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Determination and Evaluation of the Heavy Metal Pollution in Obajana Industrial Belt, Central Nigeria

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Abstract

The Obajana industrial belt is a predominantly mineral rich area where cement production with attendant environmental pollution with heavy metals is occurring. The extent of heavy metal pollution on the agricultural soil from this industrial area was carried out using Flame Atomic Absorption Spectrometric technique. The results of heavy metals from the soil indicated that Cr and Ni have elevated concentrations as the distance from the factory is increased with the values 0.52 – 6.06 mg/kg and 0.05 – 3.35 mg/kg respectively. For Fe, Cu and Cd, the concentrations reduced as the distance from factory is increased with the value ranging from 1.20 – 4.90 mg/kg, 0.24 – 0.74 mg/kg and 0.09 - 0.59 mg/kg respectively. The geo accumulation index analysis indicated that the soil Cr, Cu, Cd, Mg and K are unpolluted to moderately polluted, Fe and Na are moderately to strongly polluted. Zn and Ni were observed to be very strongly polluted. This high content of Zn and Ni may plausibly come as a result of the industrial emissions from the mineral rich soil. The soils around the Obajana industrial belt are not fit for agricultural purpose due to the objectionable increase in the levels of some of the heavy metals.

Keywords: Agricultural soils, FAAS, Heavy metals, Industrial belt, Cement, Pollution.

Introduction

Cement production is noted for particulate pollution of the environment because of high dust emissions and heavy metals that deposited in soil. Heavy metals in soils are one of the main sources of environmental pollution. Metal contamination of surface soils [1], agricultural soils [2][3], from industries [4][5][6] and waste disposal sites [7] are well known.

Heavy metal contamination of the environment is a world-wide problem that has attracted a great deal of attention. One of the major routes of heavy metals introduction into the environment is rapid industrialization including dust emissions from cement production and its

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heavy metal contamination of the environment. Heavy metals in the soil can also generate airborne particles and dust, especially in dry seasons, which affects the air quality [8][9].

Dust pollution has also been found to be problematic around cement factories [10]. Soils are regarded as the ultimate sink for heavy metal discharged into the environment. In a study by Khashman and Shawabkeh [11], soils around cement factories showed high concentrations of heavy metals especially Pb, Zn and Cd on top soils of 0-10 cm deep. Semhi [10] in their study on dust emitted from cement industries in Oman has shown high concentrations of heavy metals in soils within a radius of 0.5 to 2 km around the cement factory. Their studies showed dust affecting plants and the biota around the factories. Also the fine particulates of dust can be inhaled along with air and in course of time cause respiratory problems in people living near and working in factory.

The environmental concern in cement manufacture is primarily related to the emission of dust and gases [12]. Prabakaran [13] reported that, 1 kg of cement manufacture generate about 0.07 kg of dust in the atmosphere. Cement dust can spread over large areas through wind and rain and are accumulated in and on soils, plants and have the potential to affect animal and human health adversely [14].

The problem of air pollution in the form of particulates has become a threat to the survival of plants and the reduction of the integrity of soils in the industrial areas [12][15]. Excessive accumulation of heavy metals in agricultural soils, resulting in elevated heavy metal uptake by food crops, is of great concern because of potential health risk to the local inhabitants [16]. Soil samples are differed in their properties and in content of Cd, Co, Mn, Ni, and pH depending on climate, soil origin, composition and human activities. In recent years, heavy metals in the soil have received attention as environmental contaminants because of their extended persistence, and toxicity to many organisms including plants [17]. The aim of this work was to determine the level of heavy metal pollution in Obajana soils.

Materials and Methods

Study area

Obajana is a town in Kogi State, Nigeria. It is located in the Oworo District of Lokoja Local Government Area, Kogi State. This place is situated in Kotonkar, Kogi, Nigeria, its geographical coordinates are 7^{o} 55’ O” North, 6^{o} 26’ O” East. It is the site of the largest cement plant in Africa [18].

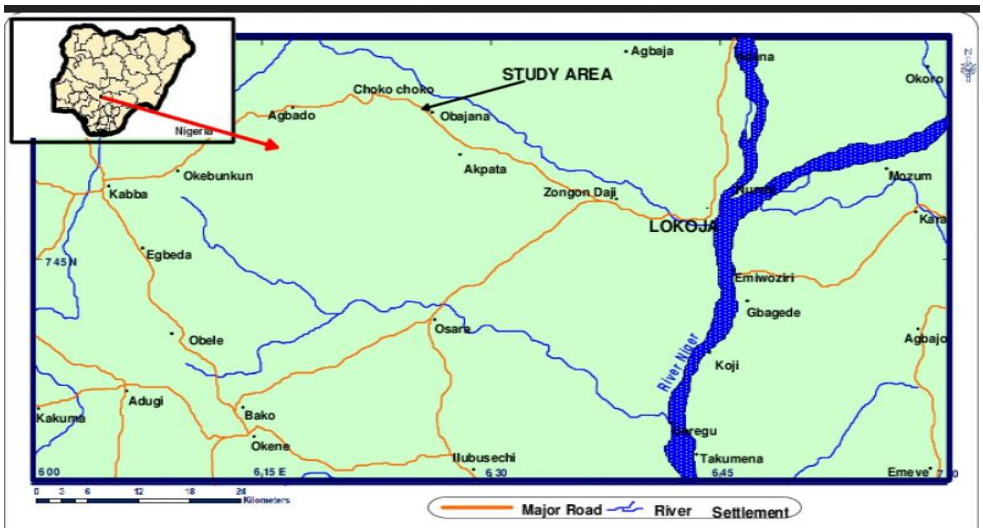


Figure 1: Map of Lokoja in Kogi State Showing Obajana study area

Materials

The materials and reagents used are: Buck Scientific VGP 210 Flame Atomic Absorption Spectrophotometer (FAAS), Water bath, Filter paper, Beakers, Measuring cylinder, Volumetric flask, Mortar and pestle, Sieve, HCI, HNO_3, De-ionized Water (all reagents used are of Analar grade).

Sample collection

The soil samples were collected within the Cement Factory at Obajana, Kogi State. The sampling sites were selected in such a manner to cover the entire vicinity of the cement factory to provide a satisfactory environmental representation of the study area. The samples were taken at the interval of 200 m away from the factory, until 2000 m was attained around the main stack of the cement factory.

Sample digestion

One gramme of the soil sample was weighed accurately into a conical flask and 10 cm^3 of concentrated HNO_3 + 5 cm^3 of HCl was added and placed in a fume cupboard. It was heated to boiling point on a hot plate until fumes of acid evolved and continued heating to precipitate most of the silica.

The mixture was cooled and 20 cm^3 of de-ionized water was added and boiled again to bring the metals into solutions. The solution was allowed to cool again then it was filtered with 125 cm^3 filter paper into 100 cm^3 volumetric flask and made to the mark with de-ionized water. The sample solution was transferred to 100 cm^3 plastic container and taken for heavy metals determination with the aid of Buck VGP 210 Flame Atomic Absorption Spectrometer (FAAS).

Results

The results of the determination and evaluation of heavy metal pollution in Obajana industrial belt, Central Nigeria is shown in Table 1, while the geoaccumulation index is indicated on Table 2.

Table 1: Concentration of heavy metals in mg/kg

S/No	Sample	K	Zn	Cr	Na	Mg	Fe	Ni	Cu	Cd
1	200 m from factory	035	0.85	0.52	5.60	9.9	2.4	0.05	0.74	0.59
2	400 m from factory	026	0.53	ND	5.75	9.1	4.7	1.47	0.29	0.09
3	600 m from factory	026	0.59	2.18	5.65	9.5	2.6	1.96	0.42	ND
4	800 m from factory	037	0.76	1.59	5.73	9.9	2.3	2.01	0.39	ND
5	1000 m from factory	031	0.53	1.55	5.72	9.6	2.1	1.85	0.51	ND
6	1200 m from factory	033	0.92	4.06	5.75	9.0	2.0	2.53	0.52	ND
7	1400 m from factory	024	0.87	3.99	5.63	9.4	4.9	3.35	0.24	ND
8	1600 m from factory	028	0.66	6.06	5.68	9.4	1.9	3.29	0.30	ND
9	1800 m from factory	028	0.70	4.59	5.60	8.0	1.2	3.09	0.31	ND
10	2000 m from factory	026	0.63	4.69	5.65	8.2	1.6	3.09	0.32	ND

Table 2: Geo-accumulation index concentration of heavy metal

S/N	Samples	Heavy metals geo-accumulation index								
		K	Zn	Cr	Na	Cu	Ni	Mg	Fe	Cd
1	200 m from factory	-0.1	7.80	-6.73	2.90	-6.2	7.74	0.36	1.67	4.77
2	400 m from factory	-0.53	0.12	ND	2.93	-7.96	5.63	0.27	2.64	-7.4
3	600 m from factory	-0.53	8.33	-4.67	2.90	-7.02	6.04	0.33	1.78	ND
4	800 m from factory	0	7.97	-5.12	2.93	-7.13	6.08	0.39	1.61	ND
5	1000 m from factory	-0.26	0.12	-5.16	2.92	-6.7	5.96	0.34	1.47	ND
6	1200 m from factory	-0.17	7.69	-3.77	2.93	-6.7	6.41	0.25	1.40	ND
7	1400 m from factory	0.37	7.77	-3.79	2.90	-7.8	6.82	0.31	2.70	ND
8	1600 m from factory	-0.41	0.07	-3.19	2.91	-7.5	6.79	0.31	1.33	ND
9	1800 m from factory	-0.41	8.09	-3.59	2.90	-7.4	6.70	0.08	0.66	ND
10	2000 m from factory	-0.53	8.24	-3.56	2.90	-7.4	6.7	0.11	1.08	ND

Major metals such as K, Na and Mg are equally analyzed around the industrial site. The range observed for K, Na and Mg are 24.0 – 37.0 mg/kg, 5.60 - 5.75 mg/kg and 8.0 - 9.90 mg/kg respectively. The concentration of the observed Zn ranged from 0.53-0.92 mg/kg. From the result it can be observed that the concentration from Zn 200 m close to factory is 0.85 mg/kg, while at 2000 m away from factory the concentration was 0.63 mg/kg. The observed Cr concentration in the soil increased as a distance from the factory is increased; the range observed was 0.52 – 6.06 mg/kg.

Table 3: Range of contamination values

Range	Pollution index
1geo=O	Unpolluted
O <lgeo< 1	Unpolluted to moderately polluted
1 = lgeo< 2	Moderately polluted
2 = lgeo< 3	Moderately to strongly polluted
3 = lgeo< 4	Strongly polluted
4 = lgeo< 5	Strongly to very strongly polluted
5= lgeo = 5	Very strongly polluted

The lowest value of Cr observed occurred at 200 m away from the factory with concentration of 0.52 mg/kg. The observed concentration for Fe ranged from 1.20 - 4.90 mg/kg. Nickel concentration was detected in the range of 0.05-3.35 mg/kg. The observed value of copper ranged from 0.24-0.74 mg/kg. Cadmium was detected only at 200 and 400 m away from the factory with respective concentrations of 0.59 and 0.09 mg/kg.

Discussion

Sodium (Na), Potassium (K) and Magnesium (Mg)

The K, Na and Mg observed have a uniform distribution in all the soils suggesting that the anthropogenic factors have no effect in their distributions in the study soils.

Zinc (Zn)

There is no definite pattern for the distribution of Zn with regard to distance from the factory, plausibly suggesting that Zn occurred in the soil in their natural state. Particulate matter from the industrial emissions from the cement factory may be responsible for this variation as this particulate matter are carried by wind over a distance before settling on soil.

Previous studies have suggested that Zn is associated with cement processing [19]. Other studies have also indicated that in rural areas atmospheric Zn are typically in 10 and 100 mg/kg, whereas levels in urban areas commonly falls within the range of 100 kg/cm^3 [20][21]. In comparism with the standard for Zn as prescribed by Sediment Quality Guideline (SQG), these values are far below the prescribed limit. Zinc is an essential element in all-living organisms. Nearly 200 Zn-containing organisms have been identified [22].

Chromium (Cr)

This progressive increase in the value of the observed Cr as the value of distance in increased may be attributed to wind assisted deposition of particulate matter and exhaust emissions from the

industry. Previous research has shown that Cr is associated with vehicular and industrial emission. The guideline value for Cr in the soil is 52.3 mg/kg indicating that the observed Cr are quite below these value.

However, plant grown 1200 m away to 2000 m from the factory may through bio-accumulation increase the levels of Cr in them. Another factor that maybe responsible for elevated concentration in the level of Cr as the distance is increased may be due to pH, the presence of oxidizing or reducing compound, the kinetics of the redox reaction and the formation of complexes of Cr salt. In soil Cr (lll) predominate and Cr (vi) can easily be reduced to Cr (III) by organic matter, for example, its occurrence in the soil is often as a result of human activities. Food contains Cr at concentration ranging from < 10 to 1300 ug/kg [23]. This result may increase progressively with time thereby increasing the ecological risk in the environment.

Iron (Fe)

The value of Fe reduced as the distance from the factory is increased. This may be as a result of the high density of Fe and its ability to settle quickly on top soil. The Fe may be associated with the industrial activities taking place in the area. Iron is one of the elements that is naturally occurring in the soil and the earth crust. The observed concentration does not pose a threat to biological systems.

Nickel (Ni)

The value of Nickel observed increase as the distance increased from the factory. The reason for this may be due to wind assisted particulate matter emission and depositions away from the industrial site. Previous studies have indicated that Ni has the tendency to form stable complexes and that may account for the concentration of Ni observed as the distance is increased. The Ni observed may be absorbed by plant and thereby increase the Ni dose in them.

The natural Ni content of various food items varies from 0.20 – 10.0 mg/kg as reported by literature [24]. The formation of stable Ni complexes may partly be responsible for the observed result of Ni in the soil. Previous results have shown that Ni ion combined with oxygen, nitrogen and sulphur containing compounds to form an extensive complex in solution, including hydroxides, carbonates, hydroxylic acids, phosphates, amines and thioles [25][26]. The threshold effect SQG for Nickel is 18.0 mg/kg [27].

Copper (Cu)

Copper being a metal of high-density decrease in concentration as the distance from the factory site is increased. This suggesting that the Cu may be from industrial activities and it distribution may be wind assisted particulate matter emission. Copper has the tendency to be leached and be affected by the pH of the soil thereby altering the rate of it mobility [28][29]. Even though the concentration of Cu decreased as the distance is

increased the value observed does not pose any enological risk on the environment.

Cadmium (Cd)

With a high density of 8.64 g/cm^3, Cd has a high deposition rate and therefore is not easily transported by the wind. This is an indication that the observed value may be contributed by the industrial activities from the factory. Cd compounds are used in electronic component and therefore the existence of these in the factory site may contribute to the elevated level of Cd in the factory site [1][23][30]. This level is the same as the limit prescribed by sediment quality guidelines and therefore the factory site can be said to be polluted.

Conclusion

Based on the results of this work, it can be concluded that the soil concentrations of Cr, Ni and Cd increased as the distance from the factory is increased. Iron and Cu decreased in concentration as the distance from the factory is increased. The concentration of Cr, Ni and Cd was attributed to the activities of cement processing in the factory. Elevated concentrations were observed as the distance from the factory is reduced. Thus farmlands located at less than 600 m from the site may be affected by this elevated concentration since plants uptake them through absorption.

Conflicting Interest

There is no conflicting interest in this work.

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References

[1] Li, Z., Ma, Z van der Kuijp, T.J., Yuan, Z., & Huang, L. (2014). A review of soil heavy metal pollution from mines in China: pollution and health risk assessment. *Sci. Total Environ.*, **468**, pp. 843-853. DOI: https://doi.org/10.1016/j.scitotenv.2013.08.090

[2] Yang, Z., Lu, W., Long, Y., Bao, X., & Yang, Q. (2011). Assessment of heavy metals contamination in urban topsoil from Changchun city, China. *J. Geochemical Explor*., **108**(1), pp. 27-38. DOI: https://doi.org/10.1016/j.gexplo.2010.09.006

[3] Sharma, V.K., Rhudy, K.B., Cargill, J.C., Tacker, M.E., & Vazquez, F.G. (2000). Metals and Grain Size Distributions in Soil of the Middle Rio Grande Basin, Texas, USA. *Environ. Geol*., **39**(2), pp. 698-704. DOI: https://doi.org/10.1007/s002540050484

[4] Pekey, H. (2006). Heavy metal pollution assessment in sediments of the Izmit Bay, Turkey. *Environ. Monit. Assess.*, **123**(1-3), pp. 219-231. DOI: https://doi.org/10.1007/S10661-006-9192-Y

[5] Bityukova, L., Shogenova, A., Brike, M. (2000). Urban Geochemistry: A Study of Element Distributions in the Soils of Tallinn (Estonia). *Environ. Geochem. Health*, **22**, pp. 172 - 193. DOI: https://doi.org/10.1023/A:1006754326260

[6] Sterckeman, T., Douay, F., Proix, N., & Fourier, H. (2000). Vertical Distribution of Cd, Pb and Zn in Soils near Smelters in the North of France. *Environ. Pollut*., **107**, pp. 377-389. DOI:

https://doi.org/10.1016/S0269-741(99)00165-7

[7] Manta, D.S., Angelone, M., Bellanca, A., Neri, R., & Sprovieri, M. (2002). Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. *Sci. Total Environ.*, **300**(1-3), pp. 229-243. DOI: https://doi.org/10.1016/S0048-9697(02)00273-5

[8] Khan, M.N., Wasim, A.A., Sarwar, A., & Rasheed, M.F. (2011). Assessment of heavy metal toxicants in the roadside soil along the N-5, National Highway, Pakistan. *Environ. Monit. Assess.*, **182**(1-4), pp. 587-595. DOI: https://doi.org/10.1007/s10661-011-1899-8

[9] Gray, C.W., McLaren, R.G., & Roberts, A.H.C. (2003). Atmospheric Accessions of Heavy Metals to Some New Zealand Pastoral Soils. *Sci. Total Environ.*, **305**, pp. 105-115. DOI: https://doi.org/10.1016/S0048-9697(02)00404-7

[10] Semhi, K., Khirbash, S.A., Abdalla, O., Khan, T., Dupley, J., Chaudhuri, S., & Saidi, S.A. (2010). Dry Atmospheric Contribution to the Plant-Soil System around a Cement Factory: Spatial Variations and Sources—A Case Study from Oman. *Water, Air, Soil Pollut.*, **205**, pp. 343 - 357. DOI: https://doi.org/10.1007/s11270-009-0079-8

[11] Khashman, O.A., & Shawabkeh, R.A. (2006). Metal Distribution in Soils around the Cement Factory in Southern Jordan. *Environ. Pollut.*, **140**, pp. 387-394. DOI: https://doi.org/10.1016/j.envpol.2005.08.023

[12] Bilen, S. (2010). Effect of cement dust pollution on microbial properties and enzyme activities in cultivated and no-till soils. *African J. Microbiol. Res.*, **4**(22), pp. 2418-2425. WOS: 000285847700015

[13] Prabakaran, K., Nagarajan, R., Eswaramoorthi, S., Anandkumar, A., & Franco, F.M. (2019). Environmental significance and geochemical speciation pf trace elements in Lower Baram River sediments. *Chemosphere*, 219, pp. 933-953. DOI: https://doi.org/10.1016/j.chemosphere.2018.11.158

[14] U.S. Environmental Protection Agency (USEPA). 2004. Risk assessment guidance for superfundvolume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment); USEPA: Washington, DC., USA.

[15] Nicholson, F.A., Smith, S.R., Alloway, B.J., Carlton-Smith, C., & Chambers, B.J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.*, **311**(1-3), pp. 205-219. DOI: https://doi.org/10.1016/S0048-9697(03)00139-6

[16] Adriano, D.C. (2001). *Trace elements in terrestrial environments: biogeochemistry, bioavailability and risks of metals (2nd edn)*. In: Zhuang, P, McBride Mb, Xiu H, Li N, Li Z. 2009. Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. *Sci. Total Environ.*, 1551-1561. DOI: https://doi.org/10.1016/j.scitotenv.2008.10.061

[17] Kabata-Pendias, A. (2011). Trace elements in soil and plants (4th Eds.). Boca Raton, CRC press, Washington DC.

[18] Musa, D., & Kpanache, D. (2014). The impact of Obajana cement company as a growth Pole in Obajana, Kogi State, Nigeria. *Ethiopian J. Environ. Studies & Mgt.*, **7**(1), pp. 73-81. DOI: https://doi.org/10.4314/ejesm.v7i1.9

[19] Banat, K.M., Howari, F.M., & Al-Hamad, A.A. (2005,. Heavy metals in urban soils of Central Jordan. Should we worry about their environmental risks? *Environ. Res.*, **97**, pp. 258-273. DOI: https://doi.org/10.1016/j.envres.2004.07.002

[20] Nriagu, J.O., & John, W. (1980). Zinc in the environment. Ecological Cycling. *Chemosphere*, **63**, pp.1546-1552. Corpus ID: 127249274.

[21] Chukwulobe, E.E., & Saeed, M.D. (2014). Assessment of some physicochemical properties and levels of Pb, Cu and Zn in soils of selected dumpsites in Kano Metropolis, North West Nigeria. *Int. J. Biol. Chem. Sci.*, **8**(2), pp. 717-726. DOI: http://dx.doi.org/10.4314/ijbcs.v8i2.29

[22] U.S. Environmental Protection Agency (USEPA). 2001. Toxics release inventory: Public data Release Report. Online available at www.epa.gov/tri/tridata/tri01

[23] Chen, H., An, J., Wei, S., & Gu, J. (2015). Spatial patterns and risk assessment of heavy metals in soil in a resource-exhausted city, Northeast China. *PLos One*, **10**(9), pp. e0137694. DOI: https://doi.org/10.1371/journal.pone.0137694

[24] U.S. Environmental Protection Agency (USEPA). 2017. Regional screening level (RSL) summary Table. Online availablee at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017

[25] Demir, T.A., Isikli, B., Urer, S.M., Berber, A., Akar, T., Canbek, M., & Kalyoncu, C. (2005). Nickel exposure and its effects. *Biometal*, **18**, pp. 7-13. DOI: https://doi.org/10.1107/s10534-004-1209-9

[26] Okorie, E.O., & Egila, J.N. (2014a). Analysis of sediment samples for some trace and major metals from Okaba coal mine in Kogi State, Nigeria by energy-dispersive x-rayfluorescence spectrometry: Effect of seasonal variations on the concentrations of these metals. *Int. J. Biol. Chem. Sci.*, **8**(4), pp. 1927-1937. DOI: http://dx.doi.org/10.4314/ijbcs.v8i4.52.