International Journal of Chemistry, Mathematics and Physics (IJCMP)
[Vol-8, Issue-2, Apr-Mar, 2024]
https://dx.doi.org/10.22161/ijcmp.8.2.2
ISSN: 2456-866X

Physicochemical Analysis, Heavy Metals Contaminants and Health Risks Assessment in Harmattan Dust Within the Federal Polytechnic Kaura Namoda Zamfara State Nigeria

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Received: 25 Feb 2024; Received in revised form: 15 Apr 2024; Accepted: 25 Apr 2023; Available online: 03 May 2024

***Abstract*— *The increasing exposure of humans to Harmattan dust is becoming a growing concern, especially in Northern Nigeria. This study aimed to identify the heavy metal contaminants, assess the associated health risks, and evaluate the physicochemical properties of the Harmattan dust. During the sample collection period, which took place from December 2023 to February 2024, Harmattan dust samples were collected from 20 different locations, 4.5 cm above the ground, using cleaned Petri dishes. The composite samples from each month were analyzed using standard analytical techniques and AAS to examine the physicochemical properties and heavy metal contamination, respectively. The results of the physicochemical examination, which included pH, organic matter, organic carbon, electrical conductivity, and moisture content, showed a significant difference ($p \geq 0.05$), using statistical tools. However, there was no significant difference in the concentration of heavy metals such as pb, Cd, Ni, Zn, Cu, and Cr among the samples collected in December, January, and February. The concentration of pb and Ni was high in December and January, at 78 mg/kg and 73 mg/kg, respectively, while Ni was at 108 mg/kg and 80 mg/kg for December and January, respectively. The health risk assessment, using the model developed by EPA for children and adults, showed that Cu, Ni, and pb had a hazard index of 1.305, 1.098, and 1.205, and 1.050, respectively. Therefore, Cu and Ni pose health risks for children, while pb poses health risks for both children and adults. Protective measures, such as face masks, during the Harmattan period may help protect people from direct exposure to these heavy metals.*

***Keywords*— Harmattan dust, Physicochemical, Heavy metal, Kaura Namoda**

I. INTRODUCTION

Heavy metals' pollution of the natural environment is a global problem due to their toxic effects on living organisms. While some metals are essential for human development, higher concentrations can pose a toxicological risk (Yiran *et al*., 2023). Harmattan dust sources may include crustal minerals, construction activities, mining activities, and agricultural activities carried by wind-blown dust from one location to another (Jimoh, 2012). Inorganic pollutants, such as heavy metals, are of major concern because of their toxic and potential carcinogenic effects (Anne et al., 2009). However, heavy metals in atmospheric dust can generate airborne particles that may affect air quality, cause harm to humans, and make the environment more toxic (Omoyemi *et al*., 2021).

Harmattan dust is felt in the December, January, and February months of the year all over Nigeria and the origin has been traced to the Faya Largeau area of the Chad basin (Jimoh, 2012; Nilufer and Huseyin 2013).

The Harmattan season is different from other seasons due to its strong dryness and humid tropical air. The season constitutes environmental pollution because the dust-laden wind blowing from the Sahara carries particulate matter, toxic metals, and microorganisms from one place to another (Ichu and Emeagi 2019; Francis *et al.*, 2023). Humans' exposure to these dusts by inhalation causes their bioaccumulation in the body and results in health problems such as respiratory disease, cancer, and asthma (Yiran *et al.*, 2023).

Fig.1 December and January view of Harmattan period

According to the EPA, "Fine particles can aggravate heart and lung diseases which have been associated with premature death and a variety of serious health problems including heart attacks, chronic bronchitis and asthma attacks (Ajayi, *et al.*, 2022). The mechanisms connecting fetal dust exposure to infant and child mortality can be described as biological or economic. Pregnant mothers who inhale dust are at risk of having particulate matter enter their lungs, and then to other organs (Mfonobong *et al.*, 2023). Dust inhaled during the Harmattan in particular can carry harmful elemental particles, including heavy metals and trace metals, and can lodge deep in the lungs Adekola, & Dosumu, 2001). Several studies have suggested that seasonal dust and dryness might aggravate asthma, carry disease vectors, dry the skin, irritate the throat and eyes, produce catarrh, lead to coughing and bronchitis, and even give rise to sinusitis, pneumonia, and respiratory infections (Ichu and Emeagi, 2019).

Many studies have been performed on heavy metal contamination of soil around the world at the same time; many studies have focused on the concentration, distribution, and source of heavy metals in roadside dust (Nilufer and Huseyin, 2013, Jimoh, 2012, Anne *et al.*, 2009, Anegbe *et al.*, 2018, Francis et al., 2023). However, there are few studies about heavy metals and physicochemical analysis with the dust in the Northern part of Nigeria that has the highest peak and long period of Harmattan and also, Zamfara state where illegal mining covers almost all the local government. The determination of the concentration of the selected heavy metals and physicochemical properties will provide reliable information to help design adequate precautions during the Harmattan period.

II. MATERIALS AND METHODOLOGY

2.1 SAMPLES COLLECTION

Dust samples were collected from December 2023 to February 2024. A cleaned plastic or polythene sheet with a flat surface was placed 5.8 cm above the ground to trap the suspended dust in the atmosphere. The campus was divided into strata, and each sample was treated as a composite for each month: December, January, and February

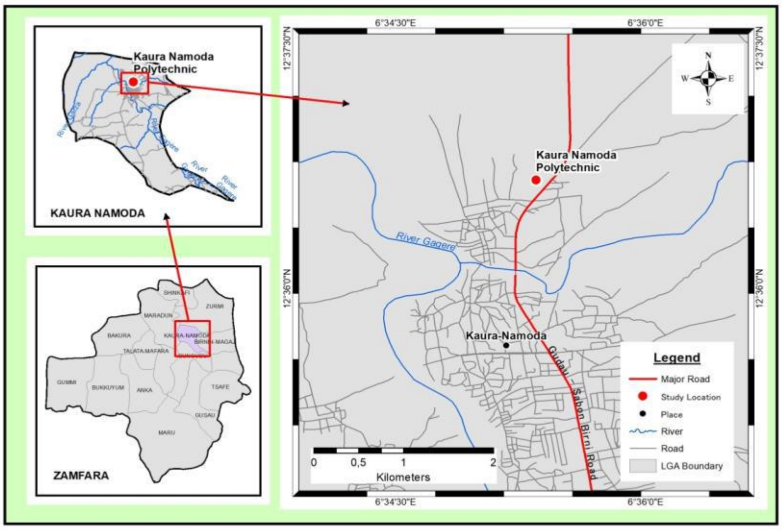

Fig.2 map of sample area

2.2 SAMPLE PREPARATION AND EXTRACTION

The dust samples were sieved to remove the particulates and fine dust samples were extracted using

acid digestion. 5 ml of concentrated HNO3 and 10 ml Hcl acid with 10 ml of perchloric acid in Teflon beakers. The solution was shaken for 5 hours. The residues largely consist of mineral compounds where metals are firmly bonded within the crystal structure. Analysis was carried out using AAS the instrument was programmed and it carried out metal detection by displaying three absorbance readings and what was reported was the average. Blanks were also used for correction of background and other sources of error. Apart from calibration before use, quality checks were also performed on the instrument by checking the absorbance after every ten sample runs.

2.3 DETERMINATION OF PHYSICOCHEMICAL PARAMETERS IN HARMATTAN DUST

pH: The pH of the dust samples was determined using a pH meter, 10g of each dust sample was weighed into three different cleaned beakers, and 50 ml of distilled water was added and stirred for five minutes. The solution was allowed to stand for 30 minutes. The electrode was inserted and the reading was then in triplicate and find the average.

Electrical conductivity (EC): the electrical conductivity was determined from each dust sample.20g of the dust samples was weighed and placed in a cleaned beaker and distilled was added to form a paste. The beaker was then covered with a petri dish. 50ml distilled water was added and shaken for 1 hour. 40 ml of the diluted extract was placed into a 100 ml beaker the conductivity meter was inserted and the electrical conductivity of the soil was recorded in µcm.

Oragnic carbon content, cation exchange capacity and moisture content using the analytical method describe by Anegbe, & Okuo, (2013) as shown in equation 1- 3

%organic carbon = $\frac{(MeK2Cr2O7 - Me\ Fe\ SO4)\ x\ 1.331\ X\ 100\ X\ F}{Mass\ (s)\ of\ soil\ level}$ ----------------1

CEC (C mol kg1) = $\frac{(Titre - Blank)\ x\ M\ x\ 100}{Weight\ of\ sample}$ ----------------2

Moisture content = $\frac{Loss\ in\ weight\ x\ 100}{Initial\ weight}$------------------------3

2.4 HEALTH RISK ASSESSMENT

Exposure dose

The Environmental Protection Agency (EPA) was used to calculate the dust exposure to both adults and children. The average daily dose ADD injection in mg/kg/day of a pollutant and inhalation as the means of exposure pathway was calculated using the equation below

ADD ingestion = $\frac{C \times Rinj \times CF \times EF \times ED}{BW \times AT}$ …………………….. a

LADDing = $\frac{Cs \times EF \times CF}{AT} \times \frac{IgR \times ED}{BW}\ CHIDREN + \frac{IgR \times ED}{BW}\ ADULT$……………………………b

Where ADD inhalation is the daily exposure amount of the heavy pollutant through injection in (mg/kg/day), ADD dermal is the daily exposure of the heavy metal pollutant amount through direct contact with the body skin in (mg/kg/day).

Where Cs is a concentration of a constituent in dust mg/kg and the rate of ingestion children 200 mg dust /day, adults 100mg dust /day, EF is the exposure frequency 350 days, ED is the duration of exposure children (6 years), adult (42 years), CF is the conversion factor 0.000001kg/mg, BW is the body weight children (15kg) and adult (70 kg), HQ was calculated using equation (c), and HI was calculated using equation (d). if HQ, with value > 1 indicating potential likely advance health effect. In contrast, value < 1 suggest no significance possible adverse health effect.

HQ = $\frac{ADD(ing)}{rfD}$ ……………… c

HI =∑HQ……………………………d

III. RESULTS AND DISCUSSION

Table I Result physicochemical analysis of Harmattan dust

Samples	pH	EC µs/cm	CEC Cmol/kg	OC (%)	OM (%)	SAND (%)	SILT (%)	CLAY (%)
December	4.88±0.09	482.2±0.50	5.5±0.09	0.35±0.41	1.82±0.05	80.2±0.09	18.9±0.09	1.81±0.05
January	4.60±0.04	365.7±0.09	5.07±0.10	0.18±0.09	1.83±0.02	80.3±0.09	18.2±0.07	1.76±0.01
February	5.40±0.30	457.4±0.09	4.80±0.09	0.08±0.07	1.25±0.05	90.6±0.07	8.2±0.02	10.9±0.04

The physicochemical parameters of the Harmattan dust samples from December 2023 to February 2024 are shown in Table 1 above. The pH is the most accepted parameter that controls the influence of micronutrients and the presence of heavy metals in the dust. The pH values of the dust samples range from 4.8, 4.6, and 5.4 for December, January, and February respectively. The result shows that the dust content is acidic and the acidic is high for December and January. The acidic nature of the dust sample may be responsible for the control of mobility and toxicity of the heavy metals as reported by Anegbe *et al.*, 2018. Most metals tend to be less mobile with high pH and form insoluble complexes (Anegbe & Okuo, 2013)

Electrical conductivity (EC) is the parameter that measures the salinity of the dust sample (Okuo, and Anegbe, 2016). The electrical conductivity of the Harmattan dust samples tends to be high in December 48.2µcm and lower in January. Harmattan dust density tends to be higher in January than in February, this may be the reason for lower electrical conductivity. The results show that the movements of charges are more in December dust samples and January dust samples

Organic matter generally tended to be major adsorbent of the metals that form chelate and immobility. The percentage of organic matter in these present researches is lower in February 1.25% than in December and February which have 1.82% and 1.82% respectively. The present results are also similar to the results obtained in the work (Okuo, and Anegbe, 2016).

The cation exchange capacity of the dust samples in this present study is 5.5 Cmol/kg, 5.07 Cmol/kg, and 4.80 Cmol/kg for December, January, and February, respectively. The results show that the months of December and January have higher CECs than February. This may be attributed to the higher content of the sand texture of the December and January samples. it was reported that a higher concentration of cation exchange capacity (CEC) makes the dust or the soil less leaching. These trends were also observed in the work of Anegbe *et al.*, 2014, more also in a similar research work conducted by (Okuo, and Anegbe, 2016).

The texture of the dust particle plays a vital role in the physical properties of the dust in this present research. The texture of the dust samples obtained in December, January, and February indicate that December samples and January samples have a higher percentage of 80% and 81% sand content than the samples of the February Harmattan period. This indicates that the higher density of haze and air during the Harmattan period is more of sand than other properties of soil such as silt and clay. This result of the present study is similar to the work of Anadge, *et al.*, 2014; their results also indicate the higher content of sand in the indoor dust samples.

The statistical tools (ANOVA) show that there is no significant difference among the physicochemical parameters of Harmattan dust samples obtained in December, January, and February in Kaura Namoda, Zamfara state.

Table 2 Concentrations of Heavy Metals in mg/kg^{-1}

Samples	Ni	Cd	Cu	Cr	pb	Zn
December	108 ±0.09	60±0.05	37±0.04	67±0.08	73±0.04	45±0.01
January	80±0.02	71±0.09	46±0.01	60±0.09	78±0.15	55±0.09
February	70±0.01	41±0.05	28±0.04	52±0.05	54±0.05	67±0.08

The heavy metal concentrations in the Harmattan dust are shown in Table 2 above. Using ANOVA to analyze the results shows a significant difference in the concentration of heavy metals obtained from the Harmattan dust samples.

The selected heavy metals studied in this present research are (Ni, Cd, Cu, Cr, pH, and Zn) the total concentrations are high in December and January compared to February Harmattan dust. This may be a result of the high intensity observed during December to January. Harmattan dust tends to be reduced drastically in the area of this present study.

The presence of Nickel (Ni) in the Harmattan dust sample was 108mg/kg, 80mg/kg, and 70mg/kg for December, January, and February, respectively. These can be attributed to the various human activities and indiscriminate use of pesticides by the farms. Illegal mining may also contribute to the presence of Ni in the Harmattan dust, because, the activities of illegal mining in Zamfara state are alarming. In the present study area of Kaura Namoda, there are no industrial activities, farming which is the main livelihood may involve the use of indiscriminate uses of pesticides which is another source of nickel. The concentration of Nickel in this present study is higher than the finding of Omoyemi *et al*., 2021

The long-term effect of direct exposure to arsenic by inhalation and dermal contact may result in skin problems and cognitive effects. Exposure to arsenic has also been associated with cardiovascular disease

Cadmium (Cd) is long referred to non-essential trace element that is found in our environment. The presence of cadmium in this present research shows the level of pollutant in the Harmattan dust samples from Kaura Namoda, the concentration ranging from 60mg/kg, 71mg/kg, and 41mg/kg for December, January, and February respectively. The presence of these heavy metals in the Harmattan samples can be attributed to anthropogenic, mining, and smelting sources. It was reported that illegal mining takes place in almost six local government areas in Zamfara state. Harmattan dust can move long distances from one place to another as reported by (Jimoh, 2012). Therefore the higher concentration of Cd in December and January may be a result of the high intensity of the Harmattan air that is accompanied by some pollutants such as heavy metals. It was reported by Nilufer & Huseyin, 2013, that Cd was detected in the street dust samples from Sakarya. Philip *et al.*, 2017, reported the presence of cadmium in the street dust of Yola, Adamawa State.

Copper (Cu): the concentration of copper detected in this present research is 60 mg/kg, 71mg/kg, and 41mg/kg for December, January, and February respectively. Copper was in the work of Ogunwal *et al,* 2021 and Ishaq *et al.*, 2015 in the soil. But this is lower than the concentrations of the present research; it may be a result of different locations and the level of human activities. It was reported that one of the common sources of copper in the dust is from the use of fertilizer, animal waste dump, and indiscriminate use of pesticides. Despite the essential function of copper in human health, direct exposure to copper through dust can result in certain illnesses such as kidney, and liver damage.

Chromium (Cr) is found in this present study of Harmattan dust samples in 67mg/kg, 60mg/kg, and 52 mg/kg for December, January, and February respectively. The concentration is lower than the finding of Falaye and Awade 2018 whose concentration is 270 mg/kg. The variation in the result can be attributed to the fact that his sample area is industrialization while Zamfara is not, the main livelihood in Zamfara is farming. The source of chromium may be attributed to human activities such as the application of fertilizer and pesticides during the farming period. However, farming is the main source of livelihood in the present study area. Direct exposure to chromium through inhalation of dust particles can cause a high risk of long nasal and sinus cancer. It can also result in dermatitis problems.

Lead is also reported in this present study in the Harmattan dust samples, the concentration of lead is 73mg/kg, 78mg/kg, and 54mg/kg for December, January, and February respectively. The source of this lead found in the Harmattan dust samples in this present study can be attributed to the control and regulated mining. The outbreak of lead was once reported in Zamfara state. This may be transported by Harmattan air from one location to another. The result obtained in the study shows that the lead is higher in December and January than in February. Direct exposure to lead by children and adults can cause various illnesses such as nervous system, depression in children, and breathing defects. Falaye and Aweda, 2018 reported 260 mg/kg lead concentration of lead in Harmattan dust samples. The result is higher than the present research due to the different locations and the rate of human activities.

Table 3: Health Risk Assessment of Heavy Metals in Hamattan Risk

Heavy metals	Reference dose (mg/kg/day)	ADDinha of adult in (mg/kg/day)	ADDinha children in (mg/kg/day)	Hazard index HI	Health risk HR
Cu	0.04	4.94×10^{-6}	3.16×10^{-4}	AD- 0.368	NO
				CHD- 1.035	YES
Cd	0.14	3.85×10^{-6}	2.84×10^{-6}	AD-0.004	NO
				CHD-0.008	NO
Zn	0.3	4.23×10^{-5}	5.84×10^{-5}	AD-0.205	NO
				CHD-0.004	NO
Ni	0.02	2.91×10^{-6}	2.49×10^{-7}	AD-0.840	NO
				CHD-1.098	YES
Pb	0.035	6.63×10^{-4}	6.55×10^{-3}	AD- 1.205	YES
				CHD- 1.052	YES
Cr	0.003	2.25×10^{-6}	1.15×10^{-7}	AD- 0.02	NO
				CHD- 0.05	NO

https://dx.doi.org/10.22161/ijcmp.8.2.2
ISSN: 2456-866X

From Table 3, the health assessment of the heavy metals concentration, using US-EPA, and an average weight of 70kg for adults and 15 kg for children, the results show that Cu and Ni have hazard index HI of 1.035 and 1.098 for children. This indicated that Cu and Ni posed a health risk to the children because the hazard index HI is greater or equal to 1. Pb concentration poses health risks for both children and adults because the HI is equal to or greater than 1. A higher concentration of pb concentration in the body can bioaccumulation resulting in health effects such as brain depression, growth defects, and infertility for both males and female.

IV. CONCLUSIONS

The levels of heavy metals found in the Harmattan dust with the federal polytechnic campus that posed a risk of other adverse health effects were below the EPA's threshold for tolerance except for pb levels. One major conclusion can be drawn, however, even though the numerical results of the risk assessment are affected by considerable uncertainty and should be interpreted with caution: children are expected to develop adverse health effects from exposure to Cu, Pb, and Ni in household dust alone. pb, Cu, and Zn were heavy metals with high absorbed daily dosage in both children and adults, as determined by comparing the results obtained with the data of the Environmental Protection Agency's acceptable risk thresholds. Therefore, protective measures such as face or nose masks should be enforced during the Harmattan period for both children and adults to protect the direct exposure to Harmattan dust.

ACKNOWLEDGMENTS

The Authors acknowledge TETFUND, through the management of federal polytechnic Kaura Namoda, Zamfara state, for sponsoring this research work.

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