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Heavy metal assessment of marine sediment in selected coastal districts of the Western Region, Ghana

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Abstract. A preliminary investigation to establish the status of contamination of trace metals in the Western coast of Ghana was conducted prior to the commercial production of crude oil in the area. The study revealed the presence of heavy metals such as Pb (4.00–79.64 mg/kg), As (8.81–236 mg/kg), Cu (12.86–108.06 mg/kg), V (28.07–953.32 mg/kg), Zn (7.08–264.25 mg/kg), Cr (101.69–1366.62 mg/kg), Ni (42.41–451.43 mg/kg), Mn (16.77–1890.45mg/kg), Br (7.66–142.78 mg/kg), Ti (542.03–19960 mg/kg) and Fe (7472.88–97120 mg/kg) at six sites sampled along the coast. With the exception of Ti and Fe which showed no variation in metal concentration, the rest of the metals varied significantly among the sampled locations. Potential ecological risk of metals particularly of Co, As and Br which exhibited extreme enrichment of the sediments indicates considerable metal pollution in the studied areas. The degree of contamination is of particular concern especially to benthic biota that inhabit this environment for survival.

Keywords: sediment; heavy metals; ecological risk; enrichment; degree of contamination

1. Introduction

Marine sediment is a gold mine of information in terms of giving information about the past state of the marine ecosystem. It is an important source in examining the transformation of toxic metals such as Pb, Cd, As, Hg, among others as it provides a long-term integration of metal input (Wong *et al*. 2001, Qiu *et al*. 2011). Geological structure of the aquifer and weathering processes are the major sources of trace metals but these metals are introduced to the marine environment either by natural or anthropogenic activities. Pathways for metal input to the marine environment include transport via rivers and streams, direct discharge and atmospheric fallout (Cheng *et al*. 2009, Zhang *et al*. 2012). Some of these heavy metals are toxic especially when they reach levels that impact negatively on human health. However, for some metals such as Cu, Fe, Mn and Ni, they are essential micronutrients for the life processes of animals and plants but imbalances of

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these metals may be fatal to organisms. Additionally, heavy metals such as As, Pb and Cd exhibit extreme toxicity even at low concentration (Gopalani *et al*. 2007, Qiu *et al*. 2011). Unlike organic pollutants which are biologically degraded, heavy metals accumulate in sediments by being absorbed in complex structures (Olivares-Rieumont *et al*. 2005). However, variation of some physical and chemical characteristics (pH, salinity, redox potential and content of organic matter) of the underlying sediment may provoke the release of metals back to the aqueous phase, thus under changing environmental conditions sediments may become themselves important pollution sources (Ahdy and Khaled 2009, Yılmaz *et al*. 2010, Varol 2011).

Therefore, an assessment of heavy metal contamination in sediments is an indispensable tool to assess the risk of an aquatic environment. The determination of metals in sediments has been used for long years in observing the environmental effects (Soares *et al*. 1999) of human activities on the aquatic environment. In 2007, oil was discovered in commercial quantities in the offshore regions of some parts of the Western region (mainly Half Assin, Efasu and Cape Three Points) which are in three districts of the region namely Jomoro, Ellembelle and Ahanta West. As a result many exploration companies have encroached in the offshore areas of the Western Region in a bid to explore and mine this natural resource in commercial quantities. These exploration companies unfortunately introduce large quantities of inorganic pollutants into the marine environment with potential toxic effect on the aquatic ecosystem. Although most of the activities take place in the offshore regions of the sea, their effects are not only limited to the offshore regions but the coast where most people live.

The present study was therefore carried out to determine the status of heavy metal concentration in the sediments along the coast and to verify the possibility of contamination and subsequent toxicity to the aquatic environment.

The study will also help in assessing the extent and degree of contamination if any, of metals using various indices such as enrichment factor (EF) and index of geoaccumulation (Igeo). The study will also provide baseline information necessary for developing strategies for pollution control and sediment remediation.

2. Material and methods

This study investigates the distribution of metal concentration in surface sediments of some coastal communities in the Western Region of Ghana (Fig. 1). The Western Region enjoys a long coastline lying between 5°30’N and 2°30’W. Among the six coastal districts in the region, 3 districts namely; Ellembelle (Ngalekpole), Ahanta West (Cape Three Points, Dixcove and Axim) and Jomoro (Efasu, Half-Assini and Mangyea) were earmarked for this work because oil was found in large quantities in their offshore regions. Fishing is the major source of livelihood for the inhabitants in these three districts. Dixcove is characterized by a rocky pool where the rocks consist mainly of sandstone and shale. The other sites lie within a long stretch of sandy beaches from the Cote d’Ivoire border to Axim although Axim occurs as rocky outcroppings alternating with sandy bays (Armah and Amlalo 1998).

Sampling of sediment took place in 2009 (March and April) prior to the commencement of drilling of oil in commercial quantities. The top 5 cm of the sediment was removed with a pre-cleaned spatula to prevent contamination. At least five sampling spots were identified in each sampling area and three (3) samples were collected from each spot after which they were carefully homogenised. Immediately after collection, samples were placed in clean-polyethylene zip lock

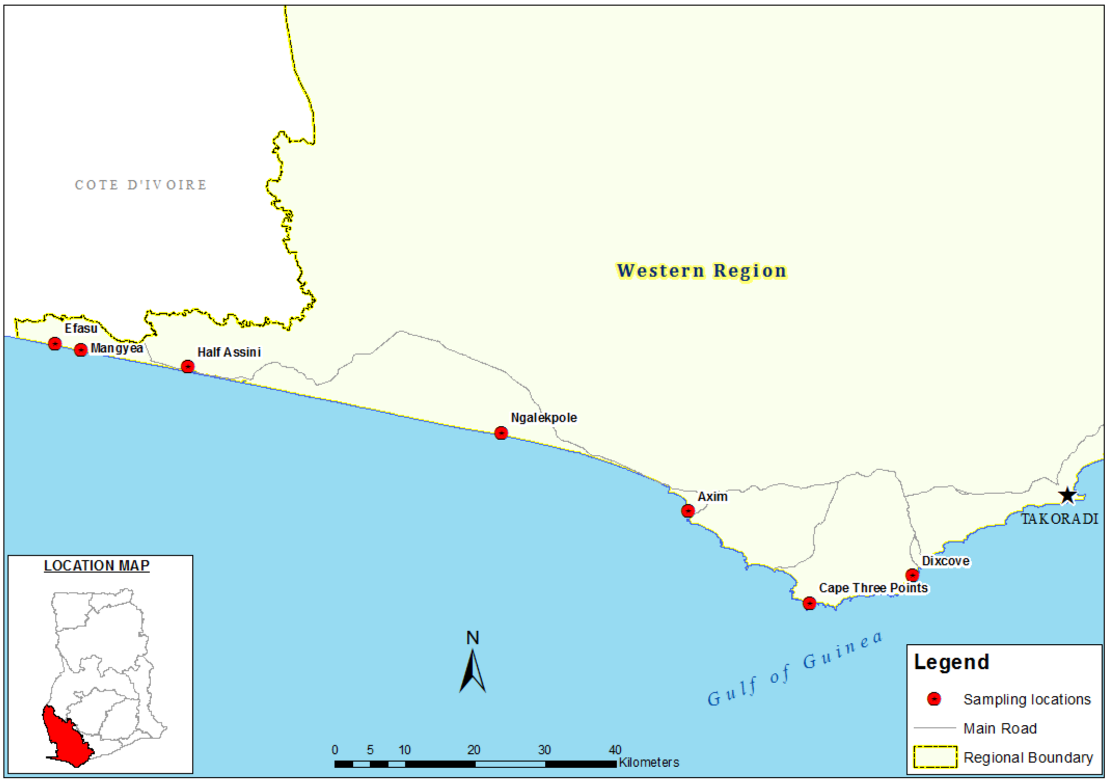

Fig. 1 Map of study area indicating sampling sites

bags, kept on ice, and transported to the laboratory for analysis. The samples were air dried for 2 weeks and sieved through 150 micron mesh size to remove large and extraneous materials. The samples were pulverized and homogenized into a very fine powder. About 10 g of the samples were made into thick sample pellets of diameter 2.5 cm using the hydraulic press (hydraulic unit model no. 3912) with an applied load of 10 metric tons. The elemental concentrations were determined using energy dispersive X-ray fluorescence (EDXRF) with a secondary target arrangement. EDXRF provides a rapid and non-destructive method for the analysis of trace and major elements in the samples (Yeung *et al*. 2003).The compact 3K5 X-ray Generator EDXRF Spectrometer which was used for the elemental analysis has a Mo anode and operated at 800 w (40 kV and 10 mA). The irradiation was done using a Mo secondary target arrangement coupled to pettier cooled silicon drift detector (SDD) with a 12 μm beryllium window thickness. The silicon drift detector has a resolution of 136 eV for 5.9 KeV x-ray energy. Sample pellets were placed at an angle of 45° to the primary beam and irradiated for 600 seconds. The EDXRF Ka line intensities were measured for all elements except Pb and Hg, for which the Lb line intensities were measured (Yeung *et al*. 2003). Applied voltage and current are chosen to acquire the required K″ or L″ energies line. The current was to maintain similar portions of live detection time. MCDWIN-(MC-A (1)) software was employed for data collection. Linear least squares fitting of the axils software programme was used for the spectrum de-convolution. Emission- transmission method in QXAS package was used to convert spectrum peak areas to concentrations.

2.1 Enrichment factor (EF)

This factor was based on the standardization of a tested element against a reference one. A reference element is one which is characterised by low occurrence variability, abundant in the earth crust and usually has no contamination concern (Sakan *et al*. 2009, Zhang *et al*. 2009). Mathematically, EF is expressed as (Ghrefat *et al*. 2010).

$$EF = \frac{\left(\frac{M}{Fe}\right) sample}{\left(\frac{M}{Fe}\right) background}$$

Where $\left(\frac{M}{Fe}\right) sample$ is the metal to Fe ratio in the sample of interest; $\left(\frac{M}{Fe}\right) background$ is the natural background value of metal to Fe ratio. The world average shale and the world average soil are among the materials normally used to provide background metal levels. The regional geochemical background values for the metals are not available. Therefore the background values used in this study were in mg/kg: 20 (Pb), 95 (Zn), 68 for Ni, 19 (Co), 90 (Cr), 45 (Cu), 850 (Mn), 47,200 (Fe), 4,600 (Ti), 130 (V) and 13 (As) (Turekian and Wedepohl 1961). These values are commonly used as background values in sediment studies to quantify the extent and degree of metal pollution (Ghrefat *et al*. 2010, Gargouri *et al*. 2011). According to the classification as suggested by Chen *et al*. (2007), $EF < 1$ indicates no enrichment, $EF = 1–3$ means minor enrichment, $EF = 5–10$ shows moderately severe enrichment, $EF = 10–25$ indicates severe enrichment, $EF = 25–50$ indicates very severe enrichment and $EF > 50$ indicates extremely severe enrichment.

2.2 Index of geoaccumulation (Igeo)

It is a sediment quality criterion used to assess contamination by comparing the current and pre-industrial concentration originally used with bottom sediments (Muller 1969). It is computed using the following equation.

$$Igeo = \log_2 \frac{c_n}{1.5B_n}$$

Where C_n is the measured concentration of the examined metal (n) in the sediment, B_n is the geochemical background concentration of the metal (n). Factor 1.5 is the background matrix correction factor due to lithogenic effects which may arise as a result of variation in the sediments. According to Muller (1969), the following classification is given for Igeo: < 0 = practically unpolluted, 0–1 = unpolluted to moderately polluted, 1–2 = moderately polluted, 2–3 = moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted and > 5 = extremely polluted.

Results obtained from IAEA soil-3 and soil-7 are given in Table 1. All metal concentrations were within acceptable ranges. Analysis of standard reference materials and reproduction of data is important to ensuring data quality.

Table 1 Trace metal concentrations (mean ± standard deviation) for IAEA soil-3 and soil-7

Metal	IAEA SOIL 7	
	This study	Certified Values
Ti	3119.00 ± 155.95	
V	67.90 ± 3.39	66.00 ± 3.30
Cr	61.70 ± 3.09	60.00 ± 3.00
Mn	650.70 ± 32.54	631.00 ± 31.55
Fe	26576.00 ± 1328.80	25700.00 ± 1285.00
Co	8.70 ± 0.44	8.90 ± 0.45
Ni	26.70 ± 1.34	26.00 ± 1.30
Cu	11.28 ± 0.56	11.00 ± 0.55
Zn	107.10 ± 5.36	104.00 ± 5.20
As	12.90 ± 0.65	13.40 ± 0.67
Br	7.16 ± 0.36	7.00 ± 0.35
Pb	61.80 ± 3.09	60.00 ± 3.00

Statistical analysis was conducted using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). The relationships between metal concentrations among the investigated sites were assessed by Pearson's correlation test. A one-way analysis of variance (ANOVA) was used to verify any statistically significant differences ($p < 0.05$) among the locations.

3. Results and discussion

Results of major and trace metal concentration found in the study area are presented in Table 2. The ranges for the mean concentration of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Br and Pb among the investigated locations were 992.50 – 8510.77, 36.08 – 692.56, 138.81 – 1102.36, 33.34 – 1574.30, 11933.55 – 52815.00, 29.74 – 554.13, 49.40 – 417.95, 13.87 – 91.27, 10.65 – 212.34, 15.53 – 182.03, 8.87 – 120.19 and 4.87 – 62.70 mg/kg, respectively. Axim recorded majority of the highest concentrations of the metals particularly for V, Cr, Mn, Co, Cu, Zn, As and Pb. The samples from Axim were taken from the main fish landing bay where there is intense human activity on daily basis. The outboard motors which are used to power the fishing boats potentially discharge oils and other contaminants close to the shore and therefore may contribute substantially to the elevated levels of heavy metals at the site. Moreover, Axim which is an ancient colonial town and houses the fort of St Anthony built by the Portuguese in 1515, has seen long standing human activities over the years which may have contributed to high levels of metal concentration. The highest concentration of Fe, Ni and Br were however measured in samples from Dixcove. The samples were taken from the main fish landing beach of the town, where outboard motor servicing, repairs and maintenance takes place. Additionally, the suspected mineral rich rocks found at the beach may be a contributory factor to the high levels of elements especially Fe observed in this location. Locations such as Efaso and Mangyea are relatively pristine with no industrial or commercial fishing activities taking place there. The Osagyefo Barge which was to make use of natural gas from the Tano Basin was not operational at the time of sampling and that might explain the low concentrations of elements found in these locations. Half Assini also recorded high levels

Table 2 Major and trace metal concentration (mg/kg) in sediment from the various sites of the Western Coast

Metal	Content	Location						p
		Axim	Dixcove	Cape Three Point	Efaso	Half-Assini	Mangyea	
Ti	Mean ± SD	3462.45 ± 75.00	1018.09 ± 333.87	1326.97 ± 81.97	1134.02 ± 741.94	8510.77 ± 7360.77	992.50 ± 296.14	NS
	Range	3375.89 – 3508.20	782 – 1254.17	1269.00 – 1384.93	542.03 – 2565.33	1051.62 – 19660.00	783.10 –1201.90	
V	Mean ± SD	692.56 ± 300.60	574.50 ±92.63	309.15 ± 255.76	75.59 ± 19.50	248.79 ± 196.78	36.08 ± 11.33	S
	Range	363.77 – 953.32	509.00 – 640.00	128.30 – 490.00	53.00 – 100.00	31.90 – 536.76	28.07 – 44.09	
Cr	Mean ± SD	1102.36 ± 259.89	517.71 ± 182.02	495.66 ±23.72	429.85 ± 351.33	138.81 ± 38.22	157.51 ± 56.33	S
	Range	847.08 – 1366.62	389.00 – 646.42	478.88 – 512.43	128.89 – 1011.00	101.69 – 199.88	117.68 – 197.34	
Mn	Mean ± SD	1574.30 ± 430.22	647.38 ± 307.19	614.14 ± 92.96	80.83 ± 40.88	235.86 ± 220.25	33.34 ± 21.88	S
	Range	1084.37 –1890.45	430.16 – 864.59	548.40 – 679.87	37.00 – 122.42	16.77.00 – 575.00	17.86 – 48.81	
Fe	Mean ± SD	40649 ± 48938.16	52815 ± 11179.36	28800 ± 23589.08	14197.15 ± 5634.49	40646.67 ± 27346.92	11933.55 ± 3035.55	NS
	Range	10621.00 – 97120.	44910 – 60720	12120 – 45480	7472.88 – 22360	11280 – 81860	9787.09 – 14080	
Co	Mean ± SD	554.13 ± 154.1	311.43 ± 14.75	206.41 ± 102.66	75.25 ± 24.29	123.17 ± 54.23	29.74 ± 1.96	S
	Range	395.81 – 703.64	301 – 321.86	133.82 – 279	46 – 107	26.31 – 176.01	28.35 – 31.12	
Ni	Mean ± SD	319.67 ± 25.93	417.95 ± 47.35	296.61 ± 76.64	153.51 ± 102.97	59.31 ± 8.87	49.40 ± 9.39	S
	Range	290.01 – 338.08	384.47 – 451.43	242.41 – 350.80	62.06 – 303.21	48.54 – 71.82	42.76 – 56.04	
Cu	Mean ± SD	91.27 ± 19.60	62.53 ± 33.60	29.53 ± 16.22	24.72 ± 9.59	30.26 ± 12.36	13.87 ± 1.43	S
	Range	69.73 – 108.06	38.77 – 86.29	18.06 – 41	14.38 – 40.42	15.39 – 49.91	12.86 – 14.88	
Zn	Mean ± SD	212.34 ± 45.83	48.19 ± 27.85	29.87 ± 17.88	14.30 ± 6.08	63.93 ± 48.66	10.65 ± 4.39	S
	Range	177.48 – 264.25	28.49 – 67.88	17.22 – 42.51	7.08 – 22.55	13.65 – 135.42	7.54 – 13.75	
As	Mean ± SD	182.03 ± 53.47	155.35 ± 2.86	131.35 ± 21.62	18.36 ±8.96	62.44 ± 46.46	15.53 ± 3.34	S
	Range	129.08 – 236	153.32 – 157.37	116.06 – 146.63	8.81 – 31.35	14.25 – 134.60	13.16 – 17.89	
Br	Mean ± SD	77.63 ± 10.34	120.13 ± 32.04	120.19 ± 30.02	10.39 ± 1.95	17.15 ± 4.90	8.87 ± 1.08	S
	Range	66.41 – 86.78	97.47 – 142.78	98.96 – 141.42	7.66 – 13.64	9.43 – 23.73	8.10 – 9.63	
Pb	Mean ± SD	62.70 ± 14.89	38.50 ± 0.71	31.42 ± 10.72	5.23 ± 1	12.83 ± 7.23	4.87 ± 0.06	S
	Range	51.70 – 79.64	38 – 39	23.84 – 39	4 – 6.44	4.61 – 21.54	2.10 – 9.64	

• SD - Standard Deviation; Range - Minimum and Maximum concentrations;

p - Test of significance; NS - Not Significant ($p > 0.005$); S - Significant ($p < 0.005$)

Table 3 Trace element concentration (mg/kg) from various regions which their coastline on the Gulf of Guinea

Sample location	Togo Coast[a]	Ondo Coast[b]	Shales[c]	Mean crust[d]	This work
Ti	n.d	n.d	n.d	n.d	542.03 – 19960.00
V	38.00 – 329.00	6.80 – 16.34	130	n.d	28.07 – 953.32
Cr	115.00 – 753.00	6.61 – 14.92	90	100	101.69 – 1366.62
Mn	n.d	982.57 – 2527.10	n.d	n.d	16.77 – 1890.45
Fe	n.d	662.05 – 1463.06	n.d	n.d	7472.88 – 97120.00
Co	n.d	9.97 – 62.99	n.d	n.d	26.31 – 703.64
Ni	19.00 – 281.00	n.d	68	n.d	42.41 – 451.43
Cu	22.00 – 184.00	n.d	45	50	12.86 – 108.06
Zn	60.00 – 632.00	76.47 – 193.49	95	75	7.08 – 264.25
As	n.d	0.38 – 0.80	n.d	n.d	8.81 – 236.00
Br	n.d	n.d	n.d	n.d	7.66 – 142.78
Pb	22.00 – 176.00	20.32 – 48.85	n.d	14	4.00 – 79.64

• n.d: not determined
[a] Gnandi and Tobschall 1999
[b] Adebowale et al. 2009
[c] Wedepohl 1991
[d] Bowen 1979

Table 4 Pearson correlation matrix for the analysed metals in the studied sediment from the Western Coast, Ghana

	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Br
V											
Cr		0.49*									
Mn		0.90**	0.70**								
Fe	0.59**										
Co		0.92**	0.69**	0.97**							
Ni		0.61**	0.79**	0.63**		0.67**					
Cu		0.79**	0.79**	0.84**	0.57**	0.85**	0.68**				
Zn		0.84**	0.60**	0.91**		0.88**		0.83**			
As		0.95**	0.55*	0.91**	0.45*	0.90**	0.69**	0.77**	0.79**		
Br		0.67**	0.44*	0.62**		0.66**	0.81**	0.50*		0.81**	
Pb		0.92**	0.69**	0.96**		0.97**	0.70**	0.86**	0.86**	0.95**	0.75**

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

of some elements mainly due to activities at the landing site and the presence of discarded fishing vessel close to the sampling site. Statistically, there was no significant difference ($p > 0.05$) in Ti and Fe among the various locations. Titanium, probably as ilemenite, is one of the most stable elements in the aquatic environment and represents the most indicator of detrital origin (Santos *et al*. 2005). Therefore no significant difference among the sampling locations shows that lithological sources are the same. Meanwhile there was a significant difference ($p < 0.05$) in other metals.

Variation in concentrations of major and trace metals from the different study sites could be attributed to the difference in hydrodynamic process, terrestrial inputs and atmospheric deposition conditions (Gargouri *et al*. 2011).

To understand the extent of pollution of the studied sediments, comparison was made between the measured metal concentrations and those given in literature (Bowen 1979, Wedepohl 1991) and results from two countries (Togo and Nigeria) which have their coastline on the Gulf of Guinea. There were no elemental background concentrations for comparison but when compared with the mean crust and shales (Table 3), some sites in the study area were contaminated with the measured elements. Comparison of the metals concentrations in the sediments with the sediments from other polluted marine environment such as Togo and Nigeria (Table 3) which have their coastline on the Gulf of Guinea indicates that the Western coast of Ghana is polluted with these selected metals except Mn which was relatively low in comparison with Ondo coast (Adebowale *et al*. 2009). The levels of Cu, Zn and Pb were also low in comparison with Togo coast (Gnandi and Tobschall 1999).

Elsewhere, the results reported for Cu is similar to what has been reported by Yang *et al*. (2012) in sediment samples of the Pearl River Estuary. Values of Ni in this study are also comparable to concentrations (283–426 mg/kg) reported by Uluturhan (2010) from the Gokova Gulf of the Eastern Aegean Sea although those of Pb were higher than concentration reported by Reitermajer *et al*. (2011) from Brazil.

Pearson's correlation coefficients for V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Br, Pb observed from the study is presented in Table 4. The matrix gives a summary of the strength of the linear relationships between each pair of variables. The Mn-V ($r = 0.93$), Co-V ($r = 0.95$), As-V ($r = 0.95$), Mn-Cr ($r = 0.70$), As-Pb ($r = 0.95$), among other pairs are significantly positively correlated with each other at the 99% confidence level indicating either a common or similar geochemical behaviour or anthropogenic origin. The statistical analysis of intermetallic relationship revealed that the high degree of correlation and significant regression relation among the metals indicate the identical behaviour of metals in the marine environment (Neser *et al*. 2012). There was a strong positive correlation between V and most of the metals, thus indicating a common source for these metals. Vanadium in sediment solution occurs in the +5 and +4 oxidation states as the vanadate forms and as the vanadyl cation, VO^{2+}. According to Liaghati *et al*. (2003), under oxidised conditions with pH from neutral to alkaline, vanadium has high mobility and bioavailability. Under reductive conditions, humus promotes easy reduction of vanadate to vanadyl and causes the immobilization of vanadium when it is bound to organic material. This immobilization factor might have contributed to the abundance of this metal in the study area.

With the exception of Mn which showed minor enrichment, the sediments were enriched with all the metals at the various sites. The EF values for Co are the highest among the metals and it has a severe to extremely severe enrichment. The metals, As and Br also show severe to extremely severe enrichment of the sediments thus indicating a considerable metal pollution in the study area. Vanadium, chromium and nickel also show moderately severe enrichment.

The geoaccumulation index (Igeo) may contribute to the estimation of the degree of the sediment contamination (Table 6). The average of the geoaccumulation index indicates that Co could be considered as moderate to strong pollutants as suggested by the Muller (1969) scale while As and Br show signs of moderate pollution. The element of particular interest in this study is Vanadium. It can be found in the environment in algae, plants, invertebrates, fishes and many other species. In mussels and crabs, vanadium has the potential to bioaccumulate, leading to concentrations which can be several times greater than the concentrations that are found in seawater. Vanadium causes the inhibition of certain enzymes in animals, which has several neurological effects. Next to the neurological effects, vanadium can cause breathing disorders,

Table 5 Metal enrichment factors in the surface marine sediments from the Western coast of Ghana

	Mean	SD	Range
Ti	1.76	0.55	0.004 – 10.13
V	5.27	1.79	1.09 – 37.08
Cr	6.69	1.68	1.56 – 35.44
Mn	0.63	0.11	0.001 – 2.43
Co	22.42	8.63	10.62 – 125.84
Ni	5.45	2.46	0.63 – 49.07
Cu	2.52	1.3	0.51 – 24.89
Zn	1.78	0.77	0.23 – 12.00
As	13.99	5.66	3.39 – 114.75
Br	20.35	8.53	2.66 – 178.45
Pb	2.88	1.2	0.70 – 21.13

Table 6 Geoaccumulation index (Igeo) values of metals in the surface marine sediments from the Western coast of Ghana

	Average	SD	Range
Ti	-1.86	0.76	-12.65 – 2.46
V	1.09	0.32	-0.89 – 5.54
Cr	1.56	0.28	-0.26 – 4.33
Mn	-1.99	0.49	-9.8 – 0.24
Fe	-6.99	1.53	-14.25 – 3.64
Co	3.35	0.16	2.15 – 4.27
Ni	0.79	0.29	-1.03 – 2.91
Cu	-0.52	0.31	-2.48 – 3.38
Zn	-1.09	0.36	-3.18 – 3.91
As	2.3	0.31	-0.27 – 5.81
Br	2.74	0.32	0.16 – 4.77
Pb	0.03	0.33	-2.52 – 3.77

• SD-Standard Deviation; Range-Maximum and Minimum

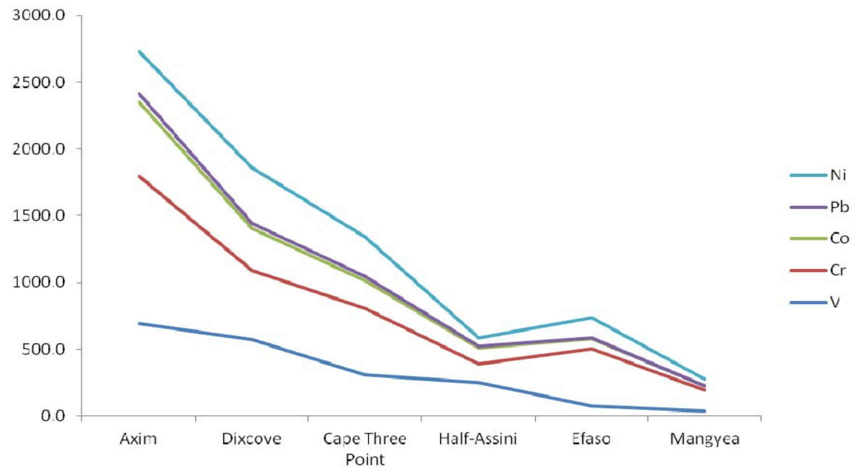

Fig. 2 Concentration of indicator and toxic metals of the sampling sites (mg/kg)

paralysis and negative effects on the liver and kidneys. Vanadium is related to the space petroleum activities, and therefore it can be used as indicator for petroleum pollution (El-Moselhy 2006). Igeo values of vanadium ranging from -0.89 – 5.54 indicating no pollution to extremely polluted reveals that anthropogenic activities involving petrochemical substances rather than natural occurrences is contributing to the pollutant load. The highest concentration of 692.56 mg/kg found in Axim may be mainly due to oil spills from outboard motors from fishing canoes which are serviced or repaired at the fish landing bay. It may also be due to the historical use of the beach as vessel docking for pre-colonial merchants. In the case of Dixcove, the rocky nature of the beach as well as the activities of outboard motor servicing may have contributed to the relatively high concentration of 574.50 mg/kg. The levels found in Cape Three points can be attributed to the oil exploration activities which were taking place offshore. For the other sites i.e., Half Assini, Efaso and Mangyea the levels were 248 mk/kg, 75.59, 36.08 mg/kg. Efaso and Mangyea are suspected to be directly impacted by the oil exploration and drilling at the Jubilee Fields which is at least 60 km offshore. Although the values are at background levels, as exploration and production activities increase the levels are likely to rise if not regulated.

The Fig. 2 reveals the general trend in the reduction in concentration of metals as one move towards Efaso area. This gives an idea of the prevailing condition in the coastlines prior to commercial production of oil in offshore.

Other metals Ti, Fe, Cu, Cr, Ni and Zn which have Igeo maxima values varying from -1.31 – 5.54 showed localised zones of the sediment which are polluted by these metals. These contaminated sites may therefore be considered as potential ecological risks. For Mn, however, the maximum Igeo value is < 1 indicating non-existence of pollution with regard to this metal.

4. Conclusions

In this paper coastal sediments from the Western Region of Ghana have been successfully assessed for metal pollution using enrichment factor (EF) and geoaccumulation factor (Igeo) approaches. The EF results show that all the metals in the study area are enriched except Mn. However, the mean Igeo values indicate that the study area is moderately to strongly contaminated with only V, Cr, Co, As and Br. Correlation matrix shows a strong positive relation between V and all the metals analysed. With the exception of Ti and Fe which were not significantly different from site to site, there was a significant difference between the metals from the various locations indicating various sources of pollution at each location. The study has revealed the background levels of metals in sediments from some coastal communities prior to the commercial production of oil from the Jubilee fields. Measures have to be put in place to check the levels so as to protect the marine ecosystem.

References

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References

Adebowale, K.O., Agunbiade, F.O. and Olu-Owolabi, B.I. (2009), "Trace metal concentrations, site variations and partitioning pattern in water and bottom sediments from coastal area: a case study of Ondo coast, Nigeria", *Environ. Res. J.*, **3**(20), 46-59.

Ahdy, H.H.H. and Khaled, A. (2009), "Heavy metals contamination in sediments of the western part of Egyptian Mediterranean Sea", *Austral. J. Bas. Appl. Sci.*, **3**(4), 3330-3336.

Armah, A.K. and Amlalo, D.S. (1998), "Coastal zone profile of Ghana: Gulf of Guinea Large Marine Ecosystem Project", *Ministry of Environment*, *Sci. Tech.*, *Accra-Ghana*, pp. 111.

Bowen, H.J.M. (1979), *Environmental chemistry of the elements*, Academic Press.

Chen, C.W., Kao, C.M., Chen, C.F. and Dong, C.D. (2007), "Distribution and accumulation of metals in sediments of Kaoshiung Harbor, Taiwan", *Chemosphere,* **66**(8), 1431-1440.

Cheng, H., Hu, Y., Luo, J., Xu, B., and Zhao, J. (2009), "Geochemical processes controlling fate and transport of arsenic in acid mine drainage (AMD) and natural systems", *J. Hazard. Mater.*, **165**, 13-26.

El-Moselhy, M. (2006), "Distribution of vanadium in bottom sediments from the marine coastal area of the Egyptian Seas", *Egyp. J. Aqua. Res.*, **32(**1), 12-21.

Gargouri, D., Azri, C., Serbaji, M.M., Jedoui, Y. and Montacer, M. (2011), "Heavy metal concentrations in the surface marine sediments of Sfax coast, Tunisia", *Environ. Monit. Assess.*, **175**(1-4), 519-530.

Ghrefat, H.A., Abu-Rukah, Y. and Rosen, M.A. (2010), "Application of geoaccumulation index and enrichment factor for assessing metal contamination in the sediments of Kafrain Dam, Jordan", *Environ. Monit. Assess.*, **178**(1-4), 95-109.

Gnandi, K. and Tobschall, H.J. (1999), "The pollution of marine sediments in the coastal region of Togo caused by dumping of cadmium-rich phosphorite tailing into the sea", *Environ. Geol.*, **38**(1), 13-24.

Gopalani, M., Shahare, M., Ramteke, D.S. and Wate, S.R. (2007), "Heavy metal content of potato chips and biscuits from Nagpur city, India", *Bull. Environ. Contam. Toxicol.*, **79,** 384-387.

Liaghati, T., Preda, M. and Cox, M. (2003), "Heavy metal distribution and controlling factors within coastal plain sediments, Bells creek catchment, Southeast Queensland, Australia", *Environ. Inter.*, **29**(7), 935-948.

Muller, G. (1969), "Index of geoaccumulation in sediments of the Rhine River", *Geo. Journ.*, **2,** 108-118.

Neser, G., Kontas, A., Unsalan, D., Uluturhan, E., Altay, O., Darılmaz, E., Kucuksezgin, F., Tekogul, N. and Yercan, F. (2012), "Heavy metals contamination levels at the Coast of Aliaga (Turkey) ship recycling zone", *Mar. Poll. Bull.*, **64**(4), 882-887.

Olivares-Rieumont, S., de la Rosa, D., Lima, L., Graham, D.W., Alessandro, K.D, Borroto, J., Martínez, F. and Sánchez, J. (2005), "Assessment of heavy metal levels in Almendares River sediments-Havana City, Cuba", *Wat. Res.*, **39**(16), 3945-3953.

Qiu, Y., Lin, D., Liu, J. and Zeng, E.Y. (2011), "Bioaccumulation of trace metals in farmed fish from South China and potential risk assessment", *Ecotoxicol. Environ. Saf.*, **74**(3), 284-293.

Reitermajer, D., Celino, J.J. and Queiroz, A.F. de S. (2011), "Heavy metal distribution in the sediment profiles of the Sauípe River Estuary, north seashore of the Bahia State, Brazil", *Micro. J.*, **99**, 400-405.

Sakan, S.M., Djordjevic, D.S., Manojlovic, D.D. and Polic, P.S. (2009), "Assessment of heavy metal pollutants accumulation in the Tisza River sediments", *J. Environ. Manag.*, **90**(11), 3382-3390.

Santos, I.R., Silva-Filho, E.V., Schaefer, C.E.G.R. and Campos, L.S. (2005), "Heavy metal contamination in coastal sediments and soils near the Brazilian Antarctic station, King George Island", *Mar. Poll. Bull.*, **50**(2), 185-194.

Soares, H.M.V.M., Boaventura, R.A.R., Machado, A.A.S.C. and Esteves da Silva, J.C.G. (1999), "Sediments as monitors of heavy metal contamination in the Ave river basin (Portugal): Multivariate analysis of data", *Environ. Poll.*, **105**(3), 311-323.

Turekian, K.K. and Wedepohl, K.H. (1961), "Distribution of the elements in some major units of the earth's crust", *Geol. Soc. Amer.*, **72**(2), 175-192.

Uluturhan, E. (2010), "Heavy metal concentrations in surface sediments from two regions (Saros and Gokova Gulf) of the Eastern Aegean Sea", *Environ. Monit. Assess.*, **1-4**(165), 675-684.

Varol, M. (2011), "Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques", *J. Hazard. Mater.*, **195**(15), 355-364.

Wedepohl, K.H. (1991), "The composition of the upper Earth's crust and the natural cycles of selected metals", In Gnandi, K. and Tobschall, H.J. (1999), "The pollution of marine seiments in the coastal region of Togo caused by dumping of cadmium-rich phosphorite tailing into the sea", *Environ. Geol.*, **38**(1), 13-24.

Wong, K., Wong, P.P.K. and Chu, L.M. (2001), "Heavy metal concentrations in marine fishes collected from fish culture sites in Hong Kong", *Arch. Environ. Con. Tox.*, **40**(1), 60-69.

Yang, Y., Chen, F., Zhang, L., Liu, J., Wu, S. and Kang, M. (2012), "Comprehensive assessment of heavy metal contamination in sediment of the Pearl River Estuary and adjacent shelf", *Mar. Pollut. Bull.*, **64**(9), 1947-1955. http://dx.doi.org/10.1016/j.marpolbul.2012.04.024

Yeung, Z.L.L., Kwok, R.C.W. and Yu, K.N. (2003), "Determination of multi-element profiles of street dust using energy dispersive x-ray fluorescence (EDXRF)", *Appl. Radiat. Isot.*, **58**(3), 339-346.

Yılmaz, A.B., Sangun, M.K., Yaglıoglu, D. and Turan, C. (2010), "Metals (major, essential to non-essential) composition of the different tissues of three demersal fish species from Iskenderun Bay, Turkey", *Food Chem.*, **123**(2), 410-415.

Zhang, W., Liu, X., Cheng, H., Zeng, E.Y. and Hu Y. (2012), "Heavy metal pollution in sediments of a typical mariculture zone in South China", *Mar. Pollut. Bull.*, **64**(4), 712-720

Zhang, W., Feng, H., Chang, J., Qu, J., Hongxia, X. and Lizhong, Y. (2009), "Heavy metal contamination in surface sediments of Yangtze River intertidal zone: an assessment from different indexes", *Environ. Poll.* **157**(5), 1533-1543.

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