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Assessment of the Levels of Some Heavy Metals Content in the Glass Sand Deposit in Kazaure, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AAA designed the study, wrote the first draft of the manuscript. Authors MW and LS managed the sample collection, laboratory analysis, literature review and statistical analysis. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: The study is aimed at analyzing soil samples from various sampling points of the Kazaure glass sand deposit for the levels of lead, cadmium, chromium, nickel, iron, zinc, copper and manganese in order to ascertain the environmental impact of the mining activity.
Study Design: To assess the levels of Heavy metals in the glass sand deposits and their effects on the environment by comparing results with reference values obtained in literature.
Place and Duration of Study: Department of Pure and Industrial Chemistry, Bayero University, Kano-Nigeria. September 2012- December 2012.
Methodology: We determined the soil pH and concentrations of Pb, Cd, Cr, Ni, Fe,

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Zn, Cu and Mn in fourteen samples of glass sand deposit from Kuma Dangibga village, south of Kazaure town in Jigawa State, Nigeria. Atomic Absorption Spectrophotometric method was used and results obtained were compared with reference values for metals in soils to ascertain the levels of metal pollution.

Results: Soil pH values ranged from 7.54 ± 0.23 to 8.36 ± 0.11 indicating neutral to slightly alkaline. The mean levels of metals obtained ranged from 1.25 ± 0.00 mg/kg Cd to 81.16 ± 5.02 mg/kg Zn and in the following order of abundance: Zn> Fe> Pb> Ni> Cr> Cu> Mn>Cd. With the exception of Cd and Cr, the concentrations of the other metals were found to be below the safe limits for metals in soils. Analysis of the result indicates that there no significant differences (p>0.05) between the metal content of the glass sand and those from the adjacent control sites.

Conclusion: The results indicate pollution by Cd and Cr which need to be addressed since the lands around the vicinity of the mining site are being utilized for agricultural purposes.

Keywords: Glass sand deposit; mining site; pollution; safe limits.

1. INTRODUCTION

The introduction of harmful substances into the environment has been shown to have many adverse effects on human health, agricultural productivity and the natural ecosystem [1]. Heavy metal pollution of the environment, even at low levels and the resulting long-term cumulative health effects are among the leading health concerns all over the world [2]. Concern over the possible ecological effects of the increasing accumulation of metallic contaminants in the environment is growing [3]. Some human activities such as industrial processing, domestic sewage generation, mining operations, garbage productions, metallurgical and cottage industrial activities have been linked to metal pollution of soils [4]. Human activities can however raise the bio-available forms of heavy metals that human beings can readily take up through crops. This happens because such activities affect a number of soil parameters such as organic matter, clay and pH levels, which in turn significantly raises availability of metal levels for the uptake by plants. In the absence of human activities, background levels of such metals are relatively low and hence pose little threats to human health [5]. Once heavy metals enter the soil, they may undergo several changes depending upon physical, chemical and biological properties of the soils. Bioavailability of these heavy metals is very important as it is a gateway for the metals into the food chain [6].

Lead, cadmium, chromium, nickel and copper are known to be very toxic and have very chronic health implications even at very low levels [7-10]. At low levels iron, zinc and manganese can be regarded as essential in the metabolic processes of living organisms [10,11,12]. The environmental effects of solid minerals mining activities in Nigeria has not been given serious attention until the limestone dust issue on the Tse-Kucha and Tse-Amua communities of Gboko, Benue state was reported [13]. Thereafter, Birnin Yauri and Argungun [14] have reported on the pollution problems of some areas of north western Nigeria but not much has been done on the heavy metal contents of the mining sites and their possible effects on the quality of soil and its biotic community. Thus, the present study is aimed at analyzing soil samples from various sampling points of the Kazaure glass sand deposit for the levels of lead, cadmium, chromium, nickel, iron, zinc, copper and manganese in order to ascertain the environmental impact of the mining activity.

2. MATERIALS AND METHODS

2.1 Study Area

Kazaure is located in Jigawa State, Nigeria between latitude 12º 39' 10" N and longitude 8º 24' 43" E. The glass sand deposit area is at Kurna Dangibga village, a distance of about fifteen kilometers, south of Kazaure town. Three other villages (Kuma dangibga, Fauriya and Dustawa) located at a distance of 500 m, 1500 m and 2000 m from the study area were selected as reference uncontaminated areas (Fig. 1).

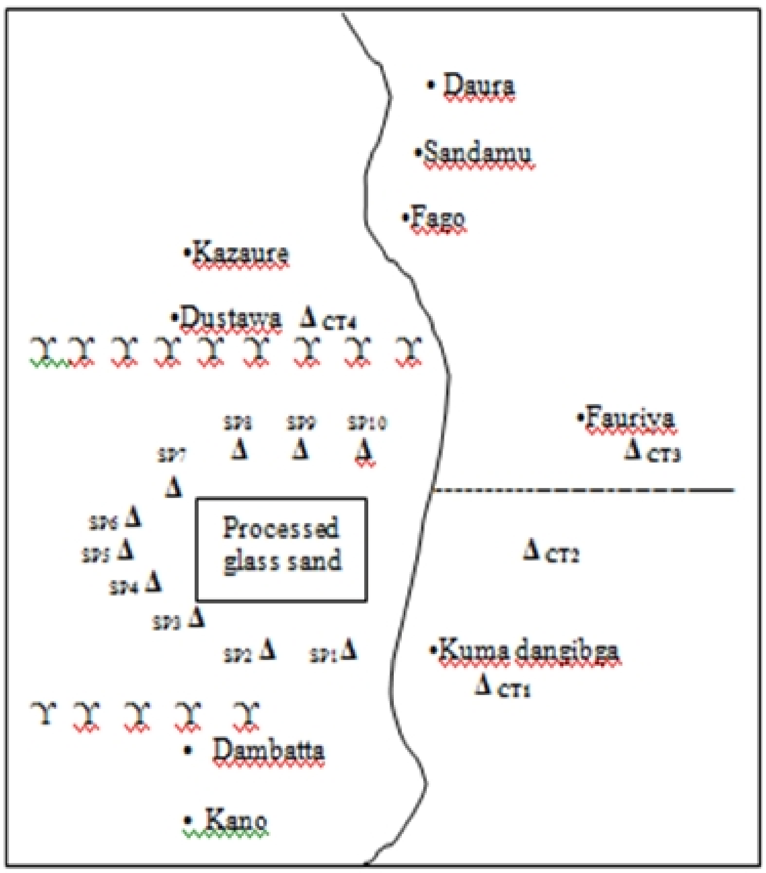

Fig. 1. Map of the study area showing sampling sites

—— Main road
------ Minor road
ϓϓ Shelterbelt
Δ Δ *Sampling points*

2.2 Sampling

Ten sampling points identified as SP1, SP2, SP3, SP4, SP5, SP6, SP7, SP8, SP9 and SP10 at a distance of 50 m from each other within the sand deposit area were selected (Fig. 1). About 150 g of the soil sample was collected from each sampling point by the use of clean stainless steel trowel from 0-15 cm depth [3]. Three representative samples (150 g) were collected from each sampling point at each sampling period using the coning and quartering method [15]. Four soil samples (controls) were also collected from the three reference areas by the same method and labeled as CT1, CT2, CT3 and CT4. The control samples were collected at distances of 500 m, 750 m, 1500 m and 2000 m respectively from the mine site. All the samples were packaged in labeled polyethylene bags and taken to the laboratory for analysis.

2.3 Sample Treatment/Analysis

The samples were air-dried in the laboratory, thoroughly mixed and sieved through a 2 mm nylon sieve and oven-dried at 105ºC to constant weight. Sample digestion and preparations were carried out according to USEPA method [16]. Serial dilution method was used to prepare the working solutions and the concentrations of the metals in each sample digest were determined using Atomic Absorption Spectrophotometer (Buck Model 210 VGP) equipped with a digital readout system.

2.4 Data Analysis

Data obtained were analyzed using Microsoft Excel and results were expressed as mean ± standard deviation. The student t-test was used to test for significant differences. Statistical variations were considered significant at $p< 0.05$.

3. RESULTS AND DISCUSSION

The results of the analysis are shown in Table 1. The pH of the soil samples ranged from 7.54 ± 0.23 to 8.36 ± 0.11 indicating neutral to slightly alkaline samples. The results showed that absorption of these metals by plants may not be feasible since at high pH, nutrients become insoluble and plants cannot readily extract them [17]. pH and organic matter are some of the most important parameters controlling the accumulation and availability of heavy metals in soil [18]. The mean concentration of the metals at the controlled areas ranged from Mn (6.28±0.88mg/kg) to Zn (47.46±1.88mg/kg). However, none of the metals exhibited any dominance at all the sampled sites. Highest levels of Cd (7.91 ± 5.02 mg/kg) and Zn (81.16±5.02 mg/kg) were recorded at SP1 while SP2 recorded highest level of Cu (23.81 ± 3.40 mg/kg) when compared to the sampled and control areas. Similarly, SP4 and SP5 sites recorded highest level of Pb (33.22 ± 3.97 mg/kg) and Ni (21.41 ± 7.01 mg/kg) respectively. Appreciable levels of Pb were also recorded at SP6, SP7, and SP10.The general trend for the mean concentrations of metals analyzed in the samples showed that: Zn> Fe> Pb> Ni> Cr> Cu> Mn> Cd.

Table 1. Table showing the pH values and the metal levels (mg/kg) of the glass sand deposit

S. Points	pH	Pb	Cd	Cr	Ni	Fe	Zn	Cu	Mn
SP1	7.54±0.23	4.58±1.98	7.91±1.44	7.69±0.00	16.82±5.30	36.41±4.86	81.16±5.02	14.74±1.96	6.79±1.18
SP2	7.76±0.14	16.04±1.98	2.92±0.72	17.95±4.45	18.35±0.00	36.41±4.86	30.43±0.00	23.81±3.40	3.39±1.17
SP3	7.60±0.10	11.46±1.97	4.53±0.72	7.69±0.00	18.35±4.59	42.02±8.41	30.43±4.35	11.34±1.97	6.11±2.04
SP4	7.60±0.06	33.22±3.97	4.99±1.25	12.82±4.44	15.29±2.65	28.01±4.85	28.98±2.51	19.28±1.96	6.11±0.00
SP5	7.80±0.12	20.62±3.44	2.92±0.72	17.95±4.45	21.41±7.01	28.01±4.85	57.97±6.64	9.07±1.96	7.47±1.18
SP6	8.12±0.04	14.89±1.98	2.08±1.44	25.64±11.8	18.35±4.59	25.21±8.40	40.58±3.83	6.80±0.00	5.43±1.18
SP7	8.21±0.06	27.49±3.44	2.50±0.00	17.95±4.45	19.88±2.65	53.22±12.8	24.64±9.05	9.07±1.96	5.43±1.18
SP8	8.36±0.11	21.76±10.5	2.08±0.72	12.82±4.44	18.35±4.59	33.61±0.00	20.29±2.51	13.61±0.00	7.47±2.61
SP9	8.25±0.07	13.75±3.44	4.16±0.72	12.82±4.44	18.35±4.59	30.81±4.85	37.68±2.51	9.07±1.96	5.43±1.18
SP10	7.98±0.12	24.05±3.44	3.33±0.72	23.08±0.00	10.70±2.65	25.21±8.40	50.72±2.51	12.47±1.97	8.15±0.00
CT1	8.00±0.03	6.87±3.44	2.92±0.72	12.82±4.44	16.82±2.65	19.61±4.85	46.38±2.51	24.94±1.96	10.86±1.18
CT2	8.04±0.04	6.87±0.00	3.75±1.25	10.25±4.44	22.94±4.59	36.41±4.86	50.72±4.51	20.41±0.00	6.79±1.18
CT3	8.10±0.03	12.60±1.99	1.25±0.00	23.08±0.00	13.76±4.59	25.21±8.40	56.52±0.00	18.14±1.96	3.39±1.17
CT4	7.82±0.02	26.34±3.97	5.41±0.72	20.51±8.89	12.23±2.65	36.42±9.71	36.23±2.51	12.47±1.97	4.07±0.00
Reference values		2.00-20.0 [a]	0.03-0.30 [a]	5.00 [a]	2.00-750 [a]	3000-5000 [b]	1.00-900 [a]	5.00-20.0 [a]	40.00-900 [c]

Values represent Mean ± Standard deviation of twelve determinations.
Key: SP= Sample Collection Point.
CT=Control Sample Collection Point.
Source: a=Bowen [19], b= Awokunmi et al. [27], c=ATSDR [26].

The mean concentrations of the heavy metals at all the studied sites are presented in Fig. 2. The mean concentration of lead in the samples (18.79 ± 3.61 mg/kg) is within the normal range of 2.00 to 20.00 mg/kg in soils as reported in literature [19]. Similar values of Pb (0.10 to 20.00 ppm) in sandy soils were reported [20].

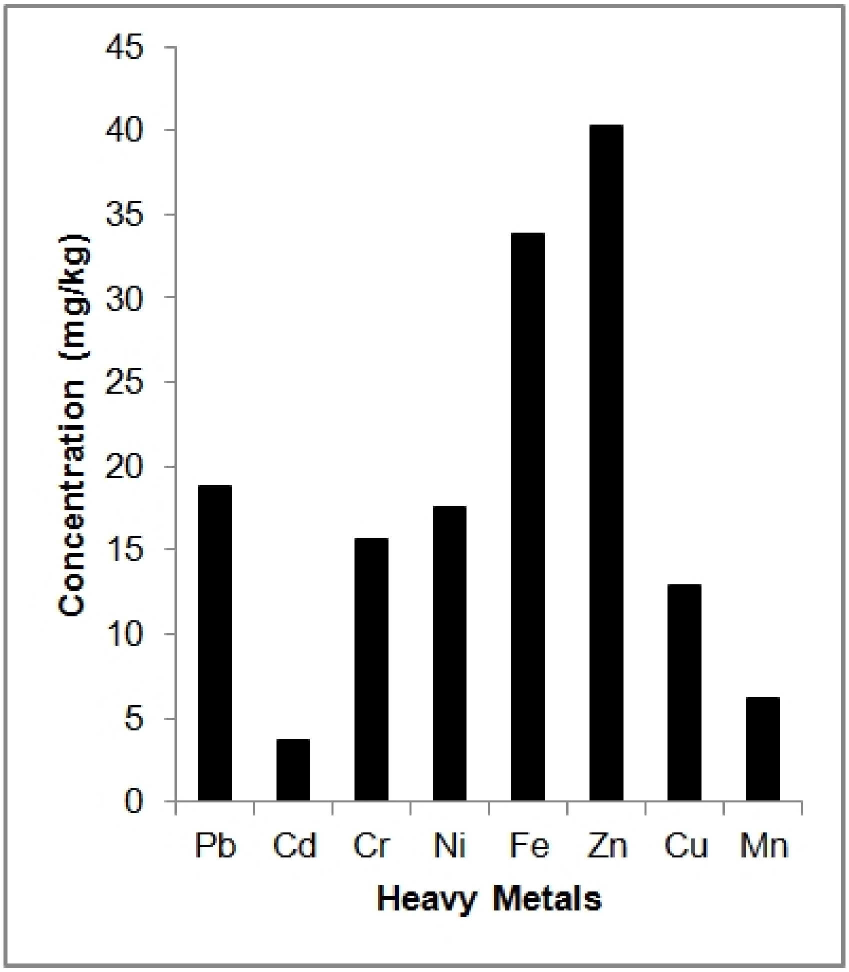

Fig. 2. Mean concentrations of the Heavy metals (mg/kg) at the mining sites
Values represent Mean ± Standard deviation of twelve determinations

The amount of Pb found in this study may be due to deposition from automobile exhaust, since the mining site lies along the Kano-Daura highway. Pb is known to improve the refractive index of the glass, providing the finished glass with a colourless and brilliant appearance [21]. Thus, the high level of lead in the glass sand is a marked advantage. On the contrary, environmental lead contamination causes serious effects in the ecosystem that encompass those environments. Lead can accumulate in soil and remain for a very long time and can wipe out large population of microorganisms. Lead also affects plants through absorption while animals experience severe effects from Pb exposure especially in the central nervous system, kidneys and blood in humans [22].

The mean concentration of cadmium in the samples is alarming because of its relatively high value (3.74 ± 0.85 mg/kg). Naturally occurring cadmium concentration ranges from 0.03 to 0.30mg/kg in soils [19]. The levels of Cd found in this study were similar to results reported in sandy soils where Cd ranged from 0.71 to 1.80 ppm [20]. Although wear-and-tear of tires is recognized as a major source of Cd along roadways, this study suggests that the combustion of fuel especially diesel and lubricants which are known to contain cadmium, may be good sources of the Cd. Cadmium levels ranging from 20 to 90 µg/g associated with car tires vulcanization has been reported [21]. Application of municipal solid wastes in farmlands as well as the use of other agrochemicals could also be other contributory factors to Cd levels [23]. High levels of Cd in the soil within the sampling points could pose serious health risk in the environment. Long term Cd toxicity can cause Itai-Itai disease [24].

The level of chromium (15.64 ± 3.84 mg/kg) is in excess of the natural concentration limit of 5.00 mg/kg in soils [19]. This finding is similar to the reported values of Cr (11.40 to 60.00 ppm) in sandy soils [20]. The high levels of chromium can be attributed to the presence of chromium compounds being excavated during the mining activity. Such high levels of chromium may impact negative effects on the finished glass as well as the environment. The presence of higher amounts of Fe_2O_3 and Cr_2O_3 as impurities in the glass sand is known to produce a green tint in the finished glass [23]. Cr (III) is an essential nutrient for humans and plants usually absorb Cr (III), but too much uptake can cause health problems ranging from skin rashes to death in humans and high concentrations of Cr in soil can lead to high levels in crops which may cause negative effects. The levels of Ni, Zn, Cu and Mn fell within the normal range in sandy soils as reported by several researchers [19,20,26]. The high levels of Zn compared to the other metals may be attributed to emissions from vehicle exhausts, wear and tears of vehicle parts worsen by the poor road surfaces as well as the lubricating oils, Zn being one of the additives in lubricating oils [4]. The effect of high levels of Zn in soil on the ability of plants to absorb essential metals such as Fe and Mn has been reported [28]. Cases of Zn poisoning in humans through inhalation and ingestion of Zn have also been reported [29]. The level of Mn in the soil is an added advantage since MnO_2 has the ability to neutralize the colour effect due to the presence of Fe and Cr [23]. However, chronic effects reported in humans from inhalation exposure to high levels of manganese include manganism, respiratory effects such as an increased incidence of cough, bronchitis, and an increased susceptibility to infectious lung diseases [26].

Analysis of the result indicates that there no significant differences ($p>0.05$) between the metal content of the glass sand and those from the adjacent control sites. This observation confirms that the introduction of the metals into the adjacent lands as well as the mining sites have a common source.

4. CONCLUSION

The results showed that the whole area surrounding the mining site belongs to the same soil type. The absorption of these metals in large quantities by the plants and crops is minimized as the pH is higher than the optimum needed to enhance effective metal absorption from the soils by plants and other crops in the adjacent farmlands. High concentrations of Cd and Cr are indications that the adjacent farmland soil pollution has resulted from the mining operations.

In this study, we focused on pH and heavy metal content but further studies will investigate other important soil properties such as organic matter, cation and anion exchange capacities, salinity, carbon to nitrogen ratio and other micronutrients.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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