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ENVIRONMENTAL POLLUTION BY METALS IN THE OIL BEARING BAKASSI PENINSULA, CAMEROON

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Abstract: The weight fractions of the nutrients and toxic elements have been determined in environmental and foodstuff samples in the oil bearing Bakassi Peninsula. This study is highly justified by the occurrence of many offshore production platforms in the peninsula that could lead to the environmental pollution. The use of a Quant´X EDXRF spectrometer and the Fundamental Parameter approach for quantification of the results enabled us to increase sensitivity and accuracy in the analysis of soil and foodstuffs. The results obtained for soil samples exhibit a predominance of iron and the presence of lead. Mercury and cadmium are below the detection limit. The analysis of foodstuffs shows a high content of potassium and calcium. Concerning water, the analysis also shows a high content of iron (Fe) (2.18±0.04) mg/L in tap water, 10 times above the accepted limit value. Concentrations of lead (2.58±0.01) mg/L in tap water and (0.30±0.01) mg/L in rain water have been determined. No cadmium has been detected in tap water but its presence (0.80±0.01) mg/L in rain water is probably due to the atmospheric deposition.

Key words: Oil bearing region, X-ray fluorescence, ICP-OES, Ion chromatography, Atomic absorption, Mineral elements, Toxic elements

1. INTRODUCTION

The exploration and exploitation of petroleum sites became a survival issue for developed countries that circle the world looking for oil reserve. Africa is regarded as a reserve for the future and drags number of countries. These actions could lead to environmental pollution. The oil-bearing areas have faced many environmental problems caused by pollution arising from oil activities such as drill cuttings, drilling mud, fluids used in production, chemicals injected to control corrosion or to separate oil from water, and general industrial waste. Added to these are problems of gas flaring and incidents of oil spills and blow outs (Aworawo, 1999). Oil exploration in Nigeria has had severe consequences for both environmental and indigenous people. The social and environmental cost of oil production has been extensive. They include destruction of wildlife and biodiversity, loss of fertile soil. Pollution of air and drinking water, degradation of farmland and damage to aquatic ecosystem, all of which have caused serious health problems for the inhabitants of the area surrounding oil production (Adati, 2012).

Metal contamination is likely to be localized. The movement of metals through soil is reduced by the presence of organic matter and by solubility limitations. However, low pH conditions caused by the presence of mineral acids could enhance the mobility of some metals. Metals attenuated in soils at, or close to, the surface may be transported by the wind action (DOE, 1995). The oil and gas industry faces a number of issues and operational constraints that make it difficult to completely eliminate its environmental footprint. For instance, drilling and resource extraction create a number of wastes, such as produced water and drilling waste. Wastes that cannot be reused or recycled must be stored or disposed of in some manner, increasing the land area affected by oil and gas extraction and raising concerns over potential leakage of drilling fluids and other wastes from storage sites. In addition, a large increase in production in the oil and gas industry (or any industry) is likely to increase air emissions significantly. Installing new technologies and controls can reduce the quantity of air emissions per amount of fuel produced but cannot eliminate relevant environmental impacts altogether (Murphy, 2008). In spite of the damaging impact of oil exploitation on the environment and livelihoods of the host communities, scientific data on the overall and long-term effects of oil exploitation on the area are only beginning to emerge (HRW, 1999; Ndidi et al., 2015; Aluko, 1999; Okonta & Douglas, 2001; Ukeje et al., 2002; Onosode, 1999).

Rudko (2002) pointed out ecological problems of Western Ukraine and changes of geological environment under the influence of oil and gas complexes functioning. Iwejingi (2013) showed that oil from Niger Delta has generated massive economic and social transformations of many parts of the country on the one hand, but it has resulted into unparalleled damage to the Niger Delta environment. Oil spills can seriously affect the environment both as a result of physical smothering and toxic effect. The severity of impact typically depends on the quantity and type of oil spilt the ambient conditions and the sensitivity of the affected organisms and their habitats to the oil (ITOPF, 2014).

Many studies reveal the toxic effect of metals released in the environment on human health (Picot, 2003; Sasha, 2009; Lauwerys et al., 1984; Exley, 2013; Boyd, 2007). Screening the presence of toxic elements and their concentration levels allows assessing the potential hazards resulting from their consumption. A number of studies have reported the mineral and heavy metals in soil, water and foodstuffs (Khairiah et al., 2012; Azrina et al., 2011; Sobukola et al. 2010).

This paper summarizes the results of a preliminary study in the oil bearing Bakassi Peninsula aiming to determine the weight fractions of the nutrients and toxic elements in environmental and foodstuff samples. It is highly justified by the occurrence of many offshore production platforms in the peninsula that could lead to the environmental pollution.

2. MATERIALS AND METHODS

2.1. Study area

As shown in figure 1, the Bakassi Peninsula is located in the hollow of the Gulf of Guinea, bounded by River Akwayafe to the West and by the Rio del Rey basin to the East (ICJ, 2002). It covers a total area of approximately 1000 km^2 between latitudes 4°25’ and 5°10’N and longitudes 8°20’ and 9°08’E with a population of about 150, 000 - 300, 000 inhabitants (Ngang, 2007). The environment is amphibious, characterised by an abundance of water, fish stocks and mangrove vegetation (Saïdou et al., 2015).

2.2. Sampling, sample preparation and analyses

2.2.1. Soil samples

Fifteen soil samples were collected in Jabane I, Jabane II, Idabato I and Idabato II using a random sampling basis because of the irregular form of the Peninsula. Each sample, with a total fresh mass of about 2 kg, was made up of a composite of material from 5 holes distributed at the 4 corners and centre of a 1m^2 surface area. A vertical soil profile was sampled at Jabane Camp BIR at depths of: 0-5 cm, 5-10cm, 10-15cm, 15-20cm and 20-25cm. The maximum depth sampled was therefore 25 cm as water was encountered right after. Samples were then kept in clean plastic papers. In laboratory, big particles were removed from the samples and they were dried in a UK Gallenkamp Hotbox Oven with fan size 3, for 2 days at 70°C. The samples were then pulverised using a German Fritsch Pulverisette with speed up to 60 rotations per minute (rpm), sieved at about 2mm diameter. Two grams of each sample were weighed on a Sartorius analytical balance (TE 153S) with a precision of 0.001g, homogenised and ground in an agate mortar to obtain micron-sized diameters that were used to press pellets of 32 mm diameter under 20T using a Manual VANEOX 25t Press. The pellets were used for XRF analyses.

2.2.2. Foodstuffs

Leafy vegetables, shrimps and various fish were bought in local markets while water samples were collected from the tap, from the sea and from a big container collecting rain water. The leaves were dried in air to remove the moisture, and then washed with tap water before rinsing with distilled water.

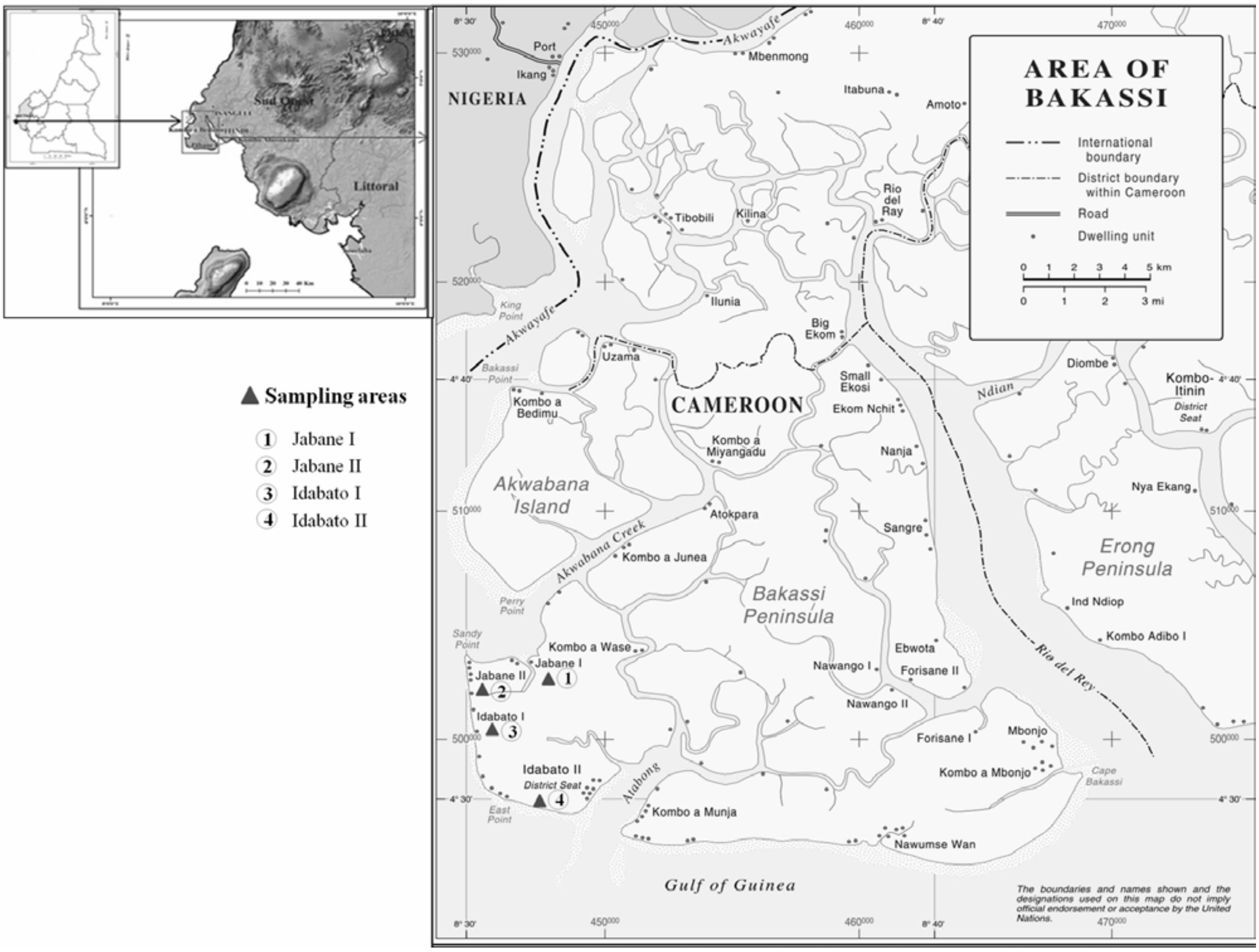

Figure 1. Location of the Bakassi peninsula (Saïdou et al., 2015).

They were dried in the Gallenkamp Hotbox Oven at 105°C for 24 hours, and pulverized to fine powder using the Fritsch Pulverisette before being pressed into pellets of approximately 2 grams.

2.2.3. Analyses

The EDXRF Quant´X spectrometer was used for analyses of soil and foodstuff pellets. Spectra acquisition and quantification were performed using Wintrace 4.1. The fundamental parameter (FP) method was used for quantification. Combined analytical uncertainty included the calibration of EDXRF Quant´X, instability of the electronics, counting statistic, and sample preparation. The Certified Reference Materials (CRMs) NIST 2704, NIST 2709, NIST 2710, PACS 1 were used to make calibration for soil analysis. The unknown elements were estimated as SiO_2: 99%. The Sandy Soil IAEA reference material was used to validate the method. Table 4 gives the z-scores calculated. Pure metals standards (Na_2CO_3, Mg, $NH_4H_2PO_4$, S, KBr, $CaCO_3$, MnO, Co, Zn, $BaSO_4$, Al, Ti, Sr, Fe, Ni, Mo, Sn, W, Pb, Cu) were used to make calibration for foodstuff analysis.

Major elements (Si, Al, Ca, Fe, K, Mg, Mn, P) with S, and U in water samples were measured using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES Perkin-Elmer 3300DV) as described in Cui et al. (2011).

Anions (F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) were measured by means of a Dionex KS-1100 Ion Chromatography at the Institute of Geological and Mining Research (IRGM) Cameroon. Cations (Na^+), K^+, Ca^{2+} and Mg^{2+}) were determined with a non-suppressed ion chromatography (DIONEX, ICS 90). Major anions (Cl^-, SO_4^{2-}, and NO_3^-) were also analyzed with suppressed ion chromatography (DIONEX, ICS-1100) at IRGM. To avoid blockage of the IC analytical column, all samples were filtered with a 0.2 µm cellulose filter.

Prior to analyses, water samples with electrical conductivity (EC) values greater than 200, between 100-199, and less than 100 were diluted 10, 5, and zero times, respectively. The dilution of a sample was performed when the electric conductivity (EC) exceeded the working capacity of the separation column chosen and also to minimize sample matrix effects. Preparation of eluents included a 180 mM Na_2CO_3 + 170 mM $NaHCO_3$ and 1M H_2SO_4 for anion analysis, which are pumped into the IC system by activating the peristaltic pumps for at least 45 minutes. Before starting the analyses of cations, a solution of 0.2M HNO_3 was prepared and pumped with the IC pump for at least 1 hour. After a standard arrangement on the auto sampler of de-ionized water, working standards with known concentrations, and samples, a sample queue was run automatically.

The concentration of ions moving through the column at a particular time is represented by height (conductivity) and breadth (retention time) of peaks that correlate to the concentration of a particular species in the sample solution. Ion concentrations were calculated from areas of peaks for each ion with the Chromeleon software. With an Excel worksheet, the peak area of each ion in a sample is converted into milligram/liter using regression equations from the line of best fit for the working standards.

Na, Cd and Pb were determined by a Flame Technique in a High Resolution Continuum Source AAS (Contr AA 700) at the Institute of Research for Agricultural Development (IRAD), Cameroon. Details of the method used are described by Welz et al., (2006).

3. RESULTS AND DISCUSSION

3.1. Weight fractions of elements in soil samples

Metal mean concentrations in soil samples in the Bakassi peninsula varie increasingly as Y< Ni< Cu< Pb< Rb< Zn< Sr< Mn< Zr< Fe. The concentration of iron (Fe) ranged from 1222 to 8742 ppm with a mean of 2999.7 ppm. The mean concentrations of Zn and Cu are respectively 53.1, 10.3 ppm. Khairiah et al., (2012) found that Fe was the most dominant metal whereas Cd had the lowest concentration for all studied soil types in some regions of Malaysia. They found that the levels of Zn, Cu, Cr, Pb and Cd in soils were naturally low.

The concentration of lead (Pb) ranged from 5 to 21 ppm with a mean of 11.8 ppm. The value 21ppm at Ecole publique Idabato exceeds the worldwide value of 17 ppm but is lower than the normal threshold in soil (20-30ppm) (Emmanuel et al., 2014). Cadmium (Cd), mercury (Hg) and lead (Pb) bio-accumulating in the environment are highly toxic to body (Picot, 2003). The variation of trace metals of interest (Cu, Ni, Pb, Zn) is illustrated in Figure 2. Mercury (Hg) and cadmium (Cd) were below the detection limit. The full result report is given in table 1.

The soil profile analysis shows a downside decreasing of elements. The profile variation of elements of interest is represented in Figure 3. This observation may be expected when the soil is not moved, i.e. in absence of mining activities. The concentration of Cu varies slightly, thus almost constant. Fe is predominant as reported by Khairiah et al., (2012). Pb ranges from 14.1 to 6.6 ppm. This evidences a possible contamination of the environment after oil exploitation.

3.2. Weight fractions of elements in foodstuff samples

Results show a predominance of potassium (K) and calcium (Ca). It can be noticed that K is largely higher than Ca in water leaves, Eru leaves, cowpea and tapioca, cassava by-product. The reverse is observed in shrimps and all the fish varieties.

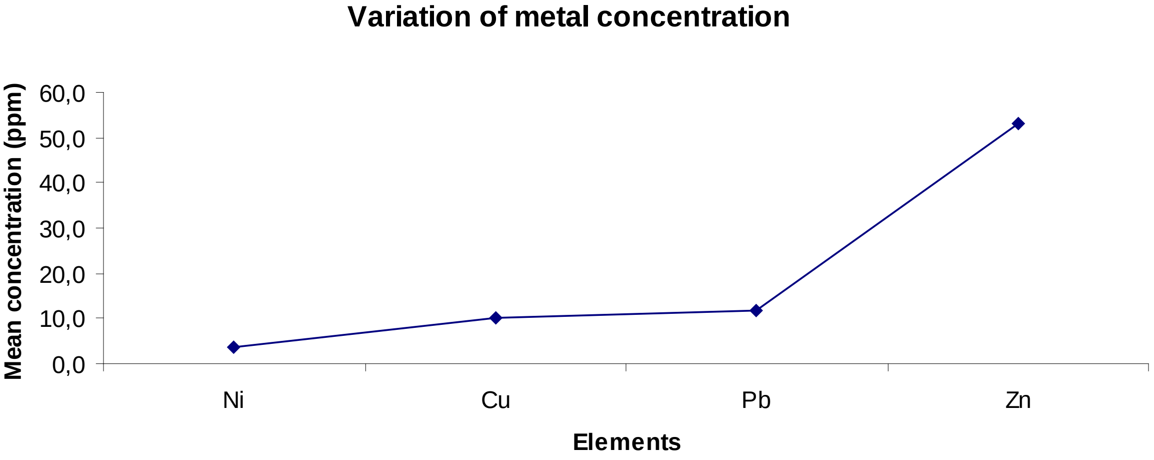

Figure 2. Variation of trace metals of interest in Bakassi samples

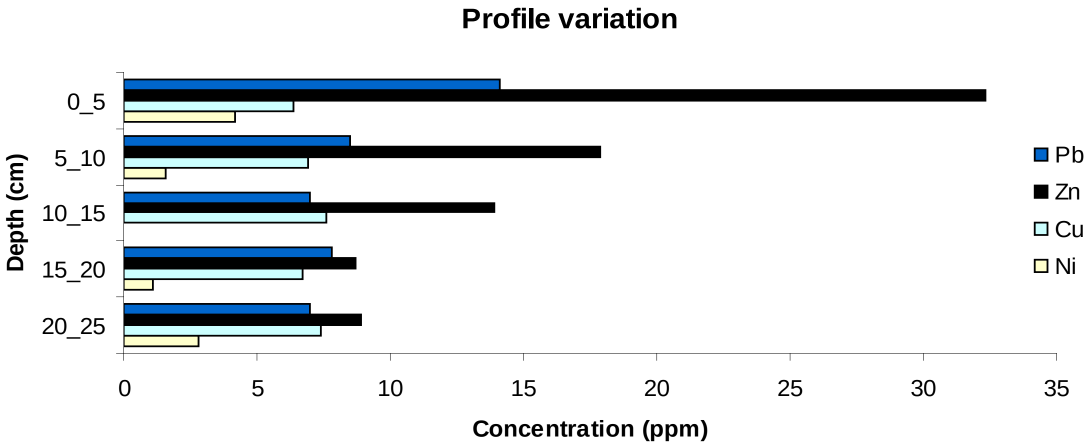

Figure 3. Profile variation of trace metals of interest

No lead, mercury and cadmium have been found in foodstuffs. Several studies reported mineral and toxic elements in leaves. Ihedioha and Okoye (2011) reported from Eastern Nigeria that K, Ca, Mg and Fe where predominant in Mucuna flagellipes leaves while Pb (0.03±0.04) and Cd (0.04±0.06) mg/100 g where below the detection limit. Ekeanyanwu et al., (2010) reported from a study in Niger Delta, Nigeria, that Fe was the most abundant mineral in the vegetables. Sobukola et al., (2009) reported that the values of Pb, Cd, Cu, Zn, Co and Ni for the leafy vegetables obtained are comparable with those available in the literature and within tolerable limits of some regulatory authorities.

On the other hand, Adepuju-Bello et al., (2013) reported in Lagos, Nigeria that all the Telfaria Occidentalis samples (100%) from 20 Local Governments in Lagos State contained Arsenic (As) and mercury (Hg) below the USP oral component limit, while 100% contained cadmium (Cd) above the oral component limit. Fawole et al. (2007) analysed Selected Fresh Water Fishes in Nigeria and reported that the species examined contained appreciable concentrations of Na, K, P, Mg, Ca, and Fe suggesting that the fish species could be used as a good source of minerals. Few heavy metals analyzed were present but within tolerable limits. Fathi et al., (2013) determined trace metal (Cu, Zn, Cd and Pb) concentrations in muscles, livers and gills of three important marine fishes from Mersing, Eastern Coast of Peninsular using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The estimated weekly and daily intakes for the studied metals were far below the Provisional Tolerable Weekly Intake and Provisional Tolerable Daily Intake limits. Their study reveals that consumption of these fishes from the study area doesn't pose a risk to human health. The full results of foodstuffs analysis are reported in table 3.

3.3. Concentrations of elements in water samples

Five water samples (2 tap water, 2 seawater, and one rain event) were collected from Jabane and Idabato. Concentrations of Al, Ca, Mg, Mn are below the maximum acceptable limit. The value (2.18±0.04) mg/L of Fe in tap water in the morning is almost 10 times above the maximum acceptable limit. This value decreases to (1.59±0.01) mg/L in the evening. Azrina et al., (2011) reported that the iron concentration of tap water from one of the 24 locations in Malaysia peninsula was higher than the standard limit, while other inorganic elements and heavy metals were below the maximum permitted levels recommended by the international drinking water standard limits.

A variation of lead concentrations from (2.58±0.01) mg/L to (1.58±0.01) mg/L has been observed for tap water in the morning and in the evening, respectively. Lead in high content in the human body disturbs the normal development of the brain, the central nervous system, the kidneys and the heart (Picot, 2003). Pb is responsible of saturnism known as lead poisoning and its limit value in blood is estimated at 10µg/dl (Sasha, 2009). Cadmium was below detection limit of the analytical equipment. This may reflects the findings of Faroon et al., (2012) which reported that cadmium and its compounds are mobilized through soil, but its mobility depends on several parameters such as pH and amount of organic matter, which will vary depending on the local environment. Generally, cadmium binds strongly to organic matter where it becomes immobile in soil and is taken up by plant life, and eventually enters the food supply chain.

Table 1. XRF analyses of soil samples from Bakassi (Cameroon)
meas.= measured

Locality	Jabane I	Jabane, Camp BIR	Ecole Publique Jabane 2	Gendarmerie Jabane	Eglise Idabato	Eglise du marché Idabato	Sayone Idabato	Quaie Idabato	Ecole publique Idabato
Coordinates	X 8°29.989´ Y 4°33.259´	X 8°29.936´ Y 4°33.008´	X 8°30.005´ Y 4°32.627´	X 8°29.974´ Y 4°32.918´	X 8°32.132´ Y 4°29.811´	X 8°32.314´ Y 4°29.835´	X 8°32.427´ Y 4°29.876´	X 8°32.502´ Y 4°29.978´	X 8°32.351´ Y 4°29.860´
Elements	meas. (ppm)								
Mn	104 ± 18	98 ±19	121 ± 19	177 ± 19	77 ±18	136 ±18	72 ±18	142 ±18	265 ±20
Fe	1849 ±20	2589 ±25	1972 ±21	3412 ± 29	2003 ±21	2661± 25	1222±16	2547±24	8742±45
Ni	10.2±1.3	1.7±1.3	3.6±1.4	3.1±1.3	2.2±1.3	4.1±1.3	1.7±1.3	2.8±1.3	3.9±1.4
Cu	7±3	4±3	14.4±3.1	14±3	12±3	9.7±3.1	10±3	10±3	11.4±3.2
Zn	29±3	33±3	6.5±2.3	100±3	61±3	86±3	18.5±2.3	43±3	101±4
Rb	17±1	14±1	12.8±0.7	12.4±0.7	10.2±0.7	8±1	7.1±0.7	10±1	17±1
Sr	45±1	36±1	27±1	178±2	36±1	45±1	22±1	51±1	68±2
Y	1.3±1.1	3.3±1.1	4.5±1.2	2.3±1.1	3.9±1.1	2.9±1.1	2.2±1.1	2.8±1.1	5.4±1.2
Zr	59±2	187±2	316±2	81±2	152±2	119±2	58±2	183±2	230±2
Pb	10.4±1.8	9.7±1.9	7.4±1.9	8.9±1.9	14.4±6.9	16.1±2.1	5±2	13.5±1.9	21±2

Table 3. XRF analysis of foodstuffs samples
meas.: measured

	Water leaf Idabato	Eru Idabato	Cowpea	White tapioca	Yellow tapioca	Schrimp Idabato	Bifaca fish	Munyanya fish Idabato	Yellow fish Jabane
Elements	meas. (%)								
Mg	2.53±0.09	4.21±0.12	2.57±0.19	2.28±0.47	3.09±0.37	1.26±0.11	0.68±0.15	0.32±0.15	0.51±0.15
Al	0.24±0.04	0.43±0.05	0.37±0.08	0.65±0.21	0.27±0.16	0.41±0.05	0.59±0.07	0.12±0.06	0.64±0.07
P	1.69±0.03	1.08±0.03	7.64±0.09	3.63±0.21	6.01±0.17	4.95±0.05	9.42±0.09	9.12±0.08	9.67±0.09
S	1.81±0.15	3.31±0.18	4.49±0.27	< DL	1.08±0.34	6.78±0.19	8.12±0.24	10.12±0.25	10.16±0.26
Cl	3.24±0.11	0.38±0.09	1.01±0.13	0.94±0.22	1.07±0.21	10.78±0.16	8.02±0.17	12.21±0.21	6.33±0.16
K	57.28±0.24	40.41±0.21	57.9±0.31	55.78±0.52	47.21±0.39	7.93±0.08	16.55±0.14	16.31±0.14	17.61±0.14
Ca	3.54±0.21	30.94±0.23	17.83±0.27	13.63±0.47	12.63±0.35	47.05±0.18	36.15±0.19	42.13±0.21	39.14±0.21
Ti	0.03±0.01	0.13±0.03	0.05±0.03	< DL	< DL	0.04±0.01	0.14±0.02	< DL	0.16±0.02
Mn	0.15±0.02	14.25±0.11	0.34± 0.06	0.30±0.21	0.24±0.13	0.04±0.01	0.09±0.02	0.07±0.02	0.07±0.02
Fe	0.39±0.02	1.13±0.05	1.00± 0.05	1.04±0.14	2.38±0.12	0.71±0.02	1.37±0.03	0.38±0.02	2.26±0.04
Zn	0.41±0.02	0.13±0.01	0.65±0.04	0.47±0.11	0.28±0.06	0.12±0.01	0.18±0.01	0.22±0.01	0.22±0.01
Sr	0.20±0.01	0.13±0.01	0.09±0.03	0.11±0.09	0.10±0.05	1.37±0.02	0.47±0.02	0.38±0.01	0.76±0.02

Table 2. XRF results of soil profile at Camp BIR
meas.= measured

Depth range (cm)	0 – 5	5 - 10	10 - 15	15 – 20	20 - 25
Elements	meas. (ppm)				
Mn	83±17	73±18	64±18	49±18	21±18
Fe	2506±23	1499±18	1673±19	1261±16	841±12
Ni	4.2±1.2	1.6±1.3	0.1±1.3	1.1±1.3	2.8±1.3
Cu	6.4±2.9	6.9±3.1	7.6±3.1	6.7±3.1	7.4±3.1
Zn	32.3±2.3	17.9±2.3	13.9±2.3	8.7±2.2	8.9±2.3
Rb	12±1	11.4±0.7	13.4±0.7	12±1	8.9±0.7
Sr	37±1	37.2±0.9	34.1±0.9	33.6±0.9	28.2±0.9
Y	4±1	2.5±1.1	2.1±1.1	1.9±1.1	3±1
Zr	185±2	100±2	124±2	81±2	94±2
Pb	14.1±1.8	8.5±1.9	7±2	7.8±1.9	7±2

Table 4. IAEA Worldwide Open Proficiency Test for X Ray Fluorescence Laboratories PTXRFIAEA10, Determination of Major, Minor and Trace Elements in a Sandy Soil, Dec. 2013 (IAEA, 2013).

Analyte symbol	**Analyte concentration (mg/Kg)**	**Standard dev.**	**Assigned value of the analyte (mg/kg)**	**Standard dev.**	**Z score**
Fe(g/kg)	6.064	0.254	6.10	0.0327	-0.09
Br	11.78	0.38	10.4	1.35	0.79
Cd	0.34	0.20	0.283	0.0554	0.69
Cu	16.6	2.50	18.0	2.63	-0.50
Mn	279	23.94	226	16.7	2.21
Ni	5.25	0.52	8.76	1.529	-2.31
Pb	14.6	2.24	26.3	3.41	-3.03
Rb	52.81	0.39	41.8	2.22	1.93
Sb	0.73	0.51	0.638	0.0858	0.56
Sr	65.98	1.61	53.7	3.87	2.60
Y	11.33	0.51	10.8	2.30	0.44
Zn	45.45	2.64	47.8	5.31	-0.55
Zr	384.85	11.08	387	65.8	-0.06

The nutrient and toxic elements concentrations are lower in tap water in the morning than in the evening. This may be a hasty conclusion to consider because the observation took place over a very short time. The concentration of cadmium (0.80±0.01) mg/L almost 207 times greater than the maximum acceptable limit for drinking water was evaluated in rain water. Cadmium damages the kidneys, lungs, and bones. Cadmium has been found in at least 1,014 of the 1,669 National Priorities List sites identified by the Environmental Protection Agency (Murphy, 2008). Observed concentration (0.30±0.01) mg/L of lead is also very high compared to that expected for drinking water. The anomalous concentration of lead in rainwater may be due to toxic aerosols in nearby Calabar Nigeria, where Uno et al., (2013) reported enrichment of lead in the atmosphere.

The concentrations of Cd (3.01±0.01) mg/L and Pb (0.17±0.01) mg/L in sea water 200m offshore are higher than their concentrations in sea water 800 m offshore where Cd (0.56±0.01) mg/L and Pb (0.00 mg/L) were measured. This variation may be due to anthropogenic pollution along the coast. In case of oil exploitation we may face environmental pollution as reported by Ashraf et al., (2010). Their results were compared with interim national water quality standards for Malaysia and found that most of physico-chemical parameters and metals concentration exceed the permissible limits. It is concluded that Bestari Jaya ex-mining catchment has a high pollution potential due to mining activities and Sungai (River) Ayer Hitam, recipient of catchment water is a highly polluted river. Table 5 gives the physico-chemical parameters and Table 6 the full report of water analysis. Taking into account of the difficult local conditions, the conditioning of water was not strictly made, thus the results of water analysis should be considered cautiously.

Table 5. Physico-chemical parameters of water samples from Bakassi (Cameroon)
TDS: Total Dissolved Solids; DO: Disolved oxygen; MS: Mass in suspension; ntu: number of tours per unit

Sample and location	Coordinates	Temp (^{o}C)	pH	Conductivity (µS/cm)	TDS (ppm)	MES (ppm)	Salinity (ppm)	Turbidity (ntu)	DO (ppm)	Alkalinity (mg/l)
Water tap (morning), Jabane	X 8°29.937´- Y 4°33.046´	21.5	7.64	469	470	20,67	0	0.4	10.66	106
Water tap (evening), Jabane	X 8°29.937´-Y 4°33.046´	20.8	7.94	467	469	20,08	0	1.51	10.6	132
Sea water (200 m offshore), Jabane	X 8°32.235´-Y 4°29.869´	21.5	6.66	30100	38633	62,5	18,7	5.25	10.6	42
Sea water (800 m offshore), Jabane	X 8°29.843´-Y 4°33.013´	22	7.4	29500	30000	13,5	18,2	1.2	10.62	42
Rain water, Ecole Publique, Idabato	X 8°29.506´-Y 4°33.368´	23.7	5.64	22.1	22,6	57	0	0.12	10.86	0

Table 6. Chemical composition (mg/l) of water samples from Bakassi (Cameroon)
LAV*: Limited accepted value (Council Direction, 1998; WHO, 1996)

Element	Tap water		Rainwater	LAV*	Seawater sampled from shore at	
	Morning	Evening			200m	800m
Al	0.07 ± 0.01	0.044 ± 0.001	1.037 ± 0.094	0.2	4.03 ± 0.06	0.555 ± 0.004
Ca	4.97 ± 0.03	4.38 ± 0.09	<DL ± 0.01	100	182.70 ± 1.51	173.80 ± 1.87
Fe	2.18 ± 0.04	1.59 ± 0.01	0.02 ± 0.00	0.2	0.64 ± 0.01	0.87 ± 0.00
K	12.47 ± 0.10	6.57 ± 0.11	0.76 ± 0.04	12	216.20 ± 2.14	186.20 ± 2.38
Mg	5.70 ± 0.05	5.04 ± 0.09	0.45 ± 0.01	30	573.50 ± 5.35	537.30 ± 5.75
Mn	0.07 ± 0.01	0.07 ± 0.01	<DL ± 0.01	0.1	0.01 ± 0.01	<DL ± 0.01
P	6.79 ± 0.04	3.09 ± 0.04	<DL ± 0.03		3.83 ± 0.08	<DL ± 0.02
S	2.90 ± 0.35	<DL ± 0.12	0.32 ± 0.06		2079 ± 22	1930 ± 12
Si	16.93 ± 0.20	17.06 ± 0.13	0.12 ± 0.01		0.98 ± 0.01	0.44 ± 0.01
Sr	0.04 ± 0.00	0.03 ± 0.00	<DL ± 0.01			
U	<DL ± 0.01	<DL ± 0.01	<DL ± 0.01	1.4	0.01 ± 0.01	0.01 ± 0.01
F^-	0.23± 0.01	0.20± 0.01	0.02± 0.01	1.5	0.07	0.12
Cl^-	23.31± 0.10	19.96± 0.10	1.20± 0.01	250	11250.11	11076.32
NO_3^-	12.50± 0.10	5.93± 0.01	1.87± 0.01	50	0.03	0
PO_4^{3-}	0.75± 0.01	0.68± 0.01	0		0	0
SO_4^{2-}	0.05± 0.01	0.02± 0.00	0.49± 0.01	500	11.88	10.66
Na	3.93± 0.01	4.61± 0.01	0	200	23.68	21.97
Cd	0	0	0.80± 0.01	0.003	3.01	0.56
Pb	2.56± 0.01	1.58± 0.01	0.30± 0.01	0.01	0.17	0

4. CONCLUSION

The present pilot study provides values of chemical elements with a focus on heavy metals in soil, foodstuffs and water samples in the Oil bearing Bakassi Peninsula. It appears that foodstuffs do not present health risk. Care should be paid to tap and rain water intended for drinking. The origin of cadmium and lead in rain water should be clearly known. This should lead to air pollution monitoring in the peninsula. The results obtained are not so much different with those reported in the literature in the absence of oil exploitation, but care should be taken in case of industrial activities to prevent environmental pollution. Taking into account of the difficult local conditions, the conditioning of water was not strictly made, thus the results of water analysis should be considered cautiously.

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