Trends in Applied Sciences Research

ISSN 1819-3579

Academic
Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 2 (6): 515-521, 2007
ISSN 1819-3579

Analytical Assessment of Some Trace Metals in Soils Around the Major Industrial Areas of Northwestern Nigeria

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Abstract: Pollution of the environment is of great concern, thus the present study investigated the concentration of trace metals in soil found around the major industrial areas of the Northwestern state of Nigeria, using atomic absorption spectrophotometry. The results obtained indicated that these metals on dry weight basis in the soil ranged between (0.1-0.7 $\mu g\ g^{-1}$) Cd, (14.2-92.7 $\mu g\ g^{-1}$) Cr, (151.5-540 $\mu g\ g^{-1}$) Pb and (3.5-24.7 $\mu g\ g^{-1}$) Ni. From the results, industrial areas seem to be relatively high in concentration of tested metals than those of the control sites. The soil pH of the sampling sites varied on the average from 6.5 to 7.12 in water indicating only a slightly acidic to neutral. The soil pH in $CaCl_2$ is within the range of 5.49 to 6.39 indicating moderately acidic soil. Generally, the concentrations obtained were higher than the tolerable limit for safe environment as prescribed by Nigerian Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO). The degree of pollution measured constitutes a threat to humanity and the ecosystem.

Key words: Pollution, trace metals, soil, industrial areas

INTRODUCTION

Pollution is one of the most important problems around the world in which thousands of millions of world inhabitants suffer health problem related to industry and atmospheric pollutants (Martinez *et al*., 2001). In recent years have witnessed significant attention being paid to the problems of environmental contamination by a wide variety of chemical pollutants including the trace metals (El-Demerdash and Elagamy, 1999). Trace metals enter into our environment from both natural and anthropogenic sources (Kataba-Pendias and Pendias, 1986). They contaminate food source and accumulate in both agricultural products and seafood through water, air and soil pollution (Lin *et al*., 2004). All trace metals are toxic at soil concentration above normal level. Addition of trace element to soil may affect microbial proliferation and enzymatic activities, possibly leading to a decrease in the rates of the biochemical process in the soil environment. The effect of trace metals on biochemical reaction in soils may vary with pH, organic matter content, particle size distribution, vegetation and total hydrocarbon content (Esser *et al*., 1991; Sims and Kline, 1991). World wide, increasing level of industrialization and urbanization has led to environmental pollution (Filazi *et al*., 2003). Industries have largely been responsible for discharging effluents containing trace metals such as zinc (Zn), Copper (Cu), Manganese (Mn), Cadmium (Cd), Mercury (Hg), Nickel (Ni), lead (Pb) and Chromium (Cr) into our environments (Ibok *et al*., 1989; Chen and Chen, 2001).

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In Nigeria, manufacturing industries constitute a major source of environmental pollution; some of them discharge their effluent in the inland rivers and streams untreated. River Kaduna, for instance, serves as the common sink for all water borne wastes produced by the industries on its bank (World Bank Report, 1988). There has also been a report of contamination of the Nigerian environment by petroleum (Kakulu and Osibanjo, 1992). Yusuf *et al.* (2003), reported the impact of industrial development on the environment in Lagos city and observed that they range from stench and coloration of water bodies to the appearance of surface films. The people of Tse-Kucha and Tse-Amua have suffered from limestone dust of Benue Cement Company (BCC) of Gboko. The dust has damaged their crops and rendered their erstwhile fertile lands infertile (Guardian, 1991).

Literature indicates that studies have been conducted on pollution problems of some areas of the North western Nigeria (Ayodele and Gaya, 1994; Parkman Nigeria Ltd., 1997; Oni, 1997; Abdulrahman and Aderibigbe, 2001; Birnin Yauri and Argungu, 2002) but not much has been done on the trace metals level of the industrial effluents emanating from industrial areas of North western Nigeria and their possible effects on the quality of soil and its biotic community. Therefore, it is important to investigate the level of trace metals in soils around major industrial areas of the zone.

MATERIALS AND METHODS

Sample Collection

The sampling was carried out in the months of August, 2004 to April; 2006 and the triplicate samples were collected from each sample location (Fig. 1) using clean, stainless materials. Soil samples were systematically collected from six different spots within 100 m radius of each industrial area and

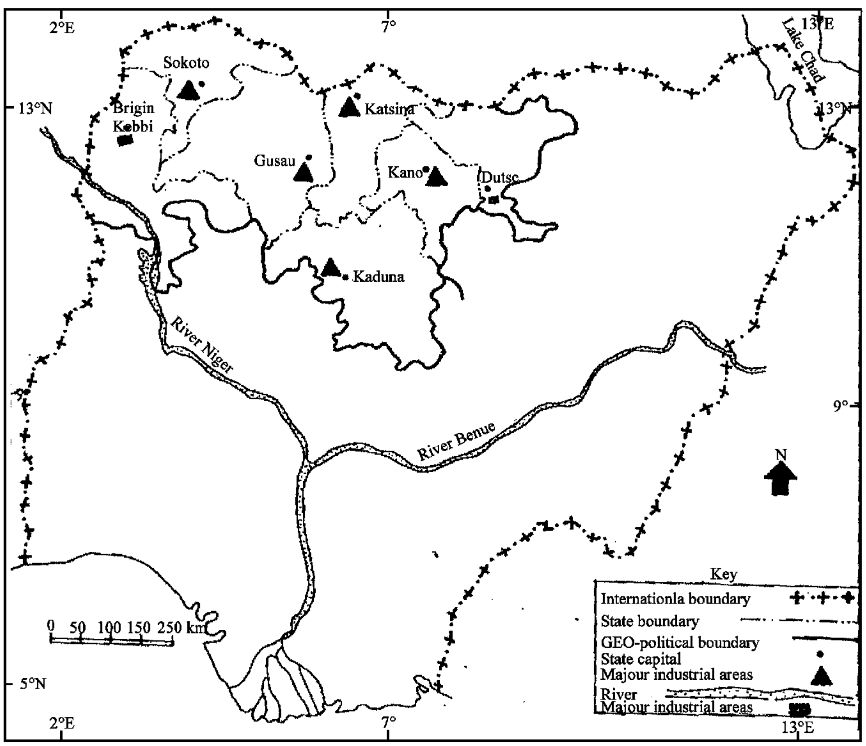

Fig. 1: Sampling sites of the major industrial and non-industrial areas of North-Western zone of Nigeria

the control site. The soils samples were obtained at a depth of 0-15 cm around the major industrial and non-industrial areas. They were thoroughly mixed and transferred into clean and labelled plastic containers for analyses in the laboratory.

Sample Treatment

The soil samples were oven dried at 105°C to constant weight for 6 h (Walinga *et al.*, 1989). The oven-dried material was crushed and sieved through a 20 μm plastic mesh from which a representative sample was obtained (Allen *et al.*, 1974; IITA, 1979).

Soil pH

The soil pH was determined in 1:1 soil water suspension and 1:2 soil-0.01 M calcium chloride suspension as described in (IITA, 1979). The mixture was stirred for 30 min and allowed to stand for 1 h. The pH readings were taken after inserting the electrode of the pH meter into the partly settled suspension and reported the result as soil pH in water and 0.01 M $CaCl_2$. The pH meter was calibrated with pH 7.0 buffer solutions before use and the electrodes were washed with distilled water and wiped with dry clean filter paper after each reading.

Apparatus and Reagents

Analyses of the metals were carried out with atomic absorption spectrophotometer UNICAM 969 and operated as per the manufacturer's manual. The reagents employed for this study were all of analytical grades (BDH chemical Ltd., Poole England) and standard solutions were prepared from 1000 μg g^{-1} stock solution of Cd, Cr, Pb and Ni. Additionally the glasswares used were thoroughly washed with (1:4) HNO_3 and then rinsed with distilled water.

Sample Digestion

One gram of the oven-dried ground soils samples in each case was placed in 100 cm^3 Kjedahl digestion flask, which has been previously washed with nitric acid and distilled water. The samples were subjected to wet digestion (AOAC, 1990) reacted with 2 cm^3 of 60% perchloric acid ($HClO_4$), 10 cm^3 concentrated nitric acid (HNO_3) and 1.0 cm^3 concentrated sulphuric acid (H_2SO_4). The mixture was swirled gently and slowly at moderate heat on a digester, under a fume hood. The heating continued until dense white fumes appeared which was then digested for 15 min, set aside to cool and diluted with distilled water. The mixture was filtered through Whatman filter paper into a 100 cm^3 volumetric flask, diluted to mark (Allen *et al.*, 1974; Sahrawat *et al.*, 2002). The blank and the samples were digested in the same way. The concentration of the metal present in each case was obtained from the calibration plot made with various concentrations of the standard.

RESULTS AND DISCUSSION

The pH of the soil is an important parameter that directly influences mineral mobility. The soil pH of the sampling sites varied on the average from 6.5 to 7.12 in water indicating only a slightly acidic to neutral (Table 1). The soil pH in $CaCl_2$ is within the range of 5.49 to 6.39 indicating moderately acidic soil. The overall mean pH indicated acidic soil with exception of Kalambaina industrial layout. In general the acidic nature of the soils is attributed to industrial pollution of acidic gases, effect of bush burning and the harmattan dust (Esu, 1987). The higher pH of Kalambaina industrial layout may be attributed to deposition of calcium oxide from Cement Company and calcium compounds in the soils of Sokoto. Brady and Weil reported in 1999 that the neutral to alkaline soil pH observed in semi arid soil such as that of Sokoto was due to low rainfall and alkaline compounds are not leached away, thus making soil of the region too alkaline.

Table 1: pH of soil samples

Source	pH in H_2O	pH in 0.01 M $CaCl_2$
Kudenda Industrial Estate, Kaduna	6.92±0.2	5.87±0.4
Kakuri Industrial Estate, Kaduna	6.62±0.1	5.87±0.2
Kawo Kaduna (control site)	6.79±0.5	5.76±0.1
Bompai, Industrial Area, Kano	6.99±0.2	5.90±0.3
Challawa Industrial Area, Kano	6.71±0.5	5.97±0.4
Sharada Industrial Area, Kano	6.98±0.2	5.49±0.6
Gwauron Dutse Kano (control site)	6.51±0.1	6.04±0.2
Sabon Gari Industrial Area, Katsina	6.81±0.2	5.79±0.4
Federal College of Education Katsina (control site)	6.84±0.3	5.71±0.2
Kalambaina Industrial layout. Sokoto	7.12±0.2	6.39±0.3
Minanta Sokoto (control site)	6.97±0.1	5.55±0.3
Samaru Industrial Area Gusau	6.78±0.4	5.72±0.1
Birnin Ruwa Gusau (control site)	6.81±0.3	5.82±0.2

Table 2: Trace metals concentration in soils of the major industrial areas and control sites in Northwestern Nigeria (μg g^{-1} dry weight)

Sampling sites	Cd	Cr	Pb	Ni
Industrial estate				
Kakuri, Kaduna	0.70±0.12	85.4±3.2	248±0.8	22.8±1.31
Kudenda, Kaduna	0.30±0.03	38.9±3.05	273.1±2.6	10.7±1.10
Bompai, Kano	0.10±0.02	21.1±0.10	420±3.4	17.1±0.27
Challawa, Kano	0.30±0.01	85.3±6.4	418±0.36	12.8±2.70
Sharada, Kano	0.60±0.45	92.7±4.3	523±0.72	12.1±0.20
Sabongari, Katsina	0.30±0.04	55.7±2.43	386±0.78	24.7±0.10
Kalambaina, Sokoto	0.10±0.02	83.4±4.3	486±1.00	22.9±1.05
Samaru, Gusau	0.30±0.03	62.6±4.5	410±0.17	4.9±0.76
Control sites				
Kawo, Kaduna	0.40±0.05	41.9±1.57	540±2.2	11.5±0.66
Gwauron Dutse, Kano	0.10±0.01	14.2±0.30	269±2.19	15.7±1.24
FCE, Katsina	0.20±0.04	41.9±1.75	246±13.7	23.6±13.1
Minanata, Sokoto	0.30±0.04	55.7±0.70	152±1.63	9.8±0.53
Birnin Ruwa, Gusau	0.40±0.05	49.9±1.40	326±0.46	3.5±0.27

The values are Mean±SD of the triplicate samples collected from sampling site

The present study, confirmed concentration of cadmium in soils within the range of 0.1-0.7 μg g^{-1}, similar to tolerable limit of 0.1-1.0 μg g^{-1} as reported by Fabis (1987). In the same vein, the cadmium concentration in soils of Kakuri industrial Estate, Kaduna has the highest mean content of 0.7 μg g^{-1}. Distribution mean of 0.6 μg g^{-1} was obtained from Sharada industrial area, Kano. Birnin Ruwa, Gusau and Kawo, Kaduna, respectively, while the control sites recorded the mean content of 0.4 μg g^{-1} each. The experimental data show that, chromium concentration (Table 2) in soils range from 14.2 to 92.7 μg g^{-1} and are within the range reported by Birnin Yauri and Argungu (2002), Sani (2003) and Aydinalp and Marinova (2003).

The results seem to be higher than the values of 0.453 μg g^{-1} reported in Ayolagha (2000); 0.86 μg g^{-1} in Ayodele and Abubakar (2001); 1.13 μg g^{-1} in Abubakar and Ayodele (2002) and 0.500 μg g^{-1} in Nwajei (2002).

Lead concentration in soils shows a range of 151.5 to 540.4 μg g^{-1}, the highest (540.4 μg g^{-1}) was found at Kawo, Kaduna and the lowest (151.5 μg g^{-1}) at Minanata control site. The lowest concentration at Minanata might be due to the less traffic density and atmospheric conditions (i.e., wind speed and direction). According to Sezgin *et al.* (2003) low wind speed might be the cause of highest concentration at distance point of closer range and higher wind speed, causes high concentration. The highest concentration is almost five times higher than the maximum concentration of (100 μg g^{-1} dry soil) found in soil (Sezgin *et al*., 2003)).

At Sharada industrial area, Kano, the concentration is about five times higher than the maximum concentrations of lead reported in soil (Sezgin *et al*., 2003). The leaded fuel commonly used by automobiles in the country contributed to the high lead content of the soil from Kawo, Kaduna control site (Yusuf *et al*., 2003). The mean concentrations of nickel in the soils determined were within the range of 3.5-24.7 $\mu g\ g^{-1}$ and the mean nickel content in soils of the world vary between 8-33 and 20-92 $\mu g\ g^{-1}$ for the light and heavy soils, respectively. Generally content of 100 $\mu g\ g^{-1}$ is recognized as an acceptable level in farmland soils (Kabata-Pendias and Pendias, 1999). Nickel concentrations determined in the present study remained within the natural limits of 10-50 $\mu g\ g^{-1}$ (Fabis, 1987).

The results in Table 2 show that Pb and Cr presented higher concentration than Cd and Ni which are in trace amounts. The metals were in the following order of abundance Pb>Cr>Ni>Cd. The high concentration of the elements in soils could be as a result of the effluents discharged by tannery, textile, ceramics and pesticides, steel rolling mills and cement factories in the surroundings (Ayolagha, 2000; Jankiewicz *et al*., 2002).

The variations in the trace metal content of the soil give an indication of an unequal distribution of the metals. Probably due to the difference in their geochemical origin (Adeyeye, 1994; Asaolu and Asaolu, 2002).The sites with higher concentrations of these metals tend to correspond to areas, with more industrial facilities. The areas with lowest metal concentrations, (Cd, Ni) have lower industrial activities and traffic intensity.

CONCLUSION

The overall results showed that there is no much difference between the concentration of the metals in the industrial areas and that of the control sites that may be as a result of geographical origin of the soil, influence of harmattan on soil, non functioning of some industries and other anthropogenic sources, being the disposal of metal products in the control sites (Adeyeye, 1994; Ayolagha, 2000; Asaolu and Asaolu, 2002). More so, of all the investigated metals, lead concentration was the highest possibly because it is used industrially, in storage batteries, accumulator plates, in paints, varnishes and pigments; with other anthropogenic sources being the combustion of leaded gasoline (Usman, 2000; Yusuf *et al*., 2003). The higher Pb and Cr concentration show that there was trace metals pollution at the sampling sites. The concentration level of the trace metals determined in the present study were generally higher than the soils tolerable limit (Table 3) for safe environment as prescribed by World Health Organization WHO, 1971, Federal Environmental Protection Agency FEPA, 1991. This indicates that the inhabitants around the major industrial areas of Northwestern zones of Nigeria are likely to have trace metals pollution.

However, all these metals have toxic potential and long term chronic effect on exposure. Monitoring of trace metals level in the soil becomes imperative, in order to prevent excessive build up of these metals in human through food chain (Yusuf *et al*., 2003). Appropriate measures should be put in place by the government thereby directing all industries, whose final processes involve discharges of one form or the other of waste to install plants to treat their waste effluents before their discharge into the surrounding environment, since this will control the level of trace metals in the soil. Nevertheless, the planting of food crops around industrial areas should be discouraged to avoid health hazard for consumers.

Table 3: DPR, FEPA and WHO permissible limits

	DPR	FEPA	WHO	ALLEN (1989)	FABIS (1987)
Trace metals			($\mu g\ g^{-1}$)		
Cadmium	0.01	0.01	0.005	0.03-0.3	0.1-1
Chromium	0.03	0.03	0.02	10-20	10-15
Lead	0.05	0.05	0.05	2-20	0.1-20
Nickel	0.1	0.1	0.5	5-50	10-50

Source: DPR (1991), FEPA (1991) and WHO (1971)

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