



Application of Contamination Indices and Human Health Risk Assessment of Inorganic elements in Dust Particulates at Funtua Textile Limited, Katsina Nigeria

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ABSTRACT

The study investigates health risks from inorganic element pollution near Funtua Textile Limited in Katsina, Nigeria. Concentrations of Cd, Cr, Cu, Ni, and Pb in particulate dust were measured using Atomic Absorption Spectrometry, and bioavailable fractions were determined via sequential extraction. Quality assurance yielded metal recoveries between 71.44% and 80.16%. Metal concentrations varied, with Cu being most abundant and Cd least. Significant correlations among metals indicated common pollution sources, primarily anthropogenic, as revealed by principal component analysis (PCA). Using the USEPA method, average daily dose (ADD), hazard quotient (HQ), and hazard index (HI) were calculated for adults and children via oral, inhalation, and skin exposure. Adults showed higher ADD, HQ, and HI through oral routes, while children showed higher values through skin contact. The study identified man-made sources like cotton dust and emissions from factory equipment as major pollutants. Indices like geoaccumulation, contamination factor, pollution load, and enrichment factors indicated severe pollution levels, particularly for Cu and Cd. Pollution in soil samples exceeded recommended limits by the European Commission and WHO. The findings highlight significant human health and ecological risks from textile industry pollution, urging immediate soil remediation and preventive measures to mitigate the transfer of inorganic elements to the environment.

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INTRODUCTION

Pollution refers to the discharge of harmful substances, residues and energy into the environment. Some of these residues are unconverted raw materials. Some are undiscovered products, some are by-products produced during manufacturing or processing (Meenaxi & Sudha, 2013). In other words, pollution is a sign of low industrial production efficiency. It can be seen as money being transported from chimneys, sewers, and waste truck factories, causing losses to manufacturers (Shinde & Sagar, 2018). Pollution is a special case of habitat destruction. It is chemical damage rather

than obvious physical damage. It occurs in all habitats, such as land, ocean, fresh water, atmosphere, vegetation, etc. The substances that cause pollution are called pollutants (Wolff *et al.*, 2006). Pollutants are any substances in the environment that can cause adverse effects, damage environmental welfare, reduce the quality of life, and ultimately lead to death. This substance must exist in the environment beyond a set of allowable limits, which itself may be ideal or acceptable within that limit. Thus, environmental pollution is the presence of a pollutant in the environment which may be poisonous or toxic and will cause harm to living things in the

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polluted environment. Pollution is a necessary evil of all development (Shinde & Sagar, 2018).

Industrialization is one of the main causes of environmental pollution in many cities in the developing world. Continued industrial development has led to a corresponding increase in pollutant levels. A UN-HABITAT report pointed out that Africa is the continent with the fastest urbanization rate, and cities are developing rapidly, which will triple the current size of Africa by 2050 (Un-Habitat, 2012). Therefore, the continuous growth of cities has had an impact on the pollution of other social services needed by urban communities. Most of the processes performed by textile mills generate atmospheric emissions. Gaseous pollutants in the textile industry have been identified as the second largest pollution problem after wastewater. Air emissions include dust, oil, acid vapor, odor and boiler exhaust (Deng & Patil, 2011).

The World Health Organization estimated that about a quarter of diseases facing mankind today occurs due to prolonged exposure to environmental pollution and it seems to be the highest (Deng & Patil, 2011). Inorganic metals are of significant environmental concern owing to their relative toxicity and accumulation potentials (Nabeshima & Yusuf, 2006). The contamination of the environment with inorganic metals even at low concentrations is known to have a potential impact on the environmental quality of human health (Luter *et al.*, 2011). Report further indicates that these metals are toxic or poisonous even at low concentrations and create definite health hazards when they enter the ecosystem (Duruibe *et al.*, 2007; Uba *et al.*, 2009; Yahaya *et al.*, 2010).

The major air pollutants in the textile industry are generated at the finishing stages, where various processes are employed for coating the fabrics (Meenaxi & Sudha, 2013). At this stage, the main sources of air pollutants include resin finishing and drying operations, printing, dyeing, fabric preparation and wastewater treatment plants. During the high-temperature drying/curing process, hydrocarbons are discharged from the drying oven and mineral oil. These processes may release formaldehyde,

acids, softeners and other volatile compounds. Acetic acid and formaldehyde are the two main emissions of concern for textiles (Javed & Usmani, 2013).

Other sources of air pollutants in textile mills are boilers, thermal units and diesel generators, which generate gaseous pollutants such as suspended particulate matter (SPM), sulphur dioxide gas and nitrogen oxides. Textile mills usually produce nitrogen and sulphur dioxide from boilers (Meenaxi & Sudha, 2013). Until now, there has been no time in history that the world can adapt to the effects of air pollution such as climate change, global warming, and the resulting effects such as acid rain and photochemical smog. The damage to life and property caused by this global threat cannot be quantified (Ihom & Offiong, 2014).

This makes particle dust research very important to determine the source, distribution and levels of these inorganic metallic pollutants in the surface environment of the textile industry. However, quantitative data on the concentration of inorganic elements, their pollution levels and pollution sources have not been systematically collected and compared, especially at this location. Therefore, the focus of this study is to determine inorganic elements pollution on particulate dust in textile mills, their sources, concentrations, pollution levels, sample collection, and analytical tools.

METHODS

Description of the Study area: Funtua is located at latitude 11032 N and longitude 7019 E it is a Local Government Area of Katsina State. It has an area of 448 km² and a population of 420,110 census estimate 2012. The mean annual rainfall in the area is 1024 mm. Annual temperature varies around 21.9 °C - 29.2°C. The selected area for this investigation is the Funtua Textile industry. It was established to make effective use of cotton which is grown in large quantities at Funtua town and environs. The industry is active 24 hours a day, six days a week. The sampling points were selected from each department and two random points within the vicinity: Ginning Department (G),

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Spinning Department: Blowing & Carding (S_1), Combing, Spinning & Roving (S_2). Weaving Department: Doubling & Bleaching (W_1), Weaving & knitting (W_2), Dyeing Department: Dyeing & finishing (D), Engineering Department: Maintenance (E_1), Power House (E_2), Ginning surrounding (Outside O_1), Dyeing surrounding (Outside O_2), with a Control area (C) at Dikke Village about 2 km away from the study area (Figure: 1.0).

Statistical Treatment of Data: The high variability associated with environmental data

makes multivariate statistics an option for the ability to evaluate large amounts of data in this study to decipher patterns in data concentration that would otherwise be unobservable. The multivariate techniques used include hierarchical cluster analysis (CA), principal component analysis (PCA) and its features maps, and the analysis was performed using Minitab version 17.0 statistical software. Perform basic statistics (descriptive) to provide initial information for all the parameters studied.

Table 1.0: Percentage Recoveries of Metals for the Total Metal Determination

Metals	Total Metal (%)
Cd	71.44
Cr	76.56
Cu	79.5
Ni	79.96
Pb	80.16

Soil Sampling: Twenty two (22) samples of dust were collected across the sampling points. The dust samples were collected using a plastic brush and tray (Charlesworth *et al.*, 2003; Lewis *et al.*, 2005) and stored in clean polythene bags (Dallatu *et al.*, 2018), thereafter, labelled using the first letters of every department.

Sample Collection: The homogenized particulate dust samples were air-dried and sieved through a 75 μm stainless steel sieve to remove extraneous matter such as pieces of brick, paving stone, and other debris. Care was taken to reduce the disturbance of the fine particles, which could be readily lost by re-suspension (Manta *et al.*, 2002).

Chemical Analysis: Furthermore, soil samples were digested by taken 2 g each, weighed into a beaker using an analytical balance -Mettler AE160, 50 cm^3 of concentrated Nitric acid (HNO_3) and 1 cm^3 Perchloric acid (HClO_4) were added. The mixture was digested by boiling gently on a hot plate. After digestion, the sample was evaporated to dryness and the residue mixed with 0.1M HNO_3 and filtered into a 100 ml flask using Whatman No.1 filter paper (Agency-USEPA & Agency-USEPA, 1998;Omoniyi *et al.*, 2016). The

blank determination was also carried out, alongside the spiking experiment by the preparation of a multi-element standard solution (MESS) to determine the efficiency of the AAS machine used for the analysis. Standard stock solutions for all the elements were prepared in the laboratory following the procedures as described in (Agency-USEPA & Agency-USEPA, 1998;Omoniyi *et al.*, 2016). Metals in the final solutions were determined using variant model AA650FS, Atomic Absorption Spectrometer (AAS). The glassware used was made from borosilicate, which was washed several times with liquid soap, rinsed with distilled water and then soaked in 10 % HNO_3 solution for 24 hours (Nejad *et al.*, 2018). Thereafter, they were washed with distilled water and dried in Memmert drying oven at 80 $^\circ\text{C}$ for 5 hours (Nejad *et al.*, 2018).

Contamination Assessment Methods: The assessment of particulate dust enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation, Pollution Load Index (PLI), and enrichment factors (Qing *et al.*, 2015). In this work, the index of geoaccumulation (Igeo), Pollution Load Index (PLI), and Enrichment

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Factor (EF) have been applied to assess inorganic elements (Cr, Cu, Cd, Pb, and Ni) distribution and contamination in the textile industry in Katsina. A quantitative measure of the extent of metal pollution in the studied soil was calculated using the geoaccumulation index proposed by (Muller, 1969). This index (Igeo) of inorganic element is calculated by computing the base 2 logarithms of the measured total concentration of the metal over its background concentration using the following mathematical relation (Ntekim *et al.*, 1993):

$$I_{geo} = \log_2(C_n/1.5B_n) \quad 1.0$$

Where; C_n is the measured total concentration of the element n in the particulate dust fraction, B_n is the average (crustal) concentration of element n in shale (background) and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects. Loska *et al.*, 2004 gave the following interpretation for the geoaccumulation index:

- I_{geo}<0 = practically unpolluted,
- 0<I_{geo}<1 = unpolluted to moderately polluted,
- 1<I_{geo}<2 = moderately
- 2<I_{geo}<3 = moderately to strongly polluted,
- 3<I_{geo}<4=strongly polluted,
- 4< I_{geo}<5= strongly to extremely polluted and
- I_{geo}>5 = extremely polluted.

Contamination Factor (CF): CF is a quantification of the degree of contamination relative to either average crustal composition of a respective metal or the measured background values from geologically similar and uncontaminated areas (Ladigbolu & Balogun, 2011). It is expressed as:

$$CF = C_m/B_m \quad 2.0$$

Where; C_m is the mean concentration, while B_m is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area. CF in this study was considered as:

- CF < 1 - Low contamination factor
- 1 < CF < 3 - Moderate contamination factor

- 3 < CF < 6 - Considerable contamination factor
- 6 > CF - Very high contamination factor (Uriah & Shehu, 2014).

Pollution Load Index: This was determined using the equation below as described by (Tomlinson *et al.*, 1980) was evaluated with the expression:

$$PLI = [\pi^n i(C_f)]^{1/n} \quad 3.0$$

Where; C_f is the contamination factor of each metal obtained by the ratio of the concentration of each metal in the soil to that of the metal in background soil or groundwater; π is the geometrical mean operator; n is the number of metals investigated in each sample.

Enrichment Factor: Enrichment Factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers. Its version adapted to assess the contamination of various environmental media is as follows:

$$EF = (C_x/C_{ref})_{sample} / (B_x/B_{ref})_{background} \quad 4.0$$

- Where; C_x = Content of the examined element in the examined environment
- C_{ref} = Content of the examined element in the reference environment
- B_x = Content of the reference element in the examined environment
- B_{ref} = Content of the reference element in the reference environment

An element is regarded as a reference element if it is of low occurrence variability and is present in the element in trace amounts. It is also possible to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects i.e. synergism or antagonism towards an examined element. The contamination categories are recognized based on the enrichment factor:

- EF<2 states deficiency to minimal enrichment,
- EF = 2-5 moderate enrichment,
- EF = 5-20 severe enrichment,

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EF = 20-40 very high enrichment and EF>40 extremely high enrichment (Manno *et al.*, 2006)

The enrichment factor, due to its universal formula is a relatively simple and easy tool for assessing enrichment degree and comparing the contamination of the different environments.

Human Health Risk Assessment

Health risk estimation includes the identification of exposure pathways, which is the course a chemical takes from a source to an organism (EPA, 1989), and an exposure route, the way a chemical comes in contact with a receptor (*i.e.*, by ingestion, inhalation, dermal contact, *etc.*). In this study, the ingestion of soils contaminated with metals was considered as the main pathway for risk assessment. The health hazard to human adults and children from metals was derived after hazard quotient (HQ) estimation. HQ is the measure of the magnitude of exposure potential or a quantifiable potential for developing health effects after an averaged exposure period. The potential for non-cancer effects was evaluated by comparing the estimated average daily dose ($\text{mgkg}^{-1}\text{d}^{-1}$) of the metal with the reference dose (RfD) ($\text{mgkg}^{-1}\text{d}^{-1}$). The total health hazard was derived simply by summing the HQ values of all the metals. This total HQ is referred to as the Hazard index (HI). Recommended equations used for estimating ADD, HQ, and HI were from EPA, (1989):

ADD

$$(\text{mgkg}^{-1}\text{day}^{-1}) = (C_s \times IR \times F \times EF \times ED) / (BW \times AT) \quad 5.0$$

$$\text{Hazard Quotient (HQ)} = \text{LADD} / \text{RfD} \quad 6.0$$

Hazard Index (HI) =

$$\text{HQ}_{\text{Cd}} + \text{HQ}_{\text{Cr}} + \text{HQ}_{\text{Cu}} + \text{HQ}_{\text{Ni}} + \text{HQ}_{\text{Pb}} \quad 7.0$$

Where C_s is the metal's concentration in soil (mg kg^{-1}), R is the soil ingestion rate (adult, 100 mg day^{-1} ; children, 200 mg day^{-1}), F is the unit conversion factor, EF is exposure frequency (365 days/year), ED is the lifetime exposure duration (children, 12 years; adults, 70 years), BW is the body weight (children, 27 kg; adults, 70 kg), and AT is the averaging time ($EF \times ED$ days). RfD is the

reference dose for individual metal ($\text{mg kg}^{-1} \text{ day}^{-1}$) (Kumar *et al.*, 2014).

RESULTS AND DISCUSSION

Inorganic element Concentrations: Table 2.0 summarizes the minimum, maximum, mean, and standard deviation of several metals (Cd, Cr, Cu, Ni, and Pb) in Twenty-two (22) samples collected at a textile factory, Funtua in Katsina State. A close look at Table 2.0 shows that the variability in the range of all the metal distributions as compared with their means respectively is an indication of pollution of the sampling points with that metal ion. The decreasing trend of averages of metal levels was as follows: $\text{Cu} > \text{Cr} > \text{Pb} > \text{Ni} > \text{Cd}$ with Cd concentration been the least.

Distribution and Enrichment of Metals: The Enrichment Factor (EF) of Cr, Cu, Cd, Pb, and Ni concentrations in the particulate dust as shown in Table 3.0 are 0.37, 1.52, 0.30, 0.12 and 0.02; Meanwhile, Enrichment Factors (EFs) of Cr, Cd, Ni, and Pb indicates that the particulate dust is uncontaminated by these inorganic elements. Similarly, Cu with EFs 1.52 showed a case of slight contamination of the particulate dust by these metals. Since the particulate dust samples were taken from the textile factory (especially engineering department) with the considerable high volume of works, heavy traffic rates, and motor vehicles burning leaded gasoline and spent engine oil from generator sets and car engine could be considered as the main sources of these Cu metal in the factory's particulate dust. Relatively higher values of Cd, Cu, and Cr EF in the analyzed soil samples is usually a reflection of anthropogenic effects which might be as a result of burning fossil fuel, wear and tear of tyres and other automobile workshop activities emanating from the said locations (Kabata-Pendias & Pendias, 1984); which was encountered in this studies, especially at the engineering department.

Furthermore, the Contamination Factors (CFS) and Pollution Load index (PLI) for the five metals across the study sites and the control site are presented in Tables 4.0; the trend is such that the highest CFS were observed in Cr (E_1, E_2, S_2, O_2, C , and G) and the least in Ni (O_1, S_1, D, W_2 ,

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and C). In general, the order of CFs was $Cr > Cu > Pb > Cd > Ni$. For variation within each department the CF values generally decrease across the particulate dust profile, the following departments; E₁, E₂, S₂, O₂, C, and G (Cd) CF > 6 is highly contaminated, whereas all other departments with CF < 1 are of low contamination based on the grading system of Harikumar *et al.*, (2009). The PLI which represents the number of times by which the metal content in the soil exceeds the average natural background concentration and gives a summative indication of the overall level of inorganic element toxicity in a particular sample was also presented. Results showed that highest PLI was recorded at E₁ department which indicates PLI > 1 and the lowest PLI at O₁, S₁, S₂, W₂, D, and C; which indicate PLI < 1. Most study sites had their PLI > 1 and control site recording PLI < 1. Based on the PLI grade standard by Harikumar *et al.*, (2009) results showed that most of the study sites were polluted and the control site was not polluted.

Thereafter, the I-geo values for the five metals across the study sites and control site were calculated; Cu has the highest value at E₁, whereas Cd has the lowest value at S₁ & O₁. In general, the decreasing order of I-geo was $Cu > Cr > Ni > Pb > Cd$. The I-geo grade standard develops by (Muller, 1969) which shows the pollution status of the metals in the environment showed that most studied sites were polluted with Cu, Cr, Ni, and Cd, except for W₂ (Cr) was not polluted.

Human Health Risk Estimates: Humans are generally exposed to inorganic elements present in soil via ingestion/oral, inhalation and contact (dermal) pathways. Exposure may occur singly or by a combination of pathways. Therefore, it is important to study these exposure pathways to understand the extent of risks these toxic metals pose to human health. The average daily dose (ADD) of Inorganic elements in the studied soil for the different age groups (adult and children) was evaluated under different exposure pathways (oral, inhalation, and dermal). Health risk assessment was based on the assumption that humans exposed to metals through soils dust may suffer harmful effects. We assume that human

adults and children are exposed to metals through ingested soil dust all the days in a year during the life span. The risk was assessed by estimating the incremental lifetime average daily dose (LADD), hazard quotient (HQ), and hazard index (HI) for the selected metals (Ma & Singhirunnosorn, 2012).

LADD is the amount of pollutant intake per kg of body weight per day that is sufficient to cause adverse health effects when absorbed into the body over a long period. If the HQ for a chemical is equal to or less than 1, it is assumed that there is no appreciable risk that health effects will occur. A hazard index (HQs) < 1 suggests that risks are not expected from any chemical, alone, or in combination with others (Ma & Singhirunnosorn, 2012).

Table 6.0 lists the average daily dose (ADD) and hazard index (HI) of metal exposures selected by adults and children due to soil contact. Many studies show that children are more exposed to toxic metals (Liang *et al.*, 2017; Hu *et al.*, 2017).

The LADD of Cr, Cu, Ni, Pb and Cd through soil dust ingestion for human adults at the factory ranged between $4.29E-06 - 0.2490 \text{ mg kg}^{-1} \text{ d}^{-1}$ (mean, $1.25E-01 \text{ mg kg}^{-1} \text{ d}^{-1}$), $0.0003 - 0.5095 \text{ mg kg}^{-1} \text{ d}^{-1}$ (mean, $2.55E-01 \text{ mg kg}^{-1} \text{ d}^{-1}$), $0.0001 - 0.0049 \text{ mg kg}^{-1} \text{ d}^{-1}$ (mean, $2.59E-03 \text{ mg kg}^{-1} \text{ d}^{-1}$), $0.0002 - 0.0073 \text{ mg kg}^{-1} \text{ d}^{-1}$ (mean, $3.84E-03 \text{ mg kg}^{-1} \text{ d}^{-1}$), and $0.0002 - 0.00727 \text{ mg kg}^{-1} \text{ d}^{-1}$ (mean, $3.85E-03 \text{ mg kg}^{-1} \text{ d}^{-1}$) respectively. However, average LADD for children at this depth was $6.46E-01 \text{ mg kg}^{-1} \text{ d}^{-1}$ (range, $2.22E-05 - 1.29 \text{ mg kg}^{-1} \text{ d}^{-1}$), $1.32E+00 \text{ mg kg}^{-1} \text{ d}^{-1}$ (range, $0.0013 - 2.64 \text{ mg kg}^{-1} \text{ d}^{-1}$), $1.34E-02 \text{ mg kg}^{-1} \text{ d}^{-1}$ (range, $0.0007 - 0.03 \text{ mg kg}^{-1} \text{ d}^{-1}$), $1.99E-02 \text{ mg kg}^{-1} \text{ d}^{-1}$ (range, $0.0010 - 0.04 \text{ mg kg}^{-1} \text{ d}^{-1}$), and $2.00E-02 \text{ mg kg}^{-1} \text{ d}^{-1}$ (range, $0.0011 - 0.04 \text{ mg kg}^{-1} \text{ d}^{-1}$) respectively for Cr, Cu, Ni, Pb and Cd from soil dust ingestion. The LADDs of total metals for adults and children ranged from $8.04E-04$ to $7.78E-01 \text{ mg kg}^{-1} \text{ d}^{-1}$ with mean value of $3.90E-01 \text{ mg kg}^{-1} \text{ d}^{-1}$, and from $4.17E-03$ to $4.03E+00 \text{ mg kg}^{-1} \text{ d}^{-1}$ with mean value of $2.02E+00 \text{ mg kg}^{-1} \text{ d}^{-1}$, respectively for children at this depth (Ma & Singhirunnosorn, 2012).

These average daily intakes (ADIs)

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were mostly above the recommended reference dose (RfD) values for Cr (Cr salt, $1.5 \text{ mg kg}^{-1} \text{ d}^{-1}$), Cu ($0.04 \text{ mg kg}^{-1} \text{ d}^{-1}$), Ni ($0.02 \text{ mg kg}^{-1} \text{ d}^{-1}$), Pb ($0.00014 \text{ mg kg}^{-1} \text{ d}^{-1}$), and Cd ($0.001 \text{ mg kg}^{-1} \text{ d}^{-1}$), except for Cr and Ni which were below the RfD (Kumar *et al.*, 2014).

The total health hazard index (HI) for adults and children ranged between $1.66\text{E}+00$ to $1.17\text{E}+02$ with mean value of $6.02\text{E}+01$ and between $8.59\text{E}+00$ to $6.07\text{E}+02$ with mean value of $3.12\text{E}+02$, respectively. These estimated higher values of HI were all above the acceptable safe risk level ($\text{HI} \geq 1$), indicating high risk to human adults and children from the studied metals through soil ingestion (Ma & Singhirunnosom, 2012) (Table 6.0). Children exhibit pica in their attempts to explore the world around them and so are constantly exposed to metals in soil (Ngozi *et al.*, 2020; Wirnkor *et al.*, 2019). Pica children are thus likely to have elevated body metals than their non-pica counterparts, which is not desirable as they are easily affected by inorganic elements toxicity due to their susceptibility related body weight and developing body systems. For example, since the beginning of 2010, more than 400 children died of inorganic elements poisoning in Zamfara State in northern Nigeria, and the survivors had to deal with problems such as low IQ stunting and organ hypoplasia etc (Verla *et al.*, 2019; Bartrem *et al.*, 2014).

Correlation analysis with Pearson's correlation coefficients was used to describe the relations between the sources of the inorganic metals in the soil from the sampling locations at a 5% significance level. Pearson's correlation coefficients for the studied metal ion are presented in (Table 7 & Figure 2.0). The metals generally showed strong correlations across sampling depths. However, strong significance and positive correlations were observed for Cd/Cr/Cu/Ni (0.895, 0.897 & 0.778 respectively), Cr/Cu/Ni (0.999 & 0.823 respectively) and Cu/Ni (0.813). Positive correlations between these inorganic metals are possible indications of their common pollution sources.

The principal component analysis (PCA) was computed to determine the precise pollution source(s) of metals in the soil. The

principal components were extracted based on Eigen value > 1 , and the results for the total variations are presented in Table 8.0. The variances for PC1 group was 0.807 (Table 8.0). As shown in figure 3 it identifies the number of components that explain most of the variation in the data, it does that by placing Eigenvalues in order from largest to smallest as indicated in figure 3 where there is an "elbow" between components 2 and 3. It, therefore, implies that only one variable can be used for the rest of the analysis. This implies, metals in each group are correlated with each other and from a precise/common source. The mixed sources may include artisanal activities, metal processing works, surface run-off, vehicle emissions in the urban area and agricultural activities around the studied area. Similar studies have shown that these sources play a significant role in introducing metals in the environments (Ibe *et al.*, 2017; Enyoh & Isiuku, 2020).

CONCLUSIONS AND RECOMMENDATION

The contamination indices indicated a significant degree of contamination typical of anthropogenic origins and furthermore confirmed the effect of textile industry activities within these areas. Overall, the results of the analyses revealed that particulate dust samples were polluted by Cd, Ni, Cu and Pb; which was also buttressed by results obtained from EF, CF, PLI and Igeo analyses. The distribution and concentrations of inorganic elements in all the sites shows that textile activities, generator set and machine parts, wear and tear originated sources could be the main source of this pollution. These results imply that pollution of the environment by textile factory dust has human health and ecological risks. Overall, results suggested that surrounding sites of the textile factory are not polluted, but pose potential health risks to children than adults as there are some residential quarters within the factory. Therefore, more attention should be paid to the potential health risks of inorganic elements to residents (particularly children) in the vicinity of the studied sites. People should be encouraged to work hard to prevent the transfer of inorganic elements in the environment around textiles, and

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soil remediation in the area should be carried out immediately to further reduce the concentration of inorganic elements.

Abbreviations

AAS: Atomic absorption spectrometer;
LADD: Lifetime average daily dose; HQ:
Hazard quotient; and HI: hazard index.

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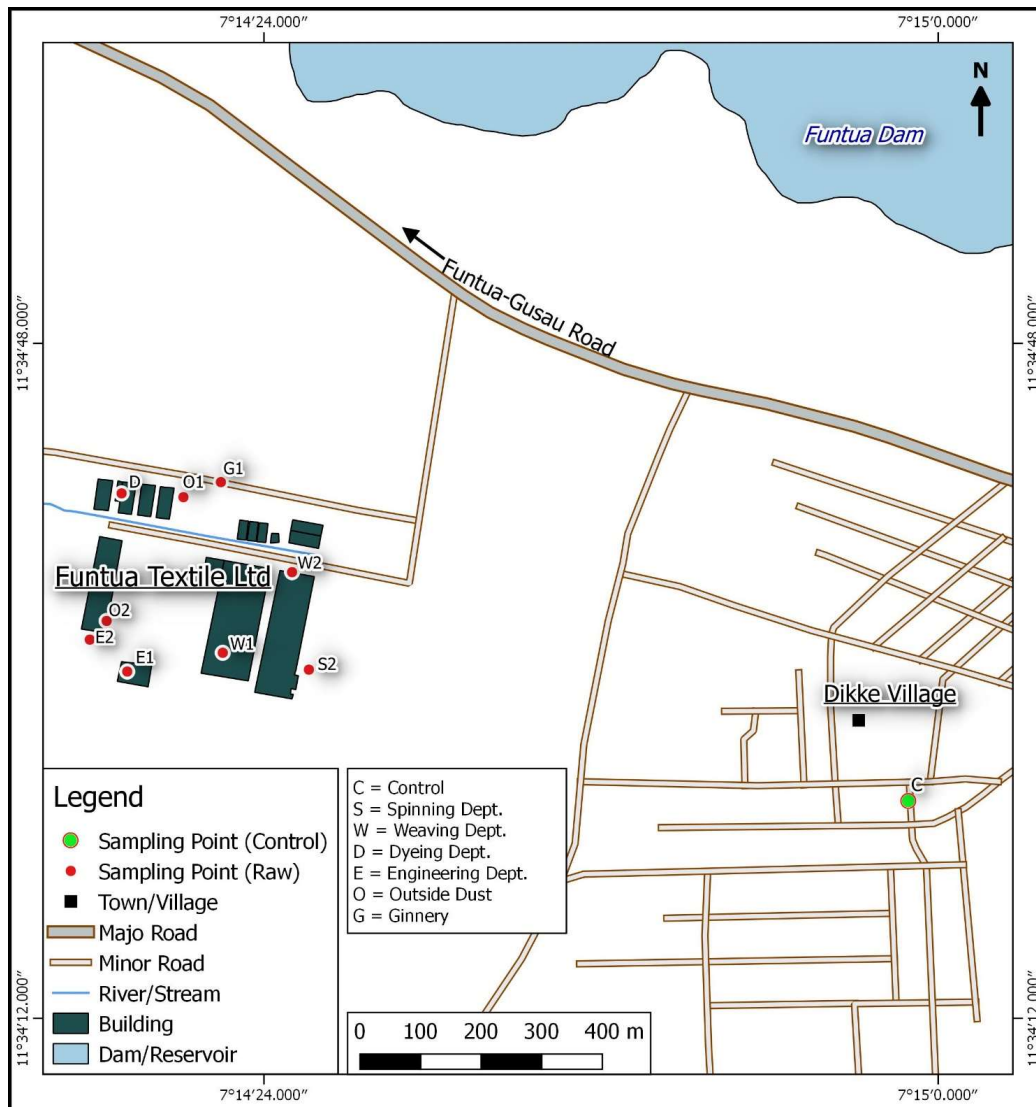


Figure 1.0 : Map of Funtua Textile Ltd. Showing Sampling Point
 Source: Modified from the Administrative Map of Funtua L.G.A.

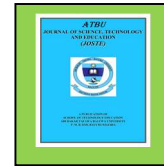


Table 2.0: Total metal concentrations (mg/kg) in the Study Area Particulates Dust

Sites	Cd	Cr	Cu	Ni	Pb
G	0.03	0.59	0.95	0.42	0.42
E ₁	0.15	174.30	356.68	3.44	3.97
E ₂	0.05	8.68	29.19	1.00	5.09
O ₁	0.02	0.05	0.18	0.09	0.41
O ₂	0.05	1.26	1.70	1.00	1.03
S ₁	0.02	0.12	0.58	0.25	0.38
S ₂	0.04	4.12	0.27	2.28	0.14
D	0.04	0.19	1.45	0.37	0.59
W ₁	0.03	0.20	1.55	0.41	0.73
W ₂	0.08	0.003	0.55	0.35	0.24
C	0.03	0.84	0.30	0.22	0.43
Sum	1.08	380.70	786.80	19.66	26.86
Mean	0.09	33.10	68.42	1.71	2.34
Std.Dev	0.04	49.92	102.24	1.03	1.63
Min	0.02	0.003	0.18	0.09	0.14
Max	0.15	174.30	356.68	3.44	5.09
Standard (WHO)	3.00	0.03	140.00	75.00	300.00

Source: Experimentation

Table 3.0: Average, Background, Enrichment Factor and Grade of Pollution intensity of Inorganic elements in Dust Samples

Metals	Average Shale Value	Soil Mean Conc.(mg/kg)	Enrichment Factor	Degree of Contamination
Cd	0.3	0.09	0.30	uncontaminated
Cr	90	33.1	0.37	uncontaminated
Cu	45	68.42	1.52	slightly contaminated
Ni	75	1.71	0.02	uncontaminated
Pb	20	2.34	0.12	uncontaminated

Source: Experimentation

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Table 4.0: Contamination Factor and Pollution Load index of Studied Location

Sites	Cd(CF)	Cr(CF)	Cu(CF)	Ni(CF)	Pb(CF)	PLI
G	0.01	19.67	0.01	0.01	0.02	0.05
E1	0.05	5810.00	2.55	0.05	0.20	1.49
E2	0.02	289.33	0.21	0.01	0.25	0.31
O1	0.01	1.67	0.00	0.00	0.02	0.00
O2	0.01	42.00	0.01	0.01	0.05	0.07
S1	0.01	4.00	0.00	0.00	0.02	0.00
S2	0.01	137.33	0.00	0.03	0.01	0.00
D	0.01	6.33	0.01	0.00	0.03	0.00
W1	0.01	6.67	0.01	0.01	0.04	0.05
W2	0.03	0.00	0.00	0.00	0.01	0.00
C	0.01	28.00	0.00	0.00	0.02	0.00

Source: Experimentation

Table 5.0: Geo-accumulation index of Studied Textile Factory Particulate Dust

Sites	Cd	Cr	Cu	Ni	Pb
G	-7.38	5.15	4.83	4.39	2.49
E ₁	-5.06	13.35	13.39	7.43	5.73
E ₂	-6.64	9.02	9.77	5.64	6.08
O ₁	-7.97	1.58	2.43	2.17	2.45
O ₂	-6.64	6.24	5.67	5.64	3.78
S ₁	-7.97	2.85	4.12	3.64	2.34
S ₂	-6.97	7.95	3.02	6.83	0.90
D	-6.97	3.51	5.44	4.21	2.98
W ₁	-7.38	3.58	5.54	4.36	3.28
W ₂	-5.97	0.00	4.04	4.13	1.68
C	-7.38	5.66	3.17	3.46	2.52

Source: Experimentation

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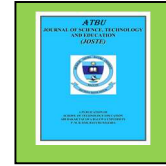


TABLE 6.0: Lifetime Average Daily Dose (LADD) (mg/kg/d) of Metals and Health Hazard through Soils ingestion for Adults and Children at the Sites

Human adults			Children			
Metals	Minimum	Maximum	Average	Minimum	Maximum	Average
Cr						
ADD	4.29E-06	0.2490	1.25E-01	2.22E-05	1.29	6.46E-01
HQ	2.86E-06	0.1660	8.30E-02	1.48E-05	0.86	4.30E-01
Cu						
ADD	0.0003	0.5095	2.55E-01	0.0013	2.64	1.32E+00
HQ	0.0064	12.7386	6.38E+00	0.0333	66.05	3.31E+01
Ni						
ADD	0.0001	0.0049	2.59E-03	0.0007	0.03	1.34E-02
HQ	0.0064	0.2457	1.29E-01	0.0333	1.27	6.70E-01
Pb						
ADD	0.0002	0.0073	3.84E-03	0.0010	0.04	1.99E-02
HQ	1.4286	51.9388	2.74E+01	7.4074	269.31	1.42E+02
Cd						
ADD	0.0002	0.00727143	3.85E-03	0.0011	0.04	2.00E-02
HQ	0.2143	51.9387755	2.62E+01	1.1111	269.31	1.36E+02
Total metals						
ADD	8.04E-04	7.78E-01	3.90E-01	4.17E-03	4.03E+00	2.02E+00
HI	1.66E+00	1.17E+02	6.02E+01	8.59E+00	6.07E+02	3.12E+02

Table 7.0: Pearson Correlation and p-value of Inorganic Elements across Sampling Sites

	Cd	Cr	Cu	Ni
Cr	0.895 0.000			
Cu	0.897 0.000	0.999 0.000		
Ni	0.778 0.005	0.823 0.002	0.813 0.002	
Pb	0.564 0.071	0.581 0.061	0.610 0.046	0.519 0.101

*Values in bold are p values

Table 8.0: Principal Component Analysis: Cd, Cr, Cu, Ni, Pb Eigen analysis of the Correlation Matrix

Eigenvalue	4.034	0.575	0.254	0.137	0.000
%Variation	0.807	0.115	0.051	0.027	0.000
Cumulative	0.807	0.922	0.973	1.000	1.000
Variable	PC1	PC2	PC3	PC4	PC5
Cd	0.464	-0.169	0.326	-0.806	-0.006
Cr	0.483	-0.185	0.243	0.421	-0.705
Cu	0.485	-0.134	0.274	0.412	0.708
Ni	0.440	-0.216	-0.870	-0.053	0.026
Pb	0.351	0.934	-0.055	-0.016	-0.033

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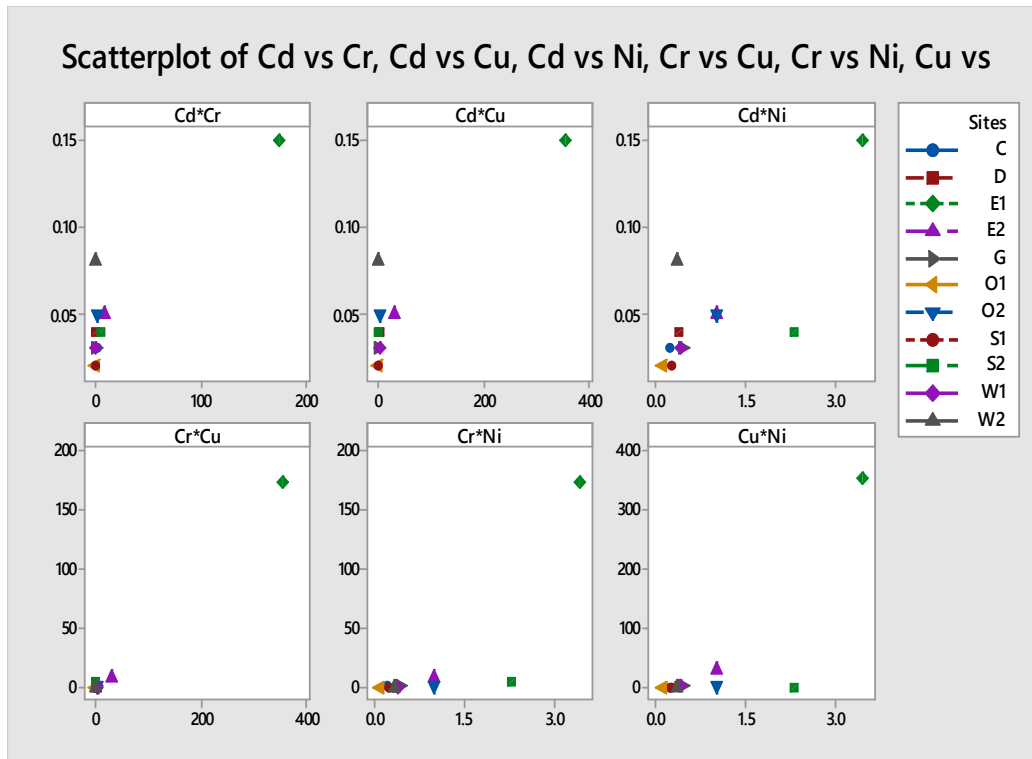


Figure 2.0: Scatter plot of Pearson Correlation and p-value of Inorganic Elements across Sampling Sites

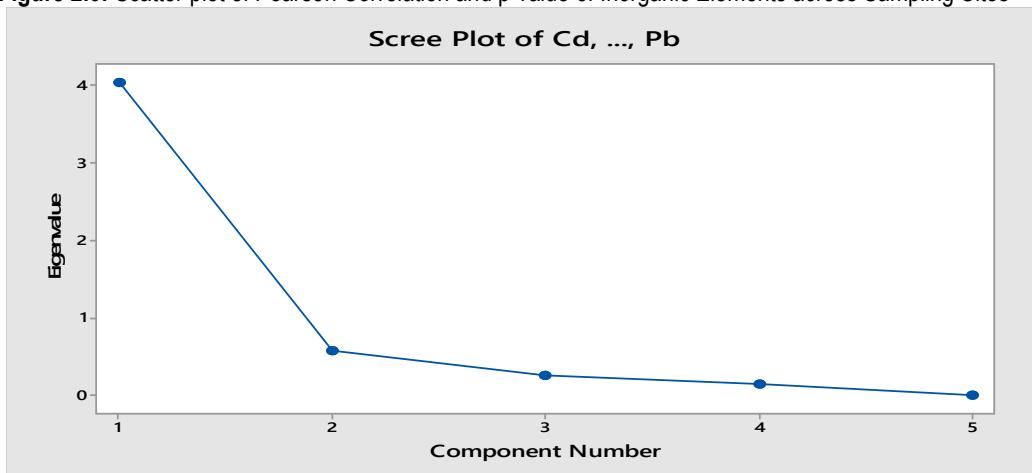


Figure 3.0: Scree plot of Inorganic elements

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