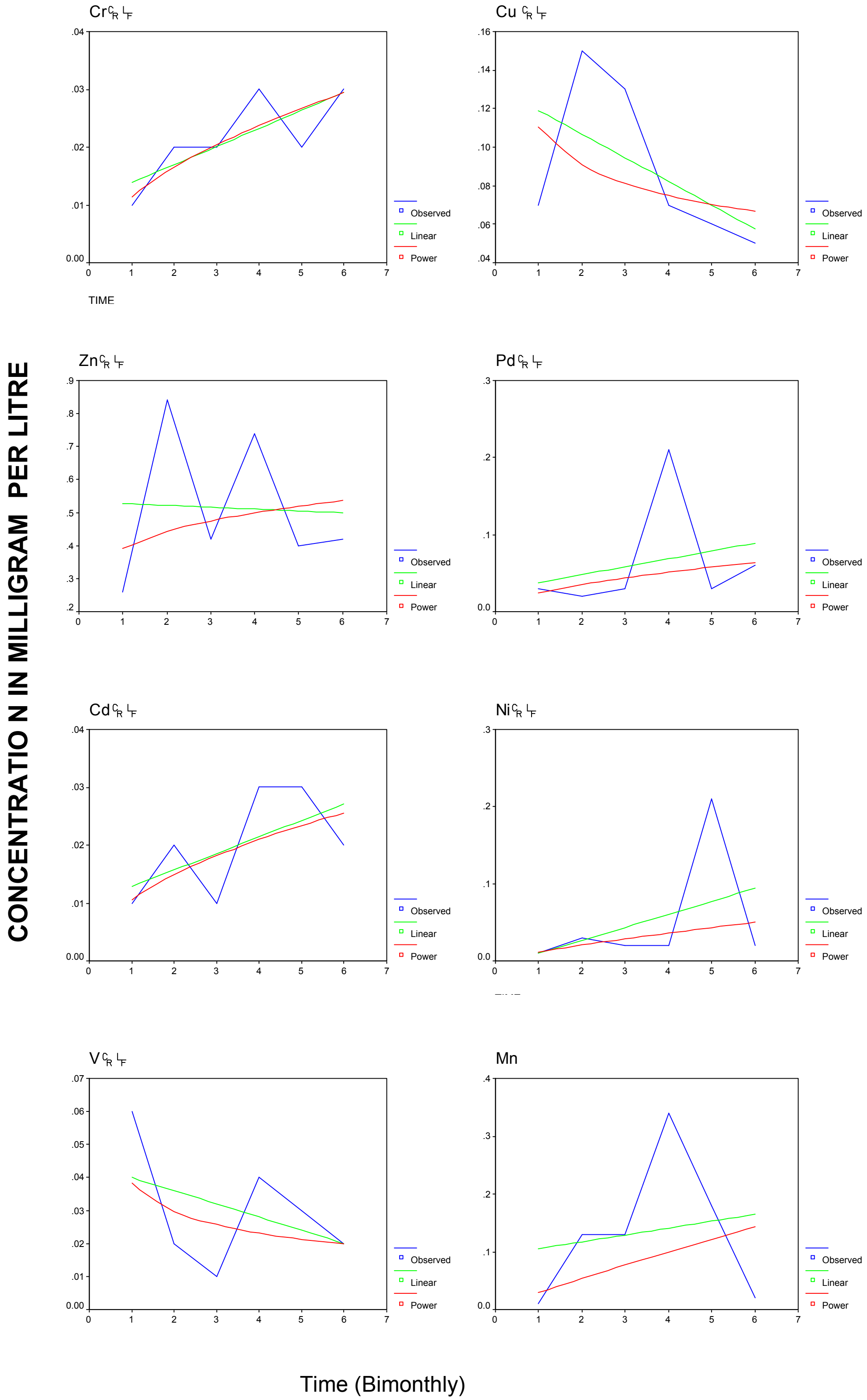


Figure 2: Concentration trend of Chromium, Copper, Zinc, Lead, Cadmium, Nickel, Vanadium, and Manganese in non oil field Borehole water

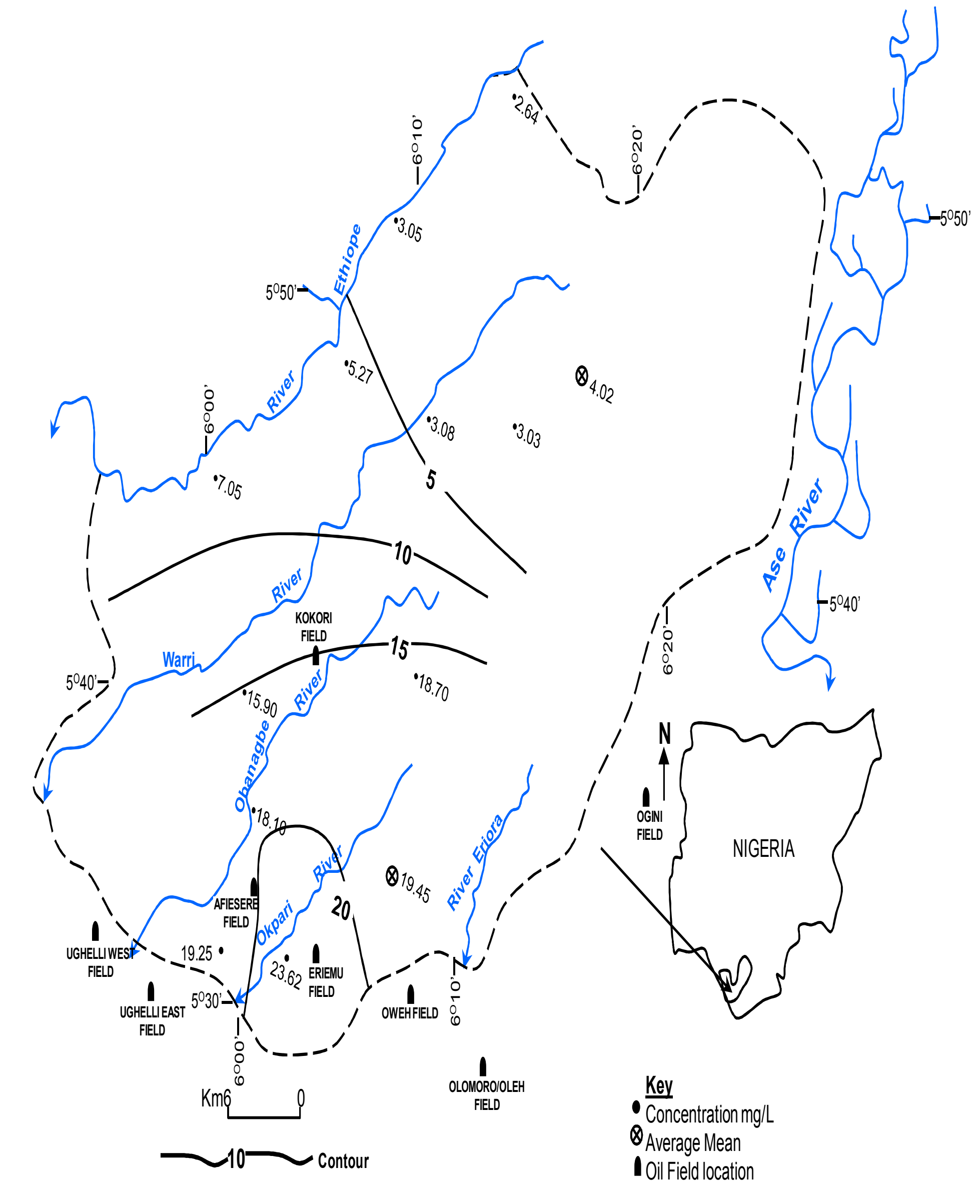
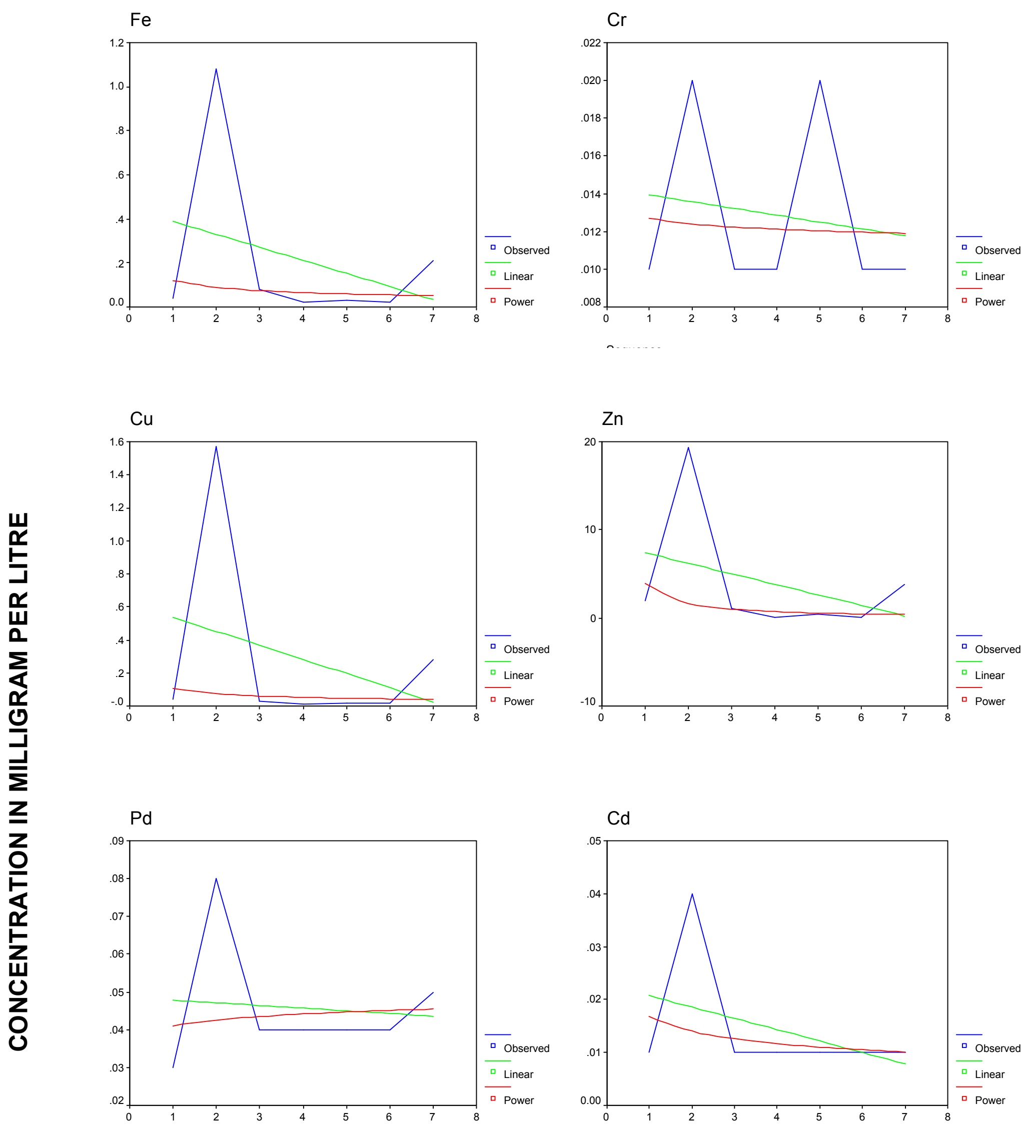


Figure 3: Sulphate Concentration in Rainwater

SURFACE WATER HIGHLIGHTS

Streams and rivers sampled in the oil producing and non-oil producing areas generally met existing guidelines for drinking water quality. However, Urban and industrial (especially oil field) land, uses have affected water quality, as indicated by higher concentration of hydrocarbon and other parameters studied in the areas dominated by the oil field land uses. Surface water samples drawn from ponds, burrow pits and rivers showed that average concentration of the studied parameters were far higher in the ponds and burrow pits than in the rivers. Mean quarterly BOD values in mg/l in burrow pits/ponds from the oil producing area ranged between 6.15-12.53 (annual average 8.35 mg/l), COD 6.80-13.71 (annual average 10.83), coliform 334-415 (annual average 401MPN/100ml). Trace metal content in the burrow pits/ponds was relatively high and in many cases above the international standards. Trace metal content based on annual average, revealed a concentration magnitude of Zn 5.15mg/l, Cu 3.2 mg/l, Mn 0.54 mg/l, Cr 0.14 mg/l, Ni 0.11 mg/l, V 0.03 mg/l in burrow pits/ponds among others. Concentrations of studied parameters in the rivers around the oil producing areas also were elevated with respect to the reference non-oil producing areas. However, concentrations in the river waters were lower than those obtained from ponds and burrow pits (artificial lakes). Unlike the non-oil producing areas, hydrocarbon was detected, in almost every stream/river and other surface waters sampled in the oil field areas at various levels. The values ranged from 0.06-25.80mg/l. Similarly, most trace metal apart from copper and Zinc were high in Okpari creek at Ughelli but relatively within drinking water standard respectively. Although the concentrations of parameters studied did not follow a particular trend, highest concentrations were measured in the early parts of the rainy season (Fig. 4). Major sources of nitrogen and phosphorus in the water system were from waste discharge and surface runoff.



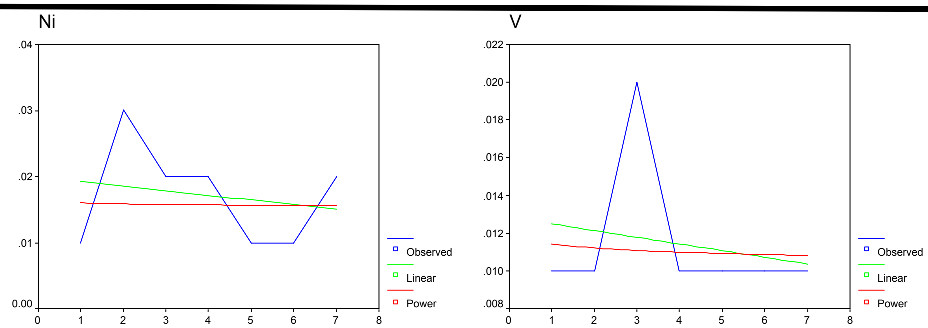


Figure 4: Concentration trend of Iron, Chromium, Copper, Zinc, Lead, Cadmium, Nickel, Vanadium in non oil field Rivers (January – December 2004)

Trace metal were detected frequently in bed sediments and water column mostly at concentrations higher than the non-oil field areas but within guidelines for drinking water. Lead, cadmium, chromium, manganese, nickel, and vanadium exceeded drinking water guidelines in a few samples. Although concentrations were not too high in sediment samples, data suggests accumulation of hydrocarbon and trace metal in surface water systems within the oil field areas. These concentrations may be harmful to humans or animals that depend directly or indirectly on the water system. Similarly, nitrate was detected in the surface water as the only nutrient with significant concentration although below the drinking water standard. High pH and acidity was also recorded in rain water samples within the oil field areas.

FLOW REGULATIONS, IMPOUNDMENT AND SURFACEWATER QUALITY

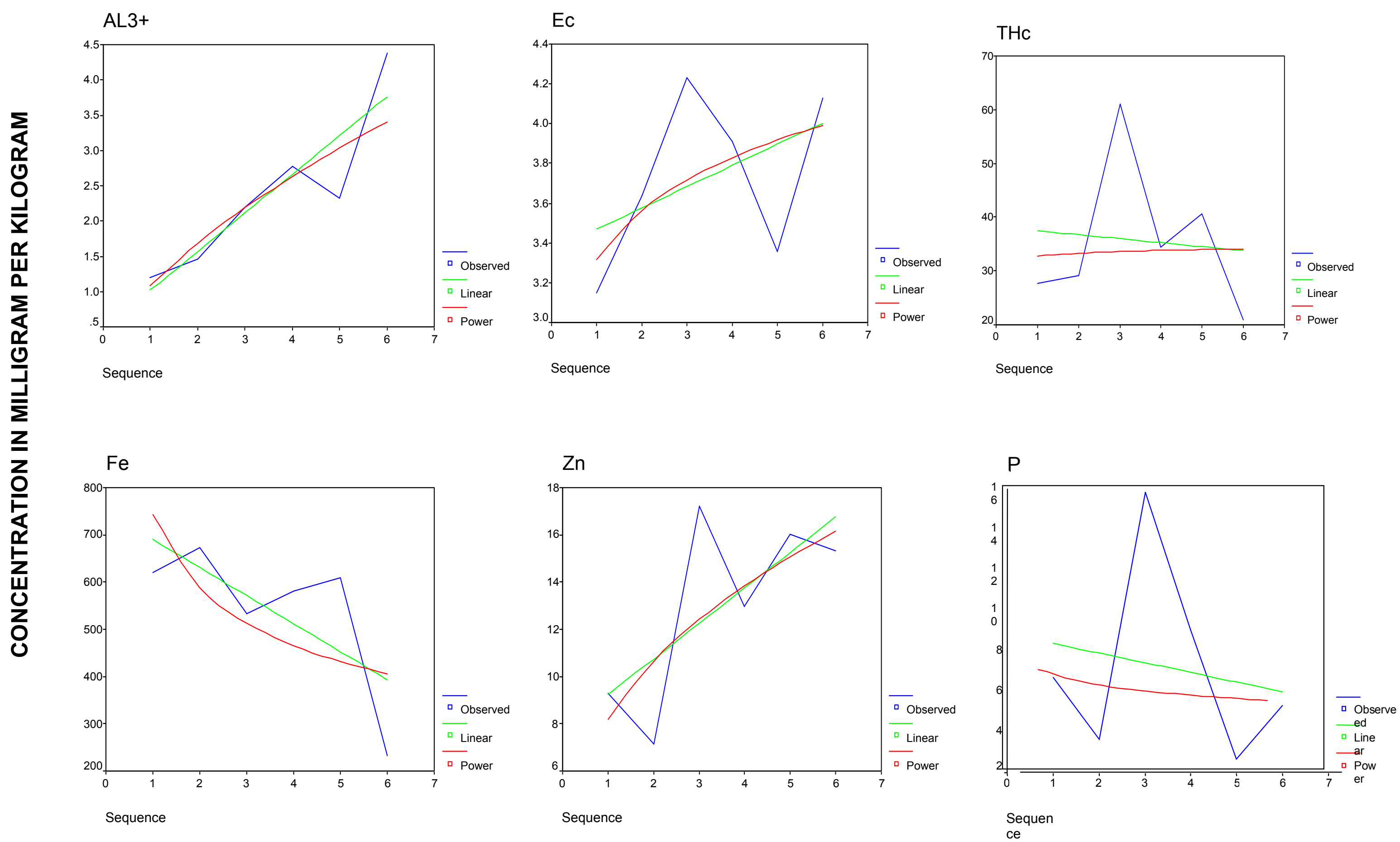
In the oil field areas (OF), the construction of burrow pits, waste pits, and ponds did not alter the historical seasonal flow patterns of the rivers. High peak flows and extreme low flows downstream the major rivers were generally similar in both areas studied. During flood periods, water in the ponds sometimes was linked directly with the streams and rivers. Thus the burrow pit influences the streams and pond chemistry since they trap various toxic chemicals and sediments, and oil that attaches to the sediments. However, in the non-oil producing areas, seasonal variation in rainfall pattern and river discharge is not affected by the burrow pits and waste pits, since these are absent except on rare occasions. Total suspended solids (TSS) comprised of organic and mineral particles that were transported in the water column. TSS in the area was closely linked to land erosion and erosion of the river channels. In the study area, TSS values were highly variable ranging from 0.05mg/l – 61.50 mg/l. The study area is generally flat and low-lying with no imposing hill or high-lying structure. Elevation measurement indicates an average of about 9m above sea level with a gentle increase towards the north and shaping towards the south. Drainage generally is limited by its flat topography resulting in swamps being developed in the lower areas and water logging of adjourning lands during the rainy reasons. In the oil field areas, watersheds showed complex morphologic features. These watersheds were drastically different from those in the non-oil field watersheds. In the oil field areas, part of the surface drainage system include water filled depressions, waste pit, burrow pits and ponds that contribute to the drainage and surface runoff only at high stages. However, such water held in depressions above the water table acts as detention storage for contaminants. In the agricultural non-oil producing watershed, groundwater flow is predominantly from recharge areas in the uplands between streams toward discharge areas along the streams. The diverse topography and scattered depressions (burrow pits, ponds and waste pits) at the oil fields create patterns of groundwater flow that are more localized than those at the agricultural non-oil produced areas. Recharge is from infiltration of precipitation through the soil and percolation from water filled depressions above the water table. Groundwater commonly flows to areas of discharge along streams, wetlands or lakes that are at lower altitudes but not necessarily within the watersheds.

SEASONAL AND SPATIAL VARIATION

The distribution of studied parameters was examined with respect to both physiograhic province and major drainage areas. The study area was divided into oil field and non-oil field areas. Because land use and population density vary within the areas, analysis by major drainage area were conducted to examine differences in studied parameters with land use. Four major drainages were selected to represent both oil and non-oil field land use. The upper Ethiope and Warri rivers lies entirely within the non-oil field area while the middle Warri, Obanagbe and Okpari Rivers drain the oil field area. Summary statistics were calculated with the Helsel and Hirsch (1992) techniques to accommodate censored data reported at minimum detection limit. Censored data are concentrations reported as less than the method reporting level. Analysis of the mean was then performed on the average parameter concentration data for the studied period to determine whether mean concentration differed among the study areas.

Mean concentrations of studied parameters show that except manganese in groundwater;

manganese and zinc in river waters; Nitrate and ammonia in the soil, most of the studied parameters were highest in the oil field area. A general decrease in concentration away from major oil installations was observed. Average monthly rainwater pH in the oil field area ranged from 5.51 - 6.10 with an annual average of 5.84. Cation concentrations were Ca 6.96 - 14.68mg/l (annual average 11.16mg/l), Mg 2.55 - 10.67mg/l (annual average 7.28mg/l), Na 1.84 - 6.63mg/l (annual average 4.41mg/l), and K 1.31-7.66mgll (annual average 4.37mg/l). Concentration of anions were HCO_3 21.98 - 36.57mg/l (annual mean 37.84mg/l), SO_4 19.45 - 54 .13mg/l (annual average 37.84mg/l), Cl 12.03 -24.11mg/l (annual average 16.73mg/l). These concentration ranges were far higher than the recorded values in the non-oil field areas with pH 6.57 - 6.76 (annual average 6.41), Ca 1.76 - 4.24mg/l (annual average 2.88mg/l), Mg 0.43 - 5.29mg/l (annual average 2.45mg/l), Na 0.68 - 8.52mg/l (annual average 3.84mg/l K 0.32 - 4.94 mg/l (annual average 2.05mg/l concentration of anions were HCO_3 3.98 -15.30mg/l (annual average 8.07mg/l), SO_4 0.36 - 9.89mg/l (annual average 3.48mg/l), Cl 3.25 - 10.97 (annual average 8.38mg/l). This result was similar to those of soil, groundwater and river water analyses. Chemical and biological indicators in soil, surface – and groundwater studied for land use setting show that soil and water quality degradation tends to be associated with the oil field area to a greater degree than with the non-oil field area. The flow station in the oil field area had the greatest effect on nutrient concentration of any identifiable source in the study area. Nitrate concentrations were appreciably higher in the oil field water (annual average NO_3 1.64 and 5.17mg/l as against 0.16 and 2.06mg/l in non oil field groundwater and rivers respectively. Similarly, THC varied between 4.47 and 8.41 in the oil field area compared with 0.23 to 1.20mg/l in the non oil field respectively. Relative to the non-oil field area, elevated concentrations of trace metals were also found in the oil field area. Generally, the tested parameter concentrations varied over time in response to hydrologic conditions. However, no seasonal pattern in concentration associated with any land use setting was evident. Generally, both surface and groundwater quality mirrored land use and soil chemistry. Average soil texture ranged between sandy loam and loamy soil. However, soils within the oil field areas recorded higher hydrocarbon contents and significant trace metal enrichment compared to the non oil field areas with little or no trace metal content. Carbonate and alumina were low indicating the vulnerability of the soil to acid radicals and increased pH (Fig. 5). However, distribution of both hydrocarbon and trace metal content in the soil studied were not determined by the soil texture but rather their closeness to major oil facilities and urban development. Although the surface water historically has not been a major source of drinking water, streams and rivers as well as burrow pits and ponds in the oil field areas are the major source of replenishment (recharge) to the underlying aquifers, the principal water supply for most of the region. Nitrate and Phosphorus concentrations from the ponds, burrow pits and waste pits were about many times greater than those from the streams/rivers within the oil field areas, and many times greater than those upstream from the non- oil producing areas.



Time (Bimonthly)

Figure 5: Concentration trend Aluminium, Iron, Exchangeable Cation, Total Hydrocarbon content, Zinc, and Lead in oil field soil.

CONCLUSION

Generally, higher concentrations of most of the studied parameters were detected in both sediments and stream water around the oil field locations compared to the non oil field area. Major influences on the stream/rivers include runoff from upland and wet lands; hydrocarbon spills and leaks from equipment maintenance, well heads and pipes as well as vandalized facilities; and high flow caused by storms and occasional flooding of the river banks. It is recommended that while potable water can be sourced from the deeper and uncontaminated aquifer to meet the needs of the people, a regular monitoring of the soil and water resource systems be carried out to prevent a build- up of toxic substances in the study area.

REFERENCE

APHA, 1995. Standard Methods for the Examination of Water and Waste Water APH/AWWA/WPCF Washngton D.C. 946pp.

Adaikpoh E.O, Kaizer A.N and Osakwe S.A., 2005. Distribution of heavy metals in subsurface soils in Abraka and Environ, Southwest Nigeria. African Scientist, 6, (1): pp 29-33.

Atakpo, E. And Chukwudebelu, J.U., 1997. Stratigraphic Cross Section of Afiesere area, Deduced from a 2 D migrated section. Bulleti`n Science Assoc. of Nigeria. 21, pp 133-143.

Assesz, O.L, 1989. Review of the stratigraphy , sedimentation and structure of the Niger Delta. In: C.A Kogbo (Editor). Geology of Nigeria, Elizabethan Press, Lagos. pp. 311-24.

Department of Petroleum Resources (DRP), 2001. Environmental Guideline and Standards for the petroleum industry in Nigeria (EGASPIN).

Kaizer, A. N. and Adaikpoh E. O., 2006. Some geotechnical properties of soils from Umutu and environ, Southwest Nigeria. Appl. Sci. Envir. Manage. 10 (4): Pp 41-45.

Kaizer, A. N., 2007a. Streambed sediment quality from some watersheds in Delta state, Nigeria. Envir. Studies, 3, (4): Pp 33-38.

Kaizer, A. N., 2007b. Trace metal and Hydrocarbon Composition of soils in Umutu and environs, Southwestern Nigeria. Sci.and Envir. 6, Pp 140-146.

Kaizer, A. N. and Osakwe S. A., 2008. Water chemistry in the Upper and middle Ethiope River, Southwestern Nigeria. Sci. and Envir. 6, Pp 147-159.

Kaizer, A. N. and Adaikpoh E. O., 2007. Trace Metal Levels in Surfacewater and Soils within Afiesere oil field area, Southwestern Nigeria. Sci.and Envir. 6, Pp 1-9.

Kogbe, C.A., 1975. The Cretaceous and Paleogene Sediments of southern Nigeria. In Geology of Nigeria, C.A. Kogbe (Ed): Elizabethan press, Lagos pp. 257-274.

Kogbe, C.A., 1989. Geology of Nigeria. Rock View Ltd, 2nd Edition. pp 311-325.

Nolan, B.T. and Stoner J.D., 2000. Nutrients in Groundwater of the conterminous United States 1992-1995. Envirmental Sciences and technology 34, (7): Pp1156-1165.

Reijers, T.J., 1996. Selected chapters on Geology, Niger Delta Basin, Published by S.P.D.C. Pp 197

Short, K.C. and Stauble, A.J., 1967. Outline of Geology of Niger Delta. A.A.P.G. Bulletin 5, pp. 761-779.

Stacher, P., 1995. Present Understanding of the Niger Delta Hydrocarbon Habitat.In: M.N. Oti and G. Postma (eds) Geology of Deltas./ Rotterdam, A.A Balkema pp. 257-267.

WHO, 2006. International standard for potable Drinking water. Geneva.