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Buba M Wufem
Chemistry Department
Plateau State University Bokkos
PMB, Jos, Plateau State, Nigeria

Abdulqadir Ibrahim
Chemistry Department Police
Academy Kano, Kano State,
Nigeria

Humphrey M Maina
Chemistry Department
Federal University of
Technology, Yola Adamawa
State, Nigeria

Nangbes J Gungsat
Chemistry Department
Plateau State University Bokkos
PMB, Jos, Plateau State, Nigeria

Nvau J Barnabas
Chemistry Department
Plateau State University Bokkos
PMB, Jos, Plateau State, Nigeria

Correspondence
Buba M Wufem
Chemistry Department
Plateau State University Bokkos
PMB, Jos, Plateau State, Nigeria

Distribution of heavy metals in cultivated soils around Ashaka cement factory in Gombe state, Nigeria

Buba M Wufem, Abdulqadir Ibrahim, Humphrey M Maina, Nangbes J Gungsat and Nvau J Barnabas

Abstract
The distribution of heavy metals in the vicinity of Ashaka Cement factory was determined with the aim of evaluating the environmental impact caused by the cement dust emissions on farmlands. Sixty two soil samples each was collected from surface (0 – 15cm depth) and subsurface (15–30cm depth) in cultivated farmlands covering an area of $112Km^2$ (6Km radius) around the factory. Acid extracted metals were analysed using Atomic Absorption Spectrophotometric Method and the result showed varied concentrations of the metals, ranging between 0.00 – 27.72gKg^{-1} Zn, 1.40 – 311.40 gKg^{-1} Mn, 0.00 – 8.00 gKg^{-1} Ni, 0.60 – 100.72 gKg^{-1}Co, 0.09 – 0.95gKg^{-1}Cu, and 2– 960.10gKg^{-1}Fe. The concentration of Iron, Manganese and Cobalt were predominantly higher in the subsurface samples indicating downward movement of the metals, while Zinc, Copper and Nickel were higher in the surface soils than the subsurface. Generally, highest concentrations for the metals analysed occurred at ≤ 2Km distance from the factory. The distribution pattern indicated decreasing concentrations of the metals with distance away from the factory. These trends suggest enrichment of cultivated farmlands by the cement factory emissions, even though there could be input from traffic and agricultural practices.

Keywords: Heavy metals, farmlands, cement, dust, pollution

1. Introduction

Heavy metals are natural elements that are found at various high background levels at different places throughout the world due to various concentrations in the bedrock and defies biodegradation as such can persist in the environment. The background levels of unpolluted soils for heavy metals have been reported and that these levels could be increased by human activities of different kinds [1, 2]. Anthropogenic activities always end up in outlets and wastes where heavy metals are transported to the environment by air, water or deposits, thereby increasing the metal concentrations in the environment. Thus, there might probably be a big problem with anthropogenically supplied metals, with higher levels of bioavailable metals than with high background levels originating from bedrock with slow weathering. Cement dust has been considered to be one of the major causes of pollution in the environment due to the emission of particulate matter to air. The presence of heavy metals, beryllium, sulphuric acid and hydrochloric acid in Cement dust [3-5] may contaminate soil, ground water and floodwater. This could be a major problem in most third world countries mostly due to economic constraints [6], even though, efforts have been put in place in most cement industries to suppress the emissions. Metal contamination of surface soils [7] from industries [8, 9] have been documented. In a study by Khashman and Shawabkeh [10], soils around cement factories showed high concentrations of heavy metals especially Pb, Zn and Cd on top soils of 0-10 cm deep. Semhi *et al*. [11] in their study on dust emitted from cement industries in Oman have shown high concentrations of heavy metals in soils within a radius of 0.5 to 2km around the cement factory. The effects of cement dust on vegetation have been reviewed by Farmer [12]. Recently, Abou Seeda *et al* [13], Kloseiko and Tilk [14] and Parn [15] reported the effects of cement dusts on metal absorption by corn, concentration of hexoses in scot pine and the radial growth of conifers respectively. The different species around Ashaka cement Factory was studied and reported Mn to be the only metal that was predominantly in the non-available form [16]. Fe, Zn, Cu, Ni, and Co were predominantly residing in the non-residual fractions [16, 17] and this suggests their potential bioavailability in the soils as indication of their anthropogenic source.

This study was carried out at the vicinity of Ashaka Cement Company, located in Jalingo Village of Bajoga, Funakaye local government area of Gombe State, Nigeria. The company was established in 1967, with an installed capacity of 500,000 MT [18] to meet the needs of construction works in the Northeastern part of Nigeria. The factory lies in the Northern part of Gombe between longitude 10^0 45'N and 11^0 00'N and latitude 11^0 15'E and 11^0 30'E. The company produced huge amount of dust and gaseous pollutants to the unsuspecting communities scattered in the area in time past. Prior to now, large proportion of the dust was deposited on farmlands, homes and water bodies including the River Gongola. This work therefore, is aimed at evaluating the environmental impact caused by Ashaka Cement factory emissions on cultivated farmlands.

2. Material and Methods

2.1 Sample Collection

Soil samples were collected from cultivated soils around the cement factory starting from the factory fence and at every 2km intervals covering 6km radius. Soils from 0-15cm and 15-30cm depths were sampled at each point. Samples were dried at 105 ^{0}C in an oven until constant weight was obtained.

2.2 Reagents and Chemicals

All analysis were performed with Analar grade chemicals and distilled water through out, unless otherwise stated.

2.3 Extraction and Determination of Acid extractable metals

1g of soil sample was weighed into a 250cm^3 conical flask and 50cm^3 of 10% nitric acid was added. It was shaken for 1 hour on a Edmund Bahler Swip mechanical shaker. The solution was filtered using a Whatman filter paper No. 44 into a 100cm^3 volumetric flask and made up to mark with distilled water. The filtrate obtained was analysed for Zn, Ni, Mn, Cu, Co, and Fe using a Buck Scientific Atomic Absorption Spectrophotometer model 210 VGP. Air-Acetylene (8:6) flame and hollow cathode lamps for the respective elements were used at their various wavelengths. Calibration standards were obtained by preparing 100µgcm^{-3} stock solution of the nitrate salts of the metals and dilution of the stock solution. Triplicate analyses were carried out for each sample.

3. Results and Discussion

The mean total available acid extractable heavy metal concentrations in cultivated soils are shown in Tables I and II for surface and subsurface soils around the cement factory. The concentration of Zinc in the soils of the study area varied over a wide range of 0.00 – 27.76gkg^{-1} for the surface and subsurface soils. The mean concentration in the surface soil (9.80gkg^{-1}) differs slightly from the subsurface soil (6.11 gkg^{-1}) which suggests a leaching of the metal down the soil profile. The mean values were above the normal concentration levels of 0.54 – 4.14mgkg^{-1} for unpolluted semi arid savanna soils [19].

Table 1: Mean Available Concentration of Heavy Metals in Cultivated Soils (0–15cm) around Ashaka Cement Factory

Mtals	No. of Samples	Mean conc. (gkg-1)	Range (gkg-1)
Fe	62	236.60	2.00 – 960.10
Zn	62	9.80	1.40 – 27.76
Cu	62	0.30	0.09 – 0.83
Mn	62	78.29	23.26 – 151.25
Ni	62	2.56	0.00 – 33.95
Co	62	27.37	0.82 – 89.52

Table 2: Mean Available Concentration of Heavy Metals in Cultivated Subsoil (15–30cm) around Ashaka Cement Factory

Mtals	No. of Samples	Mean conc. (gkg^{-1})	Range (gkg^{-1})
Fe	62	194.00	14.4 – 795.00
Zn	62	6.11	0.00 – 21.19
Cu	62	0.36	0.09 – 0.95
Mn	62	57.33	1.40 – 311.43
Ni	62	1.55	0.00 – 7.98
Co	62	26.45	0.60 – 100.72

The mean soil pH was 7.18 for surface and 6.3 for subsurface soils with pH ranges of 5.4 – 8.3 and 4.7 – 9.84 respectively. The sub soil is acidic indicating the role of the soil pH in immensely contributing to the level of available zinc. This agrees with Norvell [20], who observed that zinc concentrations were relatively high in acidic soil solution and that zinc competes very effectively with Al^{+3} and Fe^{+3} for chelating agents. Since there is relatively high Fe and Al contents in cement, deposited dust on cultivated soil might influence the Zn concentration to remain mainly in the available form. The concentration of Zn however decreases with distance away from the factory. Figure 1 shows the distribution of Zn away from the factory indicative of declining concentration with distance. This trend may be attributed to decreasing dust deposition with distance away from the cement factory. Crop plants grown on such soils have the tendency of absorbing this metal in high concentrations. It has been reported earlier that plants grown on polluted soils can accumulate trace elements at high concentrations that could cause serious risk to human health when plant based food stuffs are consumed [21, 22].

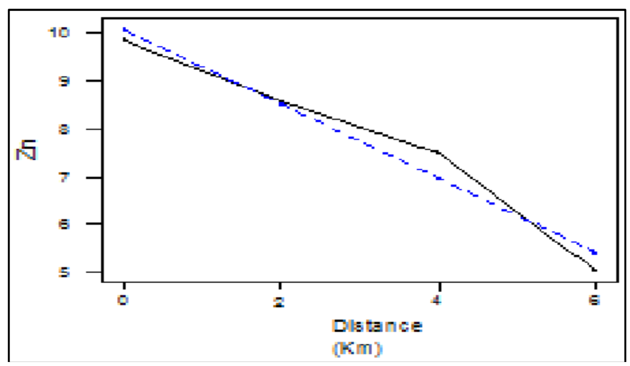

Fig 1: Distribution of zinc (gkg^{-1}) over distance

The distribution of Ni in the different soil profile around the Cement factory shows significant variation with distance away from the factory (P<0.05). Figure 2 shows the steady declining concentration of Ni with a sharp rise at the bank of a river that cuts the study area at about 4Km from the factory and this might be due to deposition of sediments during rainy season by the river. The mean Ni concentration in the two levels studied showed 2.56gkg^{-1} and 1.55gkg^{-1} for the surface and subsurface soils around the factory respectively. The concentration level spread range from 0.00 – 33.95gkg^{-1} for both the surface and subsurface soils. The mean concentration was higher than unpolluted background levels for soils [2]. The critical Ni concentration for toxicity in soils and plants vary depending on soil type and plant species, nevertheless, concentration range of 6.00–112.00mgkg^{-1} and7.00–6.00mgkg^{-1} have been documented for soils and plants respectively [23]. This suggests that there might be possibility of the soil Ni reaching critical toxic levels around the factory.

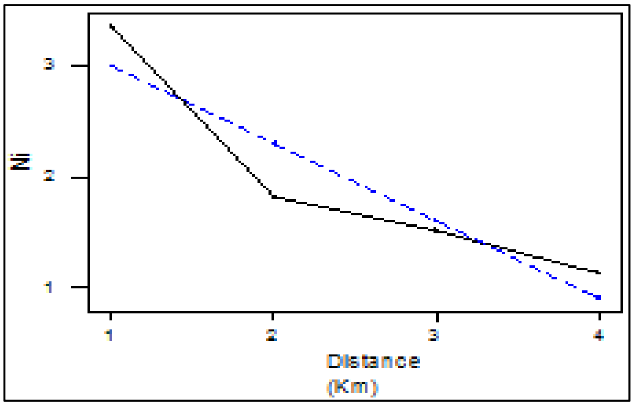

Fig 2: Distribution of nickel (gkg^{-1}) over distance

Manganese mean concentration in soils around the factory varied over a wide range of 23.26 – 151.25 gkg^{-1} and 1.40 – 311.40gkg^{-1} with mean concentrations of 78.2gkg^{-1} and 57.33g/Kg for surface and subsurface soils respectively. These values are higher than the normal concentration of 26.41$mgkg^{-1}$ for unpolluted semi arid savanna soils [19]. The distribution trend of this metal away from the factory seems to implicate aerial source and this could be seen in the Mn concentration decreasing with distance from the factory (Figure 3).

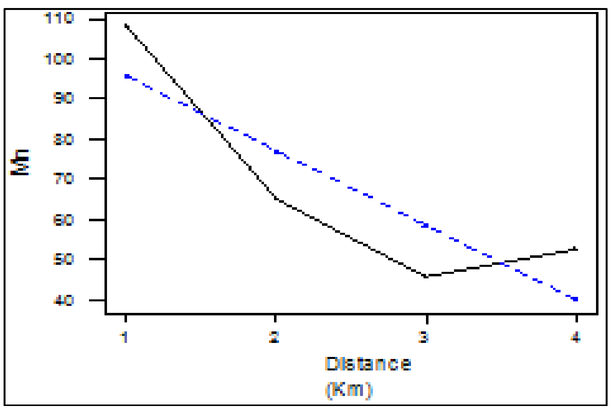

Fig 3: Distribution of manganese (gkg^{-1}) over distance

Copper levels in the soils do not differ significantly as the mean available concentrations are 0.30gkg^{-1} and 0.36gkg^{-1} for surface and subsurface respectively, with range 0.09 – 95gkg^{-1} for both soil levels considered (Table I & II). These values are higher than normal soil background concentrations of 15-20$mgkg^{-1}$ [2]. Some values are above critical limits of 60-125$mgkg^{-1}$ beyond which phytotoxicity may be expected [22]. The highest concentrations were found at the subsurface layer, indicating downward movement of the metals. The dust effect must have been minimal due to the insignificant variation of copper concentration with distance away from the factory (Fig. 4). The same pattern was observed at the top and subsurface. This indicates that the copper must have been mobilized from natural background source since it is a very common substance that occurs naturally in the environment and spreads through the environment by natural phenomena and/or human activities. Low pH enhances mobility while high or alkaline pH hinders mobility. However, when copper ends up in the soil it strongly attaches to organic matter and minerals. As a result, it does not travel very far after release and it hardly ever enters ground water. The forecast over 100Km distance away from the factory shows this trend (Fig. 4).

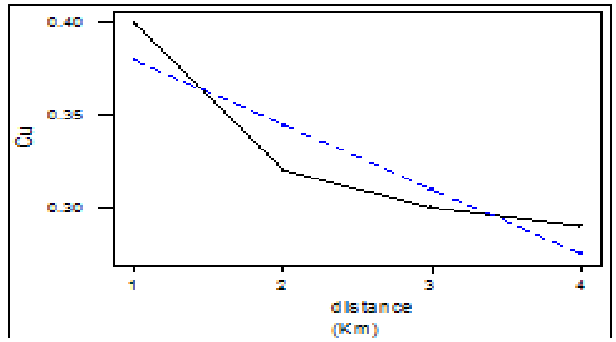

Fig 4: Distribution of copper (gkg^{-1}) over distance

The mean available iron concentration at 0 – 15cm and 0-30cm soil depth around the cement factory were found to be 236.60 and 194.0gkg^{-1} with a wide range of 2.00 – 960.10 gkg^{-1} for both surface and subsurface pooled together and a standard deviation of ±228.05gkg^{-1} for both levels (Table I & II). The relatively large standard deviation indicates the non-uniformity of dust deposition. This assertion agrees with Baker [24], that spatial dispersion of metals in the surrounding soils and vegetation's of industrial areas are rarely uniform. Alloway [22] suggested that non-uniformity in aerial dispersion of particles could be due to the influence of wind direction, chimney stack height, particle size and solubility of emissions as well as the filtering capacity of vegetation on the dust deposition; these affect metal distribution. Although iron is quite abundant in the earth's crust, its availability in aerated soils is quite low, due to the specifics of iron chemistry in aerobic environments. In aerobic system, the solubility of inorganic iron depends on ferric oxides in the soil and as soil pH is reduced concentration of ferric iron increases [25]. Dispersal of Fe in the soil is extremely variable, nonetheless related inversely to pH. The surface horizon contains more iron than the subsurface horizon (Tables I & II). The levels of iron in the soil mostly occur above adequate soil level of ≤4.5 mg/kg [26]. Dust might be the major soil enrichment source. This assertion agrees with Andrej [4] who reported the presence of Mg, Pb, Zn, Cu, and Fe in emissions from a cement factory. The distribution of iron around the factory shows a decrease in concentration with increasing distance away from the factory plant (Fig.5), and at both 0–15cm and 15–30cm depth of cultivated soils in the studied area, a similar trend was observed. A forecast over long distance using the trend analysis model agrees with the finding of this study. Iron may be used as tracer in cement dust deposition since it is a component of cement and the dust deposition decreases with increasing distance away from the source.

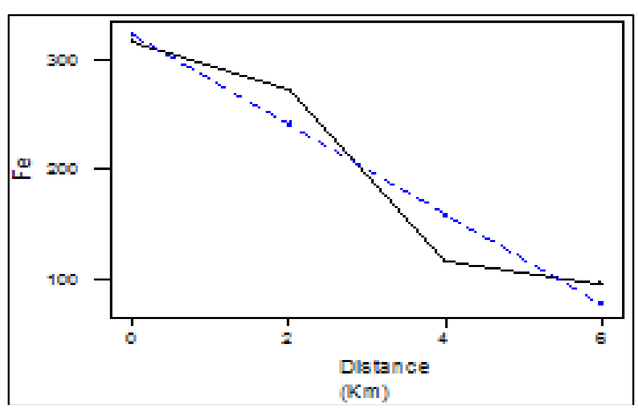

Fig 5: Distribution of iron (gkg^{-1}) over distance

The concentration of cobalt in soils around the cement factory varied widely over the range of 0.6-100.72 gkg^{-1} for both the top and subsurface soils. The mean concentrations of 27.37 gkg^{-1} and 26.45 gkg^{-1} (Tables I & II) for the surface and subsurface soils respectively were observed. These concentration levels are far above the background concentration for unpolluted sandy (5μgg^{-1}) and loamy (15μgg^{-1}) soils [2]. This indicates the possibility of pollution of the soil by cobalt. The concentration of cobalt decreases with distance away from the factory (Fig. 6). The mean top soil concentration (27.37 gkg^{-1}) is higher than the sub-soils concentration (26.45 gkg^{-1}); indicative of the possibility of aerial input. The forecast of the dust deposition could be seen clearly for cobalt concentration over long distance away from the factory with indication of decreasing influence of the aerial input on the cobalt concentration with declining distance (Fig. 6). Cobalt has been classified as highly toxic and relatively accessible element. Its concentration in the environment could pose a threat to human comfort, if found in high levels.

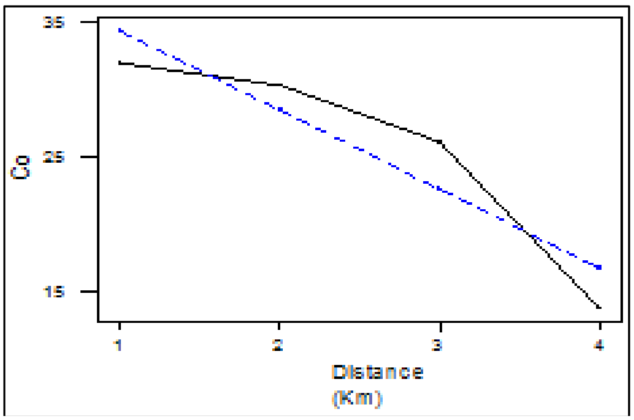

Fig 6: Distribution of cobalt (gkg^{-1}) over distance

4. Conclusion

Generally, the concentrations of Iron, Manganese and Cobalt were predominantly higher in the subsurface samples indicating downward movement of the metals, while Zinc, Copper and Nickel were higher in the surface soils than the subsurface. This agreed with the study reported by Khashman and Shawabkeh [10], on soils around cement factories where high concentrations of heavy metals especially Pb, Zn and Cd were found on top soils of 0-10 cm deep. Generally, highest concentrations for the metals analysed occurred at ≤ 2Km distance from the factory. In a similar work Semhi *et al.* [11] reported high concentrations of heavy metals in soils within a radius of 0.5 to 2km around the cement factory in Oman. The distribution pattern indicated decreasing concentrations of the metals with distance away from the factory. These trends suggest enrichment of cultivated farmlands by the factory emissions, even though there could be input from traffic and agricultural practices. The enrichment of the environment with heavy metals could bring about the association of the metals with dust and the alkaline nature of the cement dust may affect the mobility of the metals in the soil, and this may in turn affect plant available forms of the metals. This also could be inferred from the works of Wufem *et al.* [16, 17], where heavy metals were found predominantly in the Non-residual fractions of the soils around Ashaka cement Factory. The extent to which plant take up metals determines the degree of exposure of the metals to humans and animals that ultimately consume them as such there may be potential health implications as a result of cement emissions.

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