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Determination of the Elemental Contents in Soils Around Diamond Cement Factory, Aflao

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Abstract: This research is to assess the impact of the dusts particles given out by a cement factory on the physicochemical characteristics of the soil at the vicinity of the cement factory. Total concentration of five trace metals (Ca, Cu, Mn, Pb and V) was measured in soils from within and surrounding areas of the Diamond Cement Factory, Aflao. Thirty four (34) surface soils (0-20 cm) were collected during the month of November, 2009. The soil samples were air dried and sieved to appropriate sizes for analysis. The samples were subsequently pelletized and analyzed using XRF at the physics Department, Ghana Atomic Energy Commission. The results of the analysis showed the following range of concentration for the selected metals Ca (532.83-143880.3 ppm), Cu (65.46-212.65 ppm), Mn (1006.88-11099.87 ppm), Pb (0.33-1.9 ppm) and V (100.57-199.95 ppm). In addition, calculation of Enrichment Factors (Efs), Pollution Index (PIs) and Geoaccumulation Index (Igeos) was done. The calculated results of Igeo and EF of heavy metals revealed the order of are Mn>Cu>Pb>Ca>V. EF of Mn and Cu record higher percentage values indicating that there is considerable Mn and Cu pollution, which mainly originate from activities of the factory.

Key words: Aflao, edxrf, enrichment factors, geoaccumulation index, pelletized, soil

INTRODUCTION

Air pollutants are responsible for vegetation injury and crop yield losses, a lot of question are being asked by concern citizens. The major threat for plant staying alive in industrial areas is air pollution. Fast growing of industries and increase toxic substances in environment are the cause of altering the ecosystem. According to Mandre *et al.* (1998) cement dust has been shown to adversely affect the soil ecological communities. Soils surrounding cement factories, especially downward areas, exhibit elevated pH levels (Mandre *et al.*, 1998). The cement industry also plays a vital role in the imbalances of the environment and produces air pollution hazards. It was well documented by Asubiojo *et al.* (1991) and Ade-Ademilua and Umebese (2007). that work done on the composition of soil around cement factories; it has shown that there were very high levels of chromium, silica, iron and calcium with contamination levels decreasing dramatically with distance from the factories. The growths of plants in the area are being affected by those compositions (Ade-Ademilua and Umebese, 2007). The particles can enter into soil as dry, humid or occult deposits and can undermine its Physico-chemical properties. The atmospheric particles can have as consequence the reduction of biodiversity and the quality of goods and services offered by the ecosystems. The main visible pollution generated by the cement industry corresponds to the dusts. Indeed, the dusts can be emitted at every stage of the manufacturing process of the cement: extraction of the raw material, crushing, production, etc.

The main objective of this research is to assess the impact of the dusts particles given out by a cement factory on the physicochemical characteristics of the soil at the vicinity of the cement factory.

MATERIALS AND METHODS

Study area: The study area is located between latitude 60º07′-60º10′ N and longitude 10º10′-10º12′ E with a total land area of 779 km^2. It covers southern part of the Volta region on the Ghana-Togo boarder in the eastern part of Ghana (Fig. 1).

The area lies within the dry equatorial climate of the region. There are two rainfall maxima for the climatic zone. The major rainy season occurs between May and

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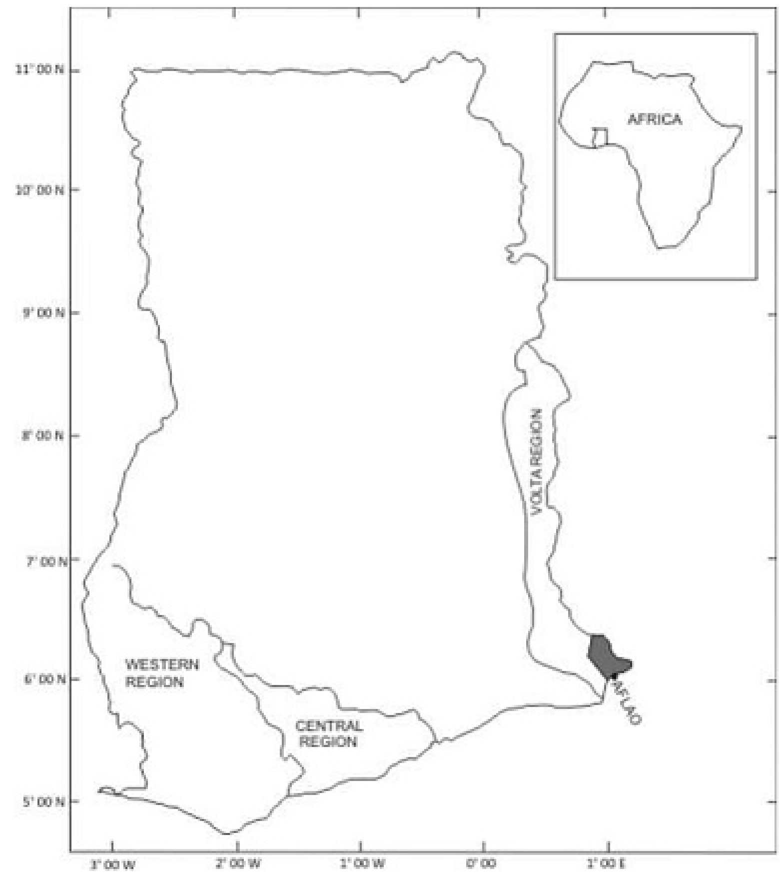

Fig. 1: Location map for study area

July with the peak occurring in June while the minor one occurs between September and October with the peak occurring in October (Dickson and Benneh, 2004). The mean annual rainfall generally varies between 740 and 890 mm for the dry equatorial climate. Mean monthly temperature ranges from 26 and 30ºC. The main vegetation is coastal grassland, scrubs and mangroves in the south. The soil type is mainly lateritic sandy soils, tropical black clays, tropical grey earths, sodium vleisols and coastal sandy soils (Dickson and Benneh, 2004).

The hydrogeological setting of the study area is the Recent and Tertiary formations that include unconsolidated sands and clays of lagoon, delta and littoral area, partly consolidated red continental deposits of sandy clay and gravel. It consists of a thick section of marine sands, clay, shale, limestone, sandstone and some gravel which underlie more recent sediments in the coastal area. The Recent deposits comprise unconsolidated sand, clay and gravels of river valleys especially along the lower Volta River, marine clays along the northern banks of the Keta lagoon and marine sands along the coastal littoral stretch from Aflao to Anyanui, (Junner and Bates, 1945).

Sampling: Thirty four (34) soil samples were taking randomly from different location around the Diamond Cement factory, Aflao in the month of August 2009. Each sample was taken at a depth of 0-20 cm. The samples were collected with a hand auger (a stainless steel screw) and hand spade and were placed in a clean polyethylene bags to avoid contaminations. The samples were well labeled. Samples with ID AK1 to AK 20 were taken from the northern part of the factory, samples with ID CE21 to CE 26 were taken very close to the Factory and samples with the ID AF 27 to AF 34 were taken on the southern part of the factory.

Sample preparation: The samples were transferred to the XRF laboratory in the Physics Department of National Nuclear Research Institute. The samples were air dried for about 2 weeks. Each sample was pulverized and homogenized into a very fine powder. About 500 mg of each sample were pelletized using a Specac press with a pressure of 2 tons/cm^2 to produce an intermediate thick pellet sample. The pellet produced was kept in a desiccator for at least 24 h to get rid of moisture in the sample.

Reference material: Two certified standard reference soil materials SOIL-7 and GBW 07106 were similarly prepared. SOIL-7 and GBW 07106 soil standards were used as standard reference materials for the validation of the analytical results.

Sample irradiation, counting and analysis: The elemental concentrations were determined using energy dispersive X-ray fluorescence (EDXRF). EDXRF provides a rapid and non-destructive method for the analysis of trace and major elements in soil samples. All measurements were carried out under the vacuum condition, using an X-Ray Generator (Compact 3K5) EDXRF spectrometer with a Mo target, equipped with a liquid- nitrogen-cooled Si (Li) detector. The incident and take-off angles were 45, with a Be window thickness of 12.5 mm. The distance between the sample (exposed diameter of 22 mm) and the detector was 4.5 cm. The energy resolution was 0.165 keV. We measured the concentrations of five (5) chemical elements: Namely, Ca, Cu, Mn, Pb and V. In order to maximize the EDXRF sensitivities for the wide range of elements in which we were interested, two different combinations of EDXRF parameters (including voltage and current). Applied voltage and current are varied to acquire the require Kα or Lα energies line. The current was adjusted to maintain similar portions of live detection time. An ORTEC maestro multichannel analyser programme was employed for data collection. Irradiations were made for each sample, being the intermediate thick sample +target for spectrum collection life time of 1500 s. linear least squares fitting of the axil software programme was used for the spectrum deconvolution (IAEA, 2005). Emission-transmission method in QXAS package was used to convert spectrum peak areas to concentrations

RESULTS AND DISCUSSION

Validation of the analytical techniques: The results were validated using IAEA- Soil-7 and GBW 07106 Certified Reference Materials as shown in Table 1 and 2. The experimental data was compared with the certified data.

Table 1: Analysis of IAEA-soil 7 by EDXRF

Element	This work	Certified values
Ca	164956±4949	163000±4890
Cu	10.69±0.31	11±0.33
Mn	635±19	631±18
Pb	60.9±2	60±1.8
V	64±1.3	66±2.0

Table 2: Analysis of GBW 07106 by EDXRF

Element	This work	Certified values
Ca	2165±92	2143±86
Cu	20±3	19±2
Mn	149±7	155±10
Pb	8.4±1.9	7.6±1.2
V	36±6	33±4

Concentration, enrichment factor, pollution index and geoaccumulation index values: A summary of the results and geochemical evaluation of the selected heavy metal in the soils of the study area is presented in Table 3.

The concentration of the heavy metals showed that Ca ranges from 532.83-143880.3 mg/kg, Cu 65.46-212.65 mg/kg; Mn 1006.88-11099.87 mg/kg; Pb 0.33-1.9 mg/kg and V 100.57-199.95 mg/kg, respectively. Most of the samples analysed showed that the selected metal contents in the soil can be classified either polluted or unpolluted. To quantify the levels of metals enrichment or pollution in soil various calculations were applied (Al-Khashman, 2007). In this study, geoaccumulation index (Igeo), Enrichment Factor (EF), Pollution Index (PI) and Integrated Pollution Index (IPI) were calculated to determine amount of the heavy metal contamination level in the soil. As shown in Table 3.

Igeo is computed by the following equation:

$$Igeo = \log_2\left[\frac{Cn}{1.5Bn}\right]$$

where,
Cn represents the measured concentration of the element of interest n
Bn is the background content of element n in abundance of chemical elements in the continental crust.

The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments. The following classification is given for geoaccumulation index [12] : <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.

The calculated results of Igeo of heavy metals in soil in farms around the cement factory are presented in Table 3. The Igeo ranges from -6.8682 to 1.2087 with a mean value of -4.2259 for Ca, -0.3338 to 1.366 with a mean value of 0.507582 for Cu, -0.5011 to 2.9615 with a mean value of 0.4216 for Mn, -1.0097 to -0.0183 with a mean value of -0.4082 for Pb and -5.8339 to -3.3062 with a mean value of -4.1145 for V. The mean values of Igeo decrease in the order of Mn>Cu>Pb>Ca>V, 100% Igeo of Pb and V, 94% of Ca, 12% of Cu and 38% of Mn are within class 0 which represent practically unpolluted areas, For unpolluted to moderately polluted, which represent class one (1), 6% of Ca, 79% of Cu and 44% of Mn fall within class one, both 9 and 12% of Igeo were

Table 3: Summary of the heavy metal contents of the soils around diamond cement factory, Aflao

	Concentration (mg/kg)		Enrichment factor		Pollution index		Geoaccumulation index	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Ca	532.83-143880.3	14684.34	0.0018-9.0903	1.0568	0.0128-3.4670	0.3538	-6.8682 - 1.2087	-4.2259
Cu	65.46-212.65	121.07	0.4747-11.7811	4.0376	1.1902-3.8664	2.2012	-0.3338 - 1.366	0.50758
Mn	1006.88-11099.87	2223.90	0.1339-31.3983	5.1265	1.0599-11.6841	2.3409	-0.5011 - 2.9615	0.5216
Pb	0.33-1.9	1.18	0.1842-6.4962	2.3580	0.745-1.4811	1.1585	-1.0097 - -0.0183	-0.4082
V	100.57-199.95	156.40	0.0052-0.5777	0.1893	0.0263-0.1517	0.0940	-5.8339 - -3.3062	-4.2845

recorded in copper and manganese respectively, these percentages were found to be in moderately to polluted classifications, Igeo obtained for Mn recorded strongly polluted to extremely polluted with a percentage of 6%.

Enrichment Factor (EF) of an element in the studied samples was based on the standardization of a measured element against a reference element. A reference element is often the one characterized by low occurrence variability, such as the most commonly used elements: Al, Fe, Ti, Si, Sr, K, etc., (Duzgoren-Aydin, 2007; Li *et al.*, 2001; Sezgin *et al.*, 2003).

The EF calculation is expressed below as:

$$EF = \frac{\left[Cx / Cref\right]_{sample}}{\left[Cx / Cref\right]_{background}}$$

where,

Cx is the concentration of the element of interest

Cref is the concentration of reference element for normalization

EF values less than 5.0 are not considered significant, because such small enrichments may arise from differences in the composition of local soil material and reference soil used in EF calculations (Sezgin *et al.*, 2003). However, there is no accepted pollution ranking system or categorization of degree of pollution on the enrichment ratio and/or factor methodology. Five contamination categories are recognized on the basis of the enrichment factor: EF < 2 states deficiency to minimal enrichment, EF = 2-5moderate enrichment, EF = 5-20 significant enrichment, EF = 20-40 very high enrichment and EF > 40 extremely high enrichment (Duzgoren-Aydin *et al.*, 2006; Sezgin *et al.*, 2003).

Enrichment factors of heavy metals were calculated for each soil sample relative to the background values of Abundance of chemical elements in the continental crust, choosing Fe as the reference element. The EF of Ca, Cu, Mn, Pb and V is in the range of 0.0018-9.0903, 0.4747-11.7811, 0.1339-31.3983, 0.1842-6.4962 and 0.0052-0.5777 with a mean of 14684.34, 121.07, 2223.90, 1.18 and 156.40, respectively in Table 3.The mean EF of Cu, Mn and Pb is higher than 2, while the mean EF of Ca and V is less than or close to unity. On the other hand, maximum EF of V is less than two (2) which shows that V in soil samples collected are deficiency to minimal enrichment. On the other hand, maximum EF of Ca, Cu, Mn and Pb is higher than 5, which shows that Ca, Cu, Mn and Pb in soil originate from anthropogenic sources. It seems, therefore, that EF can also be an effective tool to differentiate a natural origin from anthropogenic sources in the study. The mean EF (1.0568, 4.0376, 5.1265 and 2.3580) and 100% EF of Pb, Ca (88%), Cu (15%), Mn (21%) and V (59%) indicate Ca, Cu, Mn Pb and V in the samples collected are in state of deficiency to the minimal enrichment while about 6% of Ca, 62% of Cu, 62% of Mn and 32% of V belong to moderate contamination areas. Calcium (6%), Cu (24%), Mn (18%) and V (9%) have EF between 5 and 20, which show the significant enrichment.

Pollution index and integrated pollution index are also commonly used to assess the environment quality (dos Anjos *et al.*, 2000). The PI was defined as the ratio of element concentration in the study to the background content of the abundance of chemical elements in the continental crust. The PI of each element was calculated and classified as either low (PI≤1), middle (1<PI≤3) or high (PI>3). The IPI of all measured elements for each sample was defined as the mean value of the element's PI, and was then classified as low (IPI≤1), middle (1< IPI≤2) or high (IPI>2).

The PIs, calculated according to the background concentration of heavy metals in Continental average crust, vary greatly across the different metals. In vanadium (0.0263-0.1517) both minimum and maximum PI values fall within the low pollution range, while in calcium (0.0128-3.4670) and lead (0.745-1.4811), the minimum PI values are within the low pollution range but the maximum values are found to be high polluted and middle polluted classes respectively, both Cu (1.1902-3.8664) and Mn (1.0599-11.6841) are found to be within high pollution class. For arsenic and vanadium the mean PI or IPI are 0.3538 and 0.0940 respectively while Cu (2.2012) and Mn (2.3409) recorded high IPI and lead (1.1585) has its mean PI indicating contamination just above low level.

The calculated means of EF, Igeo and PI of heavy metals (Ca, Cu, Mn, Pb and V) in soil samples collected are presented in Fig. 2. The mean values of EF and PI decrease in the order of Mn>Cu>Pb>Ca>V, Ca, Pb, and V recorded negative Igeo which is good because there is no pollution while Cu and Mn show some pollution levels in the soil.

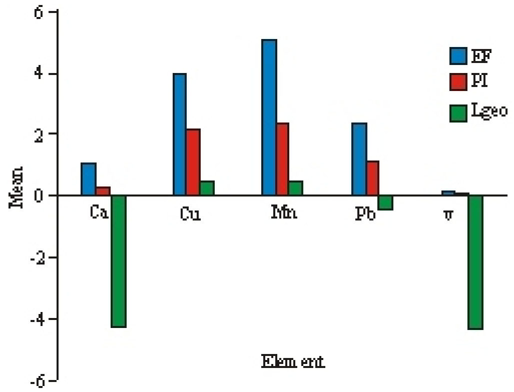

Fig. 2: The graph of mean values of EF, PI and Igeo against Elements

CONCLUSION

The concentrations of heavy metal Ca, Cu, Mn, Pb and V and their contamination level in soil collected from villages around Diamond Cement Factory, Aflao have been studied in the work. The concentration of Ca, Cu, Mn, Pb and V in the soil varies from 532.83 to 143880.3, 65.46 to 212.65, 1006.88 to 11099.87, 0.33 to 1.9 and 100.57 to 199.95 mg/kg, with a mean of 14684.34, 121.07, 2223.90, 1.18 and 156.40 mg/kg, respectively.

The calculated results of Igeo and EF of heavy metals reveal the order of Igeo and EF are Mn>Cu>Pb>Ca>V. EF of Mn and Cu record higher percentage values indicate that there is considerable Mn and Cu pollution, which mainly originate from activities of the factory.

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