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# QUANTIFICATION OF POLLUTION LEVELS ASSOCIATED WITH HEAVY METALS IN SHANONO AND BAGWAI ARTISANAL GOLD MINES, KANO STATE, NIGERIA

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**ABSTRACT**
Quantification of heavy metals pollution levels in an environment is a powerful tool for converging raw heavy metals concentrations to a comprehensive level that could easily be interpreted by decision makers, managers and the public. In this work, the heavy metals concentrations were obtained using atomic absorption spectrophotometry. Element specific pollution was assessed by contamination, ecological risk, enrichment and geo-accumulation indices; Pollution load, average pollution, risk and Nemerow pollution load integrated indices were used to quantify the overall pollution level of the studied area. All the single indices computed indicated that both the soil, water and plants were polluted at different levels by all the studied heavy metals. Pollution load index, Risk index, Average pollution index and Nemerow pollution load index were estimated at 3.5, 232.0, 23.9,172.7 respectively for soils, 2.9, 964.8, 24.2, 173.1 respectively for water, 2.2, 1166.9, 14.9, 172.5 respectively for plants. These integrated indices classified the soil and water in the studied area as polluted and under strongly high ecological risk, which calls for immediate remediation measures to be implemented by appropriate authorities to at least minimize these levels.

**Keywords**: Kano, pollution, indices, heavy metals, gold mining

## INTRODUCTION

Heavy metals environmental quality assessment indices are used to evaluate the degree to which heavy metals might adversely affect plants and animals, they also rank and prioritize the contaminated areas or the heavy metals for further investigation or remediation actions (Farkas et al., 2007). Assessment indices of heavy metal pollution have been classified as single and integrated indexes (Nan *et al*., 2015, Zhang *et al*., 2015). the single index consists of contamination factor (CF) (Chandrasekaran *et al*., 2015; Adokoh *et al*., 2011), geo-accumulation index (Igeo) (Zhu *et al*., 2012; Salati and Moora, 2010; Ma *et al*., 2016), potential ecological risk index (RI) (Zhu *et al*., 2012) and enrichment factor (EF) (Zhu *et al*., 2012; Thuong *et al*., 2013; Islam *et al*., 2015; Pekey, 2006). Pollution load index (PLI) (Islam *et al*., 2015), Degree of contamination index (DC), Risk index (RI), average pollution index ($PI_{ave}$) and Nemerow pollution load index ($PLI_{nemerow}$) were regarded as integrated indices that utilize the single indices to provide an overall quality of the environment (Nan *et al*., 2015; Zhang *et al*., 2015). Single and integrated indices have been successfully used as significant indicators of the quality of soil, water and plants following an anthropogenic activity all over the world (Bello *et al*., 2016 and 2017; Bhuiyan *et al*., 2010; Edet and Offiong, 2002; Mohan *et al*., 1993, ). However, among the single indices, contamination factors, ecological risks, enrichment factors and geo-accumulation factors were proved to be effective in gathering composite influence of heavy metals to the overall contamination of the site due to an anthropogenic or natural activity (Horton, 1965; Joung *et al*., 1979; Prasad and Bose, 2001). Heavy metals have been identified as the most frequent and ubiquitous contaminants in the world and have been widely known for their long persistence time, toxicity, non-biodegrability and bioaccumulation (Duruibe *et al*., 2007; Cadar *et al*., 2015). Due to the bioaccumulation of heavy metals, they were attributed to cause serious detriment to humans, animals and plants (Zvinowanda *et al*., 2009; Muntean et al., 2013; Senila *et al*., 2013 and 2015 and Alia et al., 2015). Mining and mineral processing has been known among the anthropogenic activities which release a variety of heavy metals (Nriagu 1990; Navarro and Martinez, 2008; El Hamiani et al. 2010; Kabata - Pendias 2011 and Zornoza *et al*. 2012). In recent years, heavy-metal pollution caused by the artisanal mining activities has been reported by several researchers in Nigeria (Oota, 2011; Adekoya, 2003). However, the pollution trend of heavy metals in soil, plants and water around the Shanono and Bagwai gold mining villages which lie between latitudes 11˚93′22″ and 12˚31′38″N and longitude 7˚81′42″ and 8˚26′26″E has received less formal attention. In this work, the pollution levels associated with heavy metals in this gold mining area has been quantified. Presently, mining in the study area, is carried out by illiterate artisans across all the ages. The crude methods of obtaining the

minerals expose the miners, immediate and adjourning environments including farmlands and water bodies to contamination. Also, the tailings (waste) is exposed to wind and the prevailing weather conditions resulting in further transportations of heavy metals to once uncontaminated areas. The clay waste from some parts of the mines is used by the locals in pottery and construction of residential homes. The populace still relies on untreated ground water (shallow wells and boreholes) and surface water for drinking and other household activities. Therefore, this study quantified the pollution level posed by the studied heavy metals in the Shanono and Bagwai gold mining environs (Alajawa, Kundila, Dutsen Bakoshi and Ginzo villages) using single and integrated indices statistical models.

## MATERIALS AND METHODS

The soil, water and plant samples (*Amaranthus spine L* (Local name: Alayyahu), *Cassia tora* L. (Local name: Tafasa) and *Moringa Oleifera L*. (Local name: Zogale)) were collected, prepared and analysed as described in Bello *et al*. (2016 and 2017). The samples were analyzed for the heavy metals (Ni, Cr, Cu, Co, Pb, Cd, Fe, Mn, As and Zn)) using atomic absorption spectrophotometer (AA-6800 Shimadzu Japan) and the concentrations obtained were used in the computations of the single and integrated indices in order to quantify the pollution levels.

### Sample collection

Soil samples were collected within the mines area, farmlands and residential villages. The soil samples were taken using a mechanical hand auger. At each sampling location, samples of soil were taken from at least five different sections of the area into labeled plastic bags. Water samples were collected in a clean 1Litre sample collection bottles with tight covers. Surface water samples were collected with the aid of a bailer, the ground water in the wells were first purged by drawing it out severally to ensure fresh samples were obtained. the borehole water samples were collected after evacuating the existing water in the pipe. The containers were rinsed thoroughly with the water to be collected and later with concentrated Nitric acid. Due to the sample availability only Four surface water and Four ground water sources were collected apart from the control. In locations where soil samples were being collected, edible plant samples of *Amaranthus spine L* (Local name: Alayyahu), *Cassia tora* L. (Local name: Tafasa) and *Moringa Oleifera L*. (Zogale) were collected from dry season farm within the mine area with each sample collected within a grid area of 10m x 10m. The samples were also packaged in plastic bags carrying and labelled with identification marks.

### Sample preparation for heavy metal analysis

All the collected soil and plant samples were air-dried at ambient laboratory temperature and ground using mortar and pestle and sieved using 20mm mesh sieve before wet digestion. 1g of each sample was weighed using an electronic weighing balance and put in an empty clean beaker. 10mL of Nitric acid ($HNO_3$), 2mL of 60% Per chloric acid ($HClO_4$) and 5mL of concentrated Sulphuric acid ($H_2SO_4$) were added to each sample in the beaker and mixed up with the sample using a glass rod. The sample was then heated on a hot plate for about 1hour and allowed to be digested up to dryness at 100$^o$C, allowed to cool at room temperature and filtered in to a standard 60mL sample bottle and were made up to the mark with distilled water. The filtrate was then kept ready for analysis.

### Experimental determination of heavy metals concentrations

The heavy metals analysis was carried out using atomic absorption spectrophotometer with model (AA-6800 Shimadzu Japan) situated at National Research Institute for Chemical Technology Located at Basawa, Zaria. Different concentrations of standard solutions were run on the instrument to obtain the calibration curves for each metal using measured absorbance and the corresponding concentration. The instrument was set to zero by reading a reagent blank. Each of the prepared samples was aspirated in to the instrument and read three (3) times, the average value of the concentration was taken for each metal in each sample. The results of the analysis were validated by digesting and analyzing standard reference materials (Lichens coded IAEA-336) following the same procedure. The analysed values and the certified value were found to be within 15% uncertainty. Distilled and Deionized water were used throughout the experiment and all reagents used were of analytical grades.

### Quantification of Heavy metals pollution

In order to assess the single element pollution level, the heavy metals concentrations were used to obtain the contamination factors, geo-accumulation, Ecological risk factors, Enrichment factors using the formulations described in (Hakanson, 1980; Sutherland, 2000; Lokeshwari and Chandrappa, 2006). The ecological risk factors were estimated for Ni, Cr, Cu, Pb, Cd, As and Zn respectively. The ERF for Mn and Fe were not computed due to unavailability of toxic response factors. Enrichment factors were calculated for soils and water only and was not calculated for plants because the immobile element (Mn) used in the estimation was not detected in control plant. Mn was used as the immobile element due to its relatively higher frequency of detection compared to Fe that was used by (Sutherland, 2000). For the assessment of the overall environmental quality associated with the studied heavy metals, integrated indices comprising Average pollution index ($PI_{ave}$), Nemerow pollution load indices ($P_s$), Risk index (RI) and Pollution load index (PLI) were computed for all the samples from the single pollution

indices using the equations provided by (Hakanson, 1980; Tomlinson *et al*., 1996 and Yang *et al*., 2017). The computations of all these single and integrated statistical indices were carried out using MS Excel version 2016 and descriptive statistics was used to obtain the mean, minimum and maximum of each of the computed factor.

## RESULTS AND DISCUSSION

Table 1, 2 and 3 presented the summary of the discussion on the results on contamination factors, geo accumulation indices, ecological risks and enrichment factors for soil, water and plants respectively. The contamination factors varied significantly and decreased in the order Co > Cr > Fe > Ni > Mn > Cu > Cd > Pb > Zn >As for soil, Pb > Cr > As > Zn > Fe > Mn > Ni > Co > Cd for water samples and As > Cr > Pb > Fe > Ni > Cd > Cu> Co for plants. the contamination factors were all higher than the threshold limit of 1.0 indicating that the soil, water and plants were polluted at varying levels. The potential ecological risk varied significantly and decreased in the order: Cr > Cd > Ni > Cu > As > Pb > Zn; Pb > As > Cr > Cd > Zn > Ni; As > Cd > Cr > Pb > Ni > Cu for soils, water and plants respectively. The Enrichment factors varied widely in soils and water and had an order: Co >Cr > Fe > Zn > Cu > Pb > Cd > As and Pb>Cr>Zn>Fe>Cd>Co>As. the geo-accumulation indices varied significantly and had the pattern: Co > Cr > Ni = Mn > Fe > Cu > Cd > Pb > As > Zn; Pb > As > Zn > Cr > Fe > Mn > Co > Cd and As > Cr > Cd > Ni > Co > Fe > Cu respectively for soil, water and plants. For the overall environmental quality, the summary of the integrated indices computed was presented in table 4. All the integrated indices used indicated that the studied area is polluted and has its quality degraded by these heavy metals since PLI >1, RI > 150 and $PI_{ave}$ >1 as recommended by (Hakanson, 1980; Tomlinson *et al*., 1996 and Yang *et al*., 2017). The enrichment, geo-accumulation, ecological risk and contamination status of these metals in the study area may be attributed to the anthropogenic activities going on in the area as well as geogenic processes such as bedrock dissolution and chemical weathering (Amadi et al., 2017). Majority of the observed elements are exposed and subsequently released from the ground into the soil through human activities such as mining and farming. The consistency in the computed pollution intensity by the different single and integrated pollution indices used is a confirmation of their efficiency in pollution studies.

**Table 1: Single index classification of pollution in the studied soils.**

| Metals | Contamination | Ecological risk | Enrichment | Geo-accumulation |
|---|---|---|---|---|
| Cr | Very high | Moderate | Significant | Moderate to strong |
| Co | Very high | NA | Extremely high | Extremely serious |
| Fe | Very high | NA | Moderate | Light to moderate |
| Mn | Considerable | NA | NA | Light to moderate |
| Pb | Moderate | Moderate | Depletion to minimal | Light to moderate |
| Cd | Moderate | Moderate | Depletion to minimal | Light to moderate |
| As | Moderate | Moderate | Depletion to minimal | Non- contamination |
| Zn | Moderate | Moderate | Depletion to minimal | Non- contamination |
| Cu | Considerable | Moderate | Depletion to minimal | Light to moderate |
| Ni | Very high | Moderate | NA | Light to moderate |

NA: Not available

**Table 2: Single index classification of pollution in the studied water.**

| Metals | Contamination | Ecological risk | Enrichment | Geo-accumulation |
|---|---|---|---|---|
| Cr | Very high | High | Extremely high | Moderate |
| Co | Moderate | NA | Depletion to minimal | Non-contamination |
| Fe | Considerable | NA | Moderate | Light to moderate |
| Mn | Moderate | NA | NA | Light to moderate |
| Pb | Very high | Very high | Extremely high | Extremely serious |
| Cd | Low | Low | Depletion to minimal | Moderate |
| As | Very high | High | Depletion to minimal | Strong |
| Zn | Very high | Low | Significant | Moderate to strong |
| Cu | NA | NA | NA | NA |
| Ni | Moderate | Low | NA | Non- contamination |

NA: Not available

**Table 3: Single index classification of pollution in the studied plants.**

| Metals | Contamination | Ecological risk | Enrichment | Geo-accumulation |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Cr | Very high | Moderate | NA | Moderate |
| Co | Moderate | NA | NA | Light to moderate |
| Fe | Moderate | NA | NA | Non-contamination |
| Mn | NA | NA | NA | NA |
| Pb | Very high | Low | NA | Light to moderate |
| Cd | Moderate | Considerable | NA | Light to moderate |
| As | Very high | Very high | NA | Strong |
| Zn | NA | NA | NA | NA |
| Cu | Moderate | Low | NA | Non-contamination |
| Ni | Moderate | Low | NA | Light to moderate |

NA: Not available

**Table 4: Integrated index classification of the studied site.**

| Sample | Parameter | PLI | $PI_{sum}$ | RI | $PI_{ave}$ | $PLI_{Nemerow}$ |
|---|---|---|---|---|---|---|
| | Average | 3.5 | 238.7 | 232.0 | 23.9 | 172.7 |
| Soil | Min | 1.4 | 137.2 | 36.0 | 13.7 | 172.1 |
| | Max | 4.6 | 350.1 | 427.6 | 43.1 | 174.5 |
| Water | Average | 2.9 | 242.3 | 964.8 | 24.2 | 173.1 |
| | Min | 1.1 | 96.2 | 457.8 | 9.6 | 172.0 |
| | Max | 5.9 | 668.2 | 1735.1 | 66.8 | 178.2 |
| Plants | Average | 2.2 | 148.6 | 1166.9 | 14.9 | 172.5 |
| | Min | 0.9 | 8.0 | 72.3 | 0.8 | 171.8 |
| | Max | 3.4 | 382.7 | 3786.5 | 38.3 | 173.9 |

PLI: Pollution load index; $PI_{sum}$: Sum of Pollution index; RI: Risk index; $PI_{ave}$: Average pollution index and $PLI_{Nemerow}$: Nemerow pollution load index.

## CONCLUSION

The statistical models used had confirmed the presence of contamination in soil, water and plants, indicating the need for precautionary measures in the site utilization and immediate implementation of remediation measures in order to protect the public from the associated consequences of these metals. All the lowest contamination factors for the studied elements in soils were recorded in Kundila, indicating that Kundila was the least affected by the mining activities, though, it was polluted too. For the overall site quality, the pollution load index (PLI), Average pollution index (PIave) and Nemerow pollution load indices (PLI Nemerow) indicated the deterioration in the quality of soil, water and edible plants due to these heavy metals in the study area. The highest values of PLI, RI, PLI Nemerow were associated with Bakoshi village and the least with Kundila village. This clearly implies that Bakoshi village residents and associates are at highest risk and Kundila residents are relatively at lowest risk.

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