

HARMATTAN DUST AND ITS EFFECTS IN SEMI-ARID ZONE OF NIGERIA, A CASE STUDY OF MAIDUGURI METROPOLIS AND ITS ENVIRONS

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ABSTRACT

The Harmattan season is known to be characterized with both human and environmental damage caused by the increase in the concentration of suspended dust particles in the atmosphere. Their impacts are enormous, thus, making it necessary to be studied further in order to properly identify and quantify the degree of their impact on human health and the environment. The concentration of Harmattan particulate matter was determined by mass using Atomic absorption Spectrometer (AAS) in the semi-arid zone of Nigeria, a case study of Maiduguri and its environs. The dust samples were collected by direct deposition method on Whatman filter paper for five months during the Harmattan season (November 2010 to March 2011). The average rate of dust deposition for the Harmattan season was 124.15g/m². The results obtained from the determination of the heavy metals showed that lead has the highest concentration of 10.14 ± 3.5µg/g while nickel has the least concentration of 0.86 ± 0.2µg/g in the ambient air during the Harmattan season. There was generally a serious evidence of air pollution with the concentrations of lead, chromium, cadmium, iron, nickel, copper and arsenic in the air exceedingly greater than the ambient air quality standard for clean air adopted by World Health Organization (WHO) and Ontario Air Quality Criteria (OAQC). A statistical correlation of the results obtained from the study showed that there is a strong correlation between arsenic and cadmium, chromium and copper, chromium and iron, nickel and lead concentrations in the Harmattan dust sample with their coefficient of correlation being: R= 0.78, 0.99, 0.98, and 0.96 respectively at 5% confidence interval. These correlations indicate the possibility of a common set of emission sources.

KEYWORDS: Heavy metals; Sahara dust; Concentration; Visibility.

INTRODUCTION

The Harmattan is a dry dusty-laden atmosphere which occurs in Nigeria from November to March each year as experienced in most parts of West Africa (Dajab, 2006). During the Harmattan, atmospheric environment in most parts of semi-arid zone of Nigeria is characterized by massive suspension and deposition of Sahara dust particles. It is transported mainly by the north easterly wind from the Bilma plain (18° N, 12° E) in Niger Republic and Faya Largeau (18° N, 19° E) in the Chad basin, particularly from the Bodele depression to Nigeria and other parts of West Africa (Pinker *et al.*, 2001; Babatunde *et al.*, 2008).

The intense heating over the Sahara desert cause sand and dust particles to be uplifted into the atmosphere by convective forces. The upliftment can be up to greater heights estimated to reach 6.0km above the ground surface (Chiemeka, 2006). Studies had shown that large particles with sizes ranging from 0.1mm-1mm in radius are usually transported over a distance of 6000km before being deposited over a surface (Chineke *et al.*, 2007). The dust particles mainly settle under gravity and aerodynamic forces. The sedimentation of the dust particles begins immediately after entrainment, with the largest particles dropping

out first and quickly. Therefore, there is a systematic reduction in the dust concentration and particle sizes with respect to the distance from the source areas. The Harmattan wind which originates from the Saharan desert usually carries much dust as it travels from remote sources into the atmosphere. These sources includes bush burning, emissions from incomplete combustion of fossil fuels, mining, solid waste disposal, fertilizers, metal processing and aerosols from weathered rock particles. The impact of Harmattan dust particles is greatly felt in Maiduguri and its environs due to its proximity to the Sahara desert. The Northeast Trade Winds which prevail during the period entrain the raised dust particles, then travel in a southwest direction, and deposit the particles over the areas the winds traverse (Sunnun, 1997). Environmentally, Harmattan affects those areas with latitudes north of the latitudinal position of the Inter-Tropical Convergence Zone (ITCZ), which separates the Sahara dust laden northeast winds from southwest monsoon winds. The Harmattan phenomenon is important to governments and scientists because of its effect on the economy and human health. The Sahara dust is not limited to the semi-arid zone of Nigeria alone.

The dust particles are also transported to distances of thousands of kilometres from the sources in the Sahara desert, across west Africa as well as the tropical Atlantic to the Caribbean and northeast coast of South America (Swap *et al.*, 1992; Romero *et al.*, 1999). The dust particles from the Sahara desert tend to be deflated by different wind patterns at different time of the year.

An important physical environmental consequence of Harmattan dust is its influence on climate during its season. The Harmattan dust affects air temperature through absorption and scattering of solar radiation. It also modifies short-wave solar radiation transmitted through to the earth's surface and long-wave infra-red radiation to the space. However, the balance between these two tendencies determines whether this creates cooling or warming, and this in turn depend upon variables such as size distribution of dust particles and their chemical composition (Resch *et al.*, 2007).

MATERIALS AND METHODS

Maiduguri is located on longitude 13° 10'E and latitude 11° 50'N (Malgwi, *et al.*, 1997), it is known to be underlain by the sediments of the Chad basin. It has a semi-arid climate characterized by long dry season and short rainy season. The duration of rainfall varies from place to place, but generally it last for about three or four months. The annual rainfall ranges from 500mm-1000mm and the rainy season is from the month of June to September (Malgwi, *et al.*, 1997). Maiduguri metropolis in Borno State of Nigeria is a frontier boarder of Sahara desert in Nigeria. It is the first to experience the hot Northeast Trade Wind that blows across the Sahara desert into Nigeria. It is also the last to experience the cool Southwest Trade Wind which blows across the Atlantic Ocean into Nigeria (Malgwi, *et al.*, 1997). The selection of the sampling site was based on several factors including ease of access, safety and minimizing potential for sample contamination. This study is based on the data collected during the Harmattan seasons of 2010 and 2011.

The total suspended particulate matter was collected by direct deposition method using Whatman filter paper with a diameter of 12.50cm inserted into a dust probe of 3.0m high. The dust probe was stationed in an open space where there was no protective shade that could interfere with the dust gravitational settlement on the filter paper. Sampling was conducted in two weeks intervals for the Harmattan seasons from November 2010 to March 2011. Samples collected were subjected to the determination of total PM deposition per unit area, measured in grams per square meter (g/m²). The concentrations of heavy metals (As, Cu, Cd, Cr, Pb, Fe, Co and Ni) in the samples were determined.

Analytical instrumentation

A Perkin-Elmer 800 model Atomic Absorption Spectrometer with inverse longitudinal Zeeman-effect background correction system was used for the quantification of heavy metals. This instrument was equipped with a Perkin-Elmer THGA type graphite oven and an AS-70 auto-sampler. The AAS apparatus was warmed for 15 to 20 minutes before carrying out the analysis. Concentration measurements were determined from a working curve after calibrating the instrument with standard solutions of known concentration.

Sample digestion and analysis

The collected dust samples were digested by wet ash method following the procedure recommended by International Organisation for Standardization, ISO 11466 (Melaku *et al.*, 2005). This consisted of using 6ml each of concentrated H₂SO₄ and HCl to digest the sample for 90 minutes over a low heat at 60° C. The digested samples were diluted to a volume of 20cm³ with deionised water and then filtered to remove silicate and other insoluble materials that could clog the atomizer. The stock solution of the samples was aspirated into the Atomic Absorption Spectrometer (AAS) equipped with mono-elemental hollow cathode lamps and digital read out to ascertain the element of interest at specific wavelength and lamp current. A plot of concentration against the absorbance constitutes the calibration curve which was used to estimate the concentration of the elements under study. The characteristic wavelength are element specific and accurate to 0.01- 0.1 nm. To obtain the element specific wavelengths, a light beam from a lamp whose cathode is made of the element being determined is passed through the graphite tube. A photon multiplier in the system was used to detect the amount of reduction of the light intensity due to absorption by the analyte, and this was related to the amount of the element in the sample.

Conversion factor

Converting atmospheric pollutant concentrations from PPMv to µg/m³ involves a conversion factor which depends on the temperature at which the conversion is to be made, usually about 20 to 25°C (Allan, 2004). At an ambient pressure of 1 atmosphere, the general equation is given as:

$$\mu\text{g}/\text{m}^3 = \frac{(\text{PPMv})(121.87)(\text{Mw})}{(273.15 + X^\circ\text{C})}$$

Where,

µg/m³ = micrograms of gaseous pollutant per meter cube of ambient air.

PPMv = gaseous pollutant per 10⁶ volumes of ambient air

Mw = Molecular weight of the gaseous pollutant

X °C = ambient air temperature in degrees centigrade.

The data collected was analysed using Analyse-it (statistical analysis add-in software for Microsoft Excel v.2.10), at 5% confidence level.

RESULTS AND DISCUSSION

The rate of deposition of the Harmattan dust in the area studied ranges from 16.47g/m² to 33.49g/m² as shown in (table 1.0) during the Harmattan season. This situation endangers the survival of crops within the semi-arid zone of Nigeria where the impact of Harmattan dust is strongly felt. The deposition of the dust on plant leaves reduces the process of photosynthesis and blocks the leaf stomata which are the principal means of gas exchange in vascular plants (Resch *et al.*, 2007). The Harmattan dust greatly damage fruits, vegetables, trees and ornamental flowers. Harmattan dusts on the ground sometimes produce changes in soil chemistry which may in a longer time result in soil impoverishment. The soil PH might increase or reduce depending on the composition of the deposited dust particles. The Harmattan dusts studied are mainly PM₁₀ and PM_{2.5} (McTainsh *et al.*, 1982). The PM_{2.5} is composed of fine dust particles which include viruses and bacteria that are transported by the Harmattan wind. These fine dust particles could easily cause blindness, which is a common affliction in the north-eastern part of Nigeria, especially in Borno State and its environs. The range and the mean concentrations of the heavy metals identified in the Harmattan dust are shown in (table 2.0). The mean concentration of the heavy metals present in the air during the Harmattan season was compared with the international set standards (World Health Organization and Ontario Air Quality Criteria) as shown in (table 3.0). The results clearly indicated that the concentration of As, Cd, Cr, Ni, Fe, Cu and Pb metals fell within the contaminated air range while that of cobalt is below the World Health Organisation (WHO, 2000) acceptable level since it was not detected. Therefore, the air could be said to be clean in terms of Cobalt.

The World Health Organisation acceptable level of Arsenic in ambient air is 0.3µg/m³ for twenty-four hours. It was observed in this study that the mean concentration of arsenic for twenty-four hours is 24.16µg/m³ (table 3.0), which is eighty times above that of the acceptable level. Hence the environment is considered polluted with arsenic. Arsenic is the most common cause of acute heavy metal poisoning in adults (Akan *et al.*, 2011). It is released into the environment by smelting process of copper, zinc and glasses. Other sources are paints, rat poisoning, fungicides and wood preservatives. Arsenic is a highly toxic metalloid element, the target organs in human body systems are the blood, kidney, central nervous, digestive and skin systems. (Rodriguez *et al.*, 2003). The World Health Organisation

(WHO) acceptable level of cadmium in ambient air is 2.0µg/m³ for twenty-four hours. It was observed in this study that the mean concentration of cadmium for twenty-four hours during the Harmattan season is 53µg/m³ (table 3.0), which is approximately twenty-six times above the acceptable level. Hence the environment is considered polluted with cadmium. Cadmium is bio-persistent and once absorbed by an organism remains resident for many years although it is eventually excreted (Berestord, 1999). The main uses of cadmium are in electroplating and as stabilizers in plastics. In humans, long term exposure to cadmium is associated with renal dysfunction (WHO, 2004). Some sources of cadmium in the environment are: batteries, inorganic fertilizers produced from phosphate ores which constitute a major source of diffuse cadmium pollution (Eaton, 2005). Severe damage to the lungs may occur through breathing high levels of cadmium (Sandstrom and Forsberg, 2008). Cadmium and cadmium compounds are known human carcinogens (ATSDR, 2000).

Chromium is found in rocks, animals, plant, and soil. It can be a liquid, solid, or gas and it is used in electroplating of metal; magnetic tape; and pigments for paints, cement, paper, rubber and other materials. Its soluble forms are used as wood preservatives. The World Health Organisation (WHO) acceptable level of chromium in ambient air is 1.5µg/m³ for twenty-four hours. It was observed that the mean concentration of chromium for twenty-four hours during the Harmattan season is 106.3µg/m³ (table 3.0), which is approximately seventy-one times above the acceptable level. Hence the environment is considered polluted with chromium. Chromium (VI) compounds are toxins and known human carcinogens, whereas chromium (III) is an essential nutrient. Breathing high levels of chromium can cause irritation to the linings of the nose leading to; nose ulcer; runny nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing. Skin contacts can cause skin ulcers. Long term exposure can cause damage to liver and kidney (ATSDR, 2000). The Ontario Air Quality Criteria (OAQC) for copper in ambient air is 50µg/m³. It was observed that the mean concentration of copper in the area studied during the Harmattan period is 143.5µg/m³ (table 3.0), which is approximately three times above that of the acceptable level. Hence the environment is considered polluted with copper. Copper is widely used in electrical wiring, roofing, various alloys, pigment, cooking utensils and chemical industry. Copper is an essential substance to human life, however in high concentrations, it can cause anaemia, liver and kidney damage (Akan *et al.*, 2011). Iron is used in the production of paints pigments, polishing agents and electrical materials.

The Ontario Air Quality Criteria acceptable level for iron in ambient air is $4\mu\text{g}/\text{m}^3$ for twenty-four hours. It was observed that the mean concentration of iron in the area studied is $138.4\mu\text{g}/\text{m}^3$ (table 3.0), which is approximately thirty-five times above the acceptable level. The area studied is polluted with iron. Maiduguri metropolis has many mechanical workshops that are made up of various sections which include filing and welding of metals, panelling of vehicle bodies, painting and engine repairs. Iron fillings from metal works and the rusting of uncoated metals could have contributed to high concentration of iron in the areas studied. Iron helps to keep plant and animal alive and plays a role in the creation of chlorophyll in plants. It is also an essential part of haemoglobin, the substance that carries oxygen within the red cells. Iron sulphate is used to treat anaemia, a blood disease. Excess of iron causes liver and heart disease (Chiemeka, 2006).

Nickel is used for the production of stainless steels and non ferrous alloys. Other uses of nickel and nickel salt are in electroplating, nickel-cadmium batteries, and welding products. The WHO acceptable level of nickel in ambient air is $2.0\mu\text{g}/\text{m}^3$. The result of this study showed that the mean concentration of nickel in the air is $14\mu\text{g}/\text{m}^3$ for twenty-four hours during the Harmattan season, which is seven times above that of the acceptable level. Hence the environment is polluted with nickel. The exposure of urban population to lead takes place through inhalation of lead emitted into the air from the combustion of leaded gasoline. Lead is used in the production of lead acid batteries, alloys and cable sheathing. Tetraethyl and tetramethyl lead are used as anti-knocking agents in petrol (Sharma and Pervez, 2003; WHO, 2004). The World Health Organisation (WHO) acceptable level of lead in ambient air is $0.5\mu\text{g}/\text{m}^3$ for

twenty-four hours. In this study, it was observed that the mean concentration of lead in the air is $568.2\mu\text{g}/\text{m}^3$ (table 3.0), which is much greater than the acceptable level. Hence the environment is heavily polluted with lead. Lead is highly toxic, non-degradable element that causes damage to the brain, kidneys, blood, central nervous system, and reproductive system when inhaled in substantial amount (Akan *et al.*, 2011). Children who are exposed to high levels of lead may experience slowed cognitive development, reduced growth, and other health effects. Anaemic children are most vulnerable. The principal source of atmospheric lead in the environment studied is vehicular emissions. The degree of pollution depends on generator and motor vehicle density. The addition of alkyl lead in motor fuels accounts for an estimated 80-90% of lead in ambient air. Potential airborne lead can contaminate food, vegetation, water and soil with significant environmental and health impacts. In pregnant women, high level of exposure to lead may cause miscarriages, and in men it can damage the organs responsible for sperm production (Sandstrom *et al.*, 2008). Due to significant negative impacts of lead on human health, the WHO recommended in 1995 that the use of lead additives in motor fuels should be phased out and that exposure to other sources of lead should be reduced (Schwela *et al.*, 2006). Visibility reduction was much significant during December and January when the concentration of the Harmattan dust particles in air was high. The reduction in visibility occurs as a result of the absorption and scattering of incident radiations from the Sun by the suspended dust particles in the air. A visit to Maiduguri airport revealed that there were some flight schedule cancellations during December, January and early February due to poor visibility caused by Harmattan dust.

Table 1.0 Rate of dust deposition in grams per meter square.

Month	Rate of dust deposition in g/m^2
November	19.15
December	30.49
January	33.49
February	24.55
March	16.47

Table 2.0 Concentration range of the heavy metals detected during the Harmattan season (November 2010 to March 2011) and their mean concentration.

Element	Range detected ($\mu\text{g}/\text{g}$)	Mean concentration	
		($\mu\text{g}/\text{g}$)	($\mu\text{g}/\text{m}^3$)
Arsenic	$0.73 \pm 0.5 - 1.62 \pm 0.5$	1.19 ± 0.9	3648
Cadmium	$1.07 \pm 2.4 - 2.4 \pm 0.85$	1.75 ± 1.1	8012
Chromium	$5.84 \pm 0.8 - 9.0 \pm 3.1$	7.55 ± 2.2	16050
Cobalt	Not detected	Not detected	Not detected
Copper	$5.73 \pm 1.5 - 10.16 \pm 1.8$	8.35 ± 2.2	21673
Iron	$6.83 \pm 1.3 - 11.21 \pm 2.7$	9.13 ± 2.4	20900
Nickel	$0.51 \pm 0.3 - 1.1 \pm 0.2$	0.86 ± 0.2	2063
Lead	$7.01 \pm 1.7 - 12.32 \pm 5.2$	10.14 ± 3.5	85800

Table 3.0 Comparison of the results obtained with the international set standards for twenty four hours.

Element	Maiduguri metropolis and its environs ($\mu\text{g}/\text{m}^3$)	Standard ($\mu\text{g}/\text{m}^3$) for clean ambient air. (WHO and OAQ, 2004)
Arsenic	24.16	0.3
Cadmium	53.0	2.0
Chromium	106.3	1.5
Cobalt	Not detected	1.0
Copper	143.5	50
Iron	138.4	4
Nickel	14	2
Lead	568.2	0.5

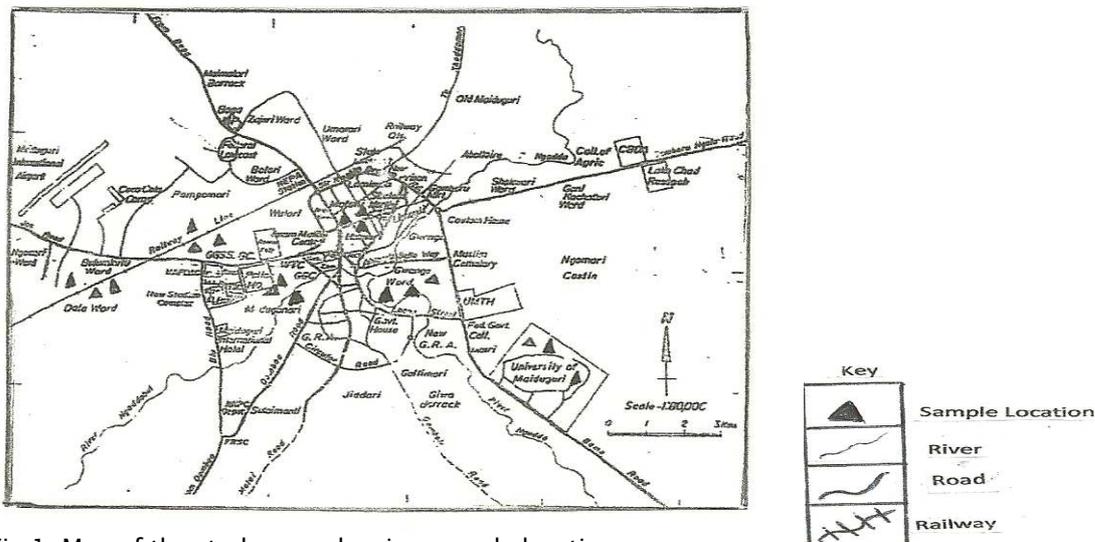


Fig.1. Map of the study area showing sample locations. Source: (Ministry of Land and Survey Maiduguri, 2000).

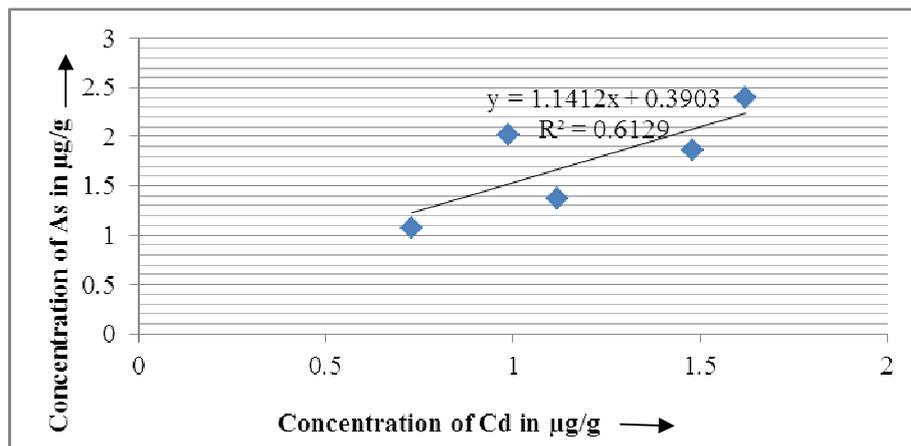


Fig.2. Correlation between As and Cd in ambient air for the Harmattan season.

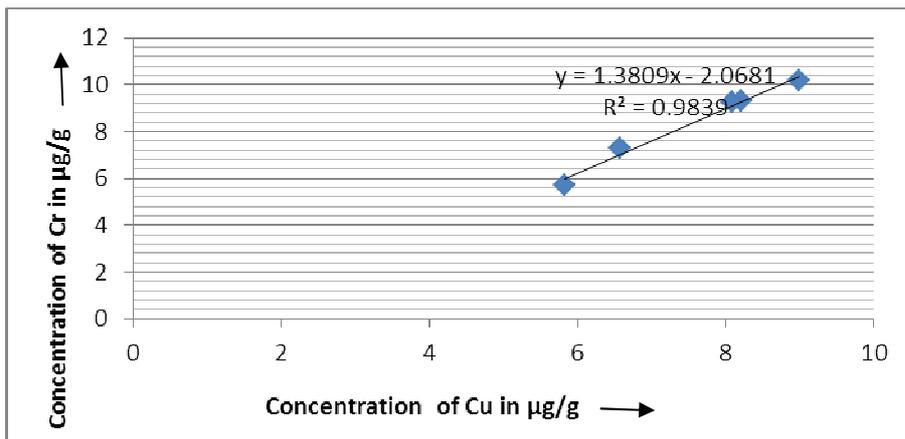


Fig.3. Correlation between Cr and Cu in ambient air for the Harmattan season.

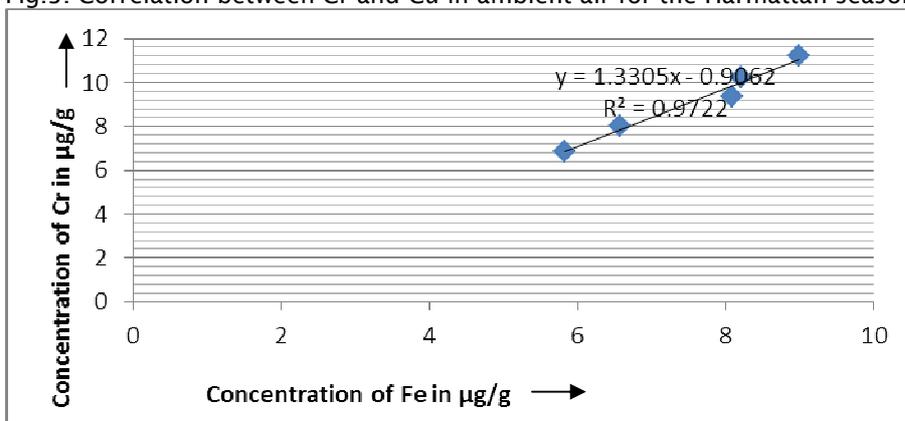


Fig.4. Correlation between Cr and Fe in ambient air for the Harmattan season.

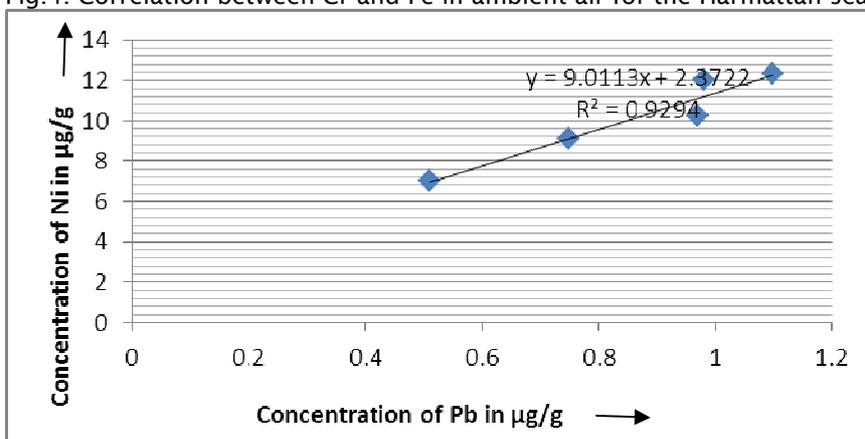


Fig.5. Correlation between Ni and Pb in ambient air for the Harmattan season.

CONCLUSION

The study revealed that the mass of dust particles deposited during the Harmattan season was high, and this eventually affects the environment in diverse ways. Visibility, buildings, ornamental structures and agriculture were affected. The analysis of the dust samples showed that the atmosphere, during the Harmattan season, was highly polluted with iron, cadmium, copper, nickel, chromium, arsenic and lead. These pollutants are responsible for diverse health problems which occur during and after the

Harmattan season. It was observed that the rate of prevalence of the following diseases; cancer, lung diseases, eye infections, coughing and other respiratory infections were on the increase during the Harmattan season and it invariably leads to high hospital admission in the University of Maiduguri Teaching Hospital as observed during visitation. The rate of deposition of dust particles in Maiduguri metropolis and its environs was 124.15g/m² during the 2010 and 2011 Harmattan season.

The magnitude of the dust deposited indicates that the Sahara dust must have imparted the top soil in the area studied negatively, by reducing its fertility. The sedimentation of Sahara dust on the top soil over the years has limited the ability of plants roots to tap the necessary nutrient from the soil. Consequentially, plant yields have reduced over the years, since most of the crops grown in this area are cereals whose root systems do not penetrate much into the soil. It is

important to state that annual soil test should be encouraged to assist famers in identifying gradual changes in soil PH values which might affect plant yields and their survival. And moreover, appropriate public awareness should be encouraged in order to reduce environmental and health effects of Harmattan dust. Finally, the result of this study will be useful to researchers in the field of agriculture, aviation, health and environmental studies.

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