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ESTIMATION OF EXCESS LIFETIME CANCER RISK DUE TO EXPOSURE TO $PM_{2.5}$ BOUND-TRACE METALS: A CASE STUDY OF PORT HARCOURT METROPOLIS, NIGERIA

[1]Uruh Ugada, [2]Ejikeme Ugwoha, [3]Udeh Ngozi N.

[1,2,3]Department of Civil and Environmental engineering, University of Port Harcourt, Choba.

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Abstract: **This study was carried out to determine the cancer and non-cancer effect induced from exposure to trace metals (TM) bounded to $PM_{2.5}$ in the indoor environment in Port Harcourt Metropolis. Indoor $PM_{2.5}$ samples were collected using a volumetric sampler. Air quality samples were collected from four (4) sampling points monthly for 8 months covering both raining and dry seasons. The concentrations of the selected TM bounded to $PM_{2.5}$ were determined using Inductively Coupled Plasma Mass Spectrometry. For accuracy and precision, each of the samples were analysed in triplicates. The concentration of the TMs observed were above WHO and US EPA recommended safe limits. The cumulative lifetime cancer risk for a receptor exposed to the target TMs via the inhalation pathway was assessed using the inhalation dosimetry methodology outlined in EPAs Risk Assessment Guidance for Superfund (RAGS) while the non-cancer risk of exposure for each metal through the inhalation was estimated using the Hazard Quotient (HQ). Results of the study showed that for all age groups there is the likelihood that As, Cd, Cr, Ni, and Pb will induce non cancer effect through inhalation if the environmental condition in the area in unabated. The cancer risk from As, Cd, Cr, Ni, and Pb were higher than the acceptable limit for all age groups. Exposure to these metals is likely to induce cancerous effects in infants, child, young adults and adults. The risk levels for the carcinogenic trace metals were higher in Infants. It was concluded that the levels of TM in the studied area might pose a risk to people's health.**

Keywords: **Black Soot, Cancer Risk, Health, Indoor, Particulate Matter, Port Harcourt, Trace Metals.**

I. INTRODUCTION

Air quality in the Niger Delta region of Nigeria particularly in the oil-rich city of Port Harcourt and its environs has been characterised by a variety of air pollution problems arising from the exploration and production activities of crude oil and gas by both national and multinational oil companies, traffic congestion and most recently the illegal refining of petroleum product [13] [19] [28]. These activities have led to the release of varieties of toxic air pollutants including particulate matters into air [1] [28].

High particulate matter (black soot) pollution has been experienced in the city of Port Harcourt and it environ since the last quarter of 2016. The ambient environment in the oil rich city has been subject to rains of visible black particulate matter (black soot). This phenomenon which is usually very visible in the early hours of the morning; as black particles are seen on surfaces of all exposed materials including cars, cloths, roofs, white cloths, tiles, and other exposed surfaces both in the indoor and outdoor environment [7] [9] [13].

Airborne particulate matter, particularly the respirable particulate matters with diameter less than 2.5microns ($PM_{2.5}$) constitutes a significant hazard to human health because of their chemical and biological toxicity, and their susceptibility to pass through the upper and lower respiratory system, penetrates the circulation system and are absorbed by the liver, kidney, and brain [5] [22] [1] [24]. Particulate matter is a mixture of hazardous biological and chemical substances including viruses, bacteria, fungi, trace metals and poly aromatic hydrocarbons and in some cases non-hazardous substance like water droplets depending on its source and origin [4] [27].

Trace metals (TM) bounded to airborne particulate matter constitutes less than 10% of its mass, nevertheless it is considered as an important component in health and environmental studies due to its persistent bioavailability, prolonged residence time in the environment, and toxicity, even at low concentration [2]. TM's like Cd, Cr, Cu, Mn, Ni, Pb, V, and Zn have been designated by the US Environmental Protection Agency as an environmental priority contaminant. The International Agency for Research on Cancer have classified these metals as human carcinogens and inorganic Pb compounds as probable carcinogen. Studies [13] [26] [24] have shown a positive correlation between airborne $PM_{2.5}$ and respiratory and cardiovascular disease particularly amongst the vulnerable populations, such as youngsters, the elderly (65 years of age or older), and those with pre-existing cardiorespiratory illnesses. Also, the World Health Organization (WHO) has stated that particulate matter ($PM_{2.5}$) is the 13th leading cause of death worldwide, causing an estimated 800,000 premature deaths each year [2].

Understanding the concentration of TM contained in airborne $PM_{2.5}$ is important for assessing the public health risk of exposure to $PM_{2.5}$ as well as determining the potential non-cancer and cancer risk associated with the exposure to airborne $PM_{2.5}$. This study seeks to determine the cancer and non-cancer risk associated with the exposure to TM bounded on airborne $PM_{2.5}$.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Port Harcourt the capital of Rivers State. . Rivers State borders include Imo to the north, Abia and Akwa Ibom to the east, Bayelsa and Delta to the west and Atlantic Ocean to the south. Port Harcourt lies along the Bonny River, and it is in the Niger Delta region of Nigeria. It is one of Nigeria's major industrial hubs, it houses a 25000-acre (1000 hectare) Trans-Amadi Industrial layout, where tires, aluminium goods, glass bottles, and paper are produced. Located 12km southeast of Port Harcourt is Nigeria first oil refinery at Alesa-Eleme. The map of the study area is presented in Fig1 and 2. The study area was delimited into three area Woji (WJI), Choba (CHB) and Port Harcourt Township (OPT), and Control point was taken at Owerri (WR). Air quality samples were collected from these sampling point twice monthly for 8months covered both raining and dry season.

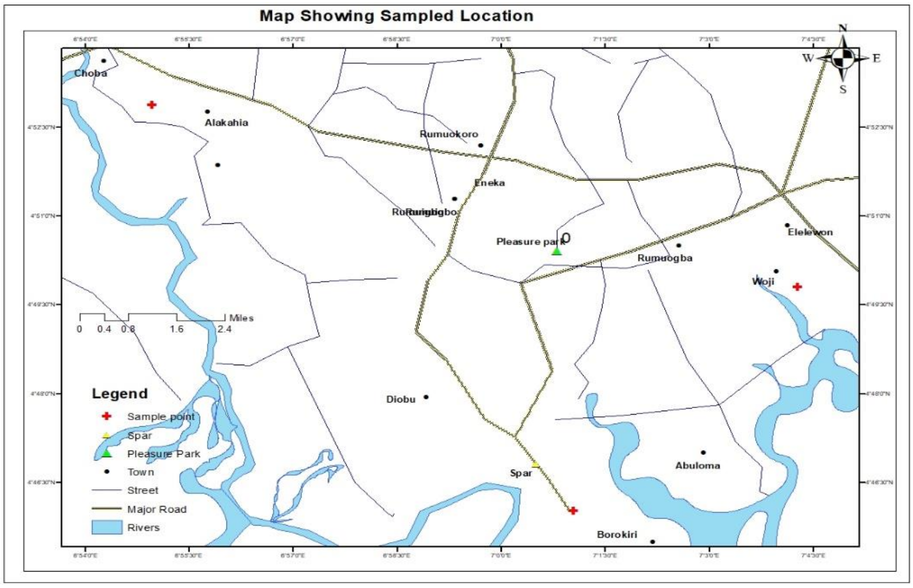

Fig.1: Map of Port Harcourt metropolis showing sampled location.

Source: Author

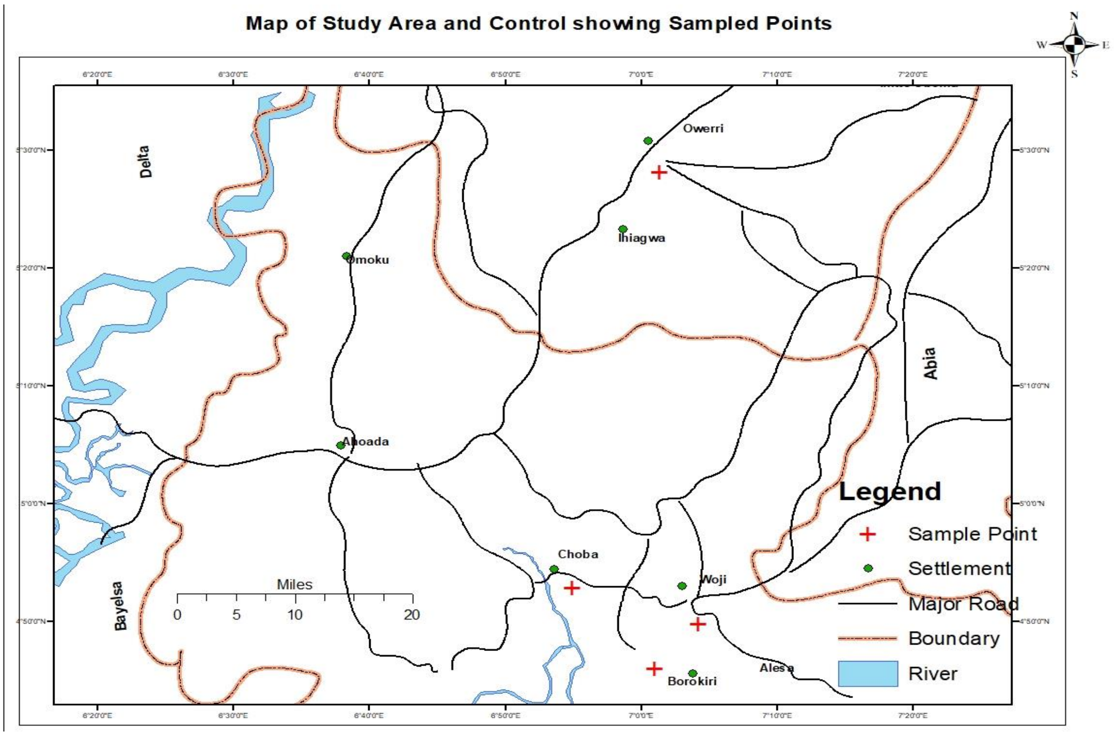

Fig.2: Map showing sampled location in Port Harcourt metropolis and Control location in Owerri.

Source: Author

2.2 Sampling of $PM_{2.5}$

A high volumetric sampler was used for sampling $PM_{2.5}$. Weighed, coded, and conditioned filters were placed in the filter holder and screwed properly before turning on the sampler. Large volumes of air were pulled through a filter-based high volume vacuum device where the particulates were collected on conditioned filters which were placed in the sampler. The flow rate and time were recorded before and after sampling for duration of four (4) hours on each site. After sampling, the filter papers were removed with forceps, stored in a petri dish, conditioned, weighed, and stored in the refrigerator at 4°C to prevent thermal degradation and evaporation of volatile components prior to further analysis. Field and laboratory blank samples were collected to reduce gravimetric bias that may result from filter handling, before, during and after sampling. Filters were handled only with tweezers coated with Teflon tape to reduce the possibility of contamination. The monitoring and sampling period were spread for eight (8) months namely June, July, August, September, October 2021 in wet season and December, January February, March, April in 2021/2022 in the dry season.

2.3 Analysis of Trace Metals Bounded to $PM_{2.5}$

Filter samples were shredded into tiny pieces with stainless steel scissor in a labelled centrifuge tube and transferred into a microwave Teflon vessel. 10.0 mL of extraction solution, 7ml of Nitric acid (HNO_3) and 3 mL HCl (70%) were added using a micro-Eppendorf pipette to the centrifuge tubes.

The concentrations of selected heavy metals in $PM_{2.5}$ were determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Calibration of the instrument was performed with multi-element calibration standards from 10 to 1000 mg/l. For accuracy and precision, each of the samples were analysed in triplicates. Blank filters and field blanks were analysed simultaneously, and the sample results were corrected by the average of blank concentrations. The concentrations obtained for the analysed trace metals were compared with the guidelines set by the World Health Organization (WHO) and United States Environmental Protection Agency (US EPA). Presented in Table 1 is the permissible limits for trace metals in air as recommended by WHO, EU and US EPA. It is noteworthy to mention that Nigeria do not have ambient exposure limits for these TMs except for lead (Pb).

Table 1. Permissible limits of concentrations of metals in ambient air

Trace Metals	WHO	EU	US EPA
Lead (Pb)	0.5	0.5	0.15
Arsenic (As)	0.00066	0.006	
Cadmium (Cd)	0.005	0.005	
Nickel (Ni)	0.0025	0.02	
Chromium (Cr)	0.000025		
Manganese (Mn)	0.15		
Vanadium (V)	1		

Source:[6][29]

2.4 Health Risk Assessment of Trace Metals in $PM_{2.5}$

Health risk assessment (HRA) model was adopted for the quantification of noncancer and cancer risk exposure to trace metals (Pb, Cu, Cd, Ni) in $PM_{2.5}$ in the study area. The cancer and noncancer risk exposure assessment was carried out among infants (0 – 1 year), children (2 – 5 years.), young adults (6 – 18 years), and adults (19 – 75 years). The assessment was based on the US EPA human health evaluation methods.

2.4.1 Estimation of Cancer Risk from Exposure to $PM_{2.5}$ Bounded Trace Metals

The cumulative lifetime cancer risk for a receptor exposed to the target trace metal species via the inhalation pathway was assessed using the inhalation dosimetry methodology outlined in EPA‟s Risk Assessment Guidance for Superfund (RAGS). The concentration of the target metal in air (µg/m^3) was used as the exposure metric, instead of the intake of contaminants in air based on inhalation rate and body weight (mg kg^{-1} day^{-1}) [31]. Excess lifetime Cancer risk (ELCR) due to inhalation was calculated using Equation 1.

$$ELCR = EC\ x\ IUR \qquad (1)$$

where: IUR is the Inhalation unit risk specific for each carcinogen (µg/m^3), EC is the Exposure concentration (µg/m^3), and ELCR is the Excess Life Cancer Risk

Exposure concentration (EC), which is a time weighted average concentration, was calculated for each individual contaminant according using Equation (2)

$$EC = \frac{CA\ X\ ET\ X\ EF\ X\ ED}{AT}$$

where: EC (µg/m^3) is the Exposure Concentration, CA (µg/m^3) is the Concentration of the metal in the air to which the person is exposed, ET (hours/day) is the Exposure time. Duration of an individual exposure in a day, EF (days/year) is the Exposure frequency (days/year). Evaluates the frequency of an individual exposure for a year. When the exposure period is less than a year, exposure frequency is expressed in days/week. ED (years) is the Exposure duration (years). Describes how long an individual is likely to be exposed during their lifetime. When the exposure period is less than a year, exposure duration is expressed in weeks, and AT (hours) is the Averaging time. For carcinogens, exposure is averaged over the course of a lifetime; AT (lifetime in years x 365 days/year x 24 hours/day) is the averaging time. IUR is the inhalation unit risk of HMs in $PM_{2.5}$. The R*f*Ci and IUR values are shown in Table 2. IUR values were obtained from databases provided by the EPA‟s Integration Risk Information System and Provisional Peer Reviewed Toxicity Values [9] [10].

Table 2: Recommended values of R*f*C and IUR.

	As	Cd	Cr	Mn	Ni	Pb
R*f*C (mg/m^3)	1.50 x10^{-05}	1.00 x10^{-05}	1.00 x10^{-04}	5.00 x10^{-05}	1.40 x10^{-05}	-
IUR (mg/m3)$^{-1}$	4.30 x 10^{-03}	1.80 x10^{-03}	8.40 x10^{-02}	-	2.40 x10^{-04}	1.20 x 10^{-05}

Source: [20] [15].

2.4.2 Estimation of Non-Cancer Risk from Exposure to Pm$_{2.5}$ Bounded Trace Metals

The non-carcinogenic risk of each metal through the inhalation was estimated using the Hazard Quotient (HQ). This was achieved by dividing the ADD from each exposure route by a definite reference dose (R*f*D). The HQ is defined as shown in Equation (3) while Equation (4) show the average daily dose (ADD$_{inh}$) of each trace metal in PM$_{2.5}$ through the inhalation route. Shown in Table 3 is the recommended parameters for equations of the daily exposure dose (ADD$_{inh}$)of PM$_{2.5}$.

$$HQ = \frac{ADD_{ihh}}{RfCi\ x\ 1000\ \mu g\ mg^{-1}} \qquad (3)$$

RfCi is inhalation reference concentrations (mg m^{-3}), ADD$_{inh}$ is the average daily dose of each metal in PM$_{2.5}$ through the inhalation route.

$$ADD_{inh} = \frac{C\ x\ InhR\ x\ EF\ x\ ED}{BW\ x\ AT} \qquad (4)$$

Where: C is the amount of PM$_{2.5}$ in ambient air(μg/m^3), ED is the exposure duration (days), BW is the body weight of the exposed group (kg), and AT is the averaging time (days)

InhR is the inhalation rate (m^3/day).

Table 3. Recommended values in equations of the daily exposure dose of PM$_{2.5}$.

Parameter	Definition	Value for Age Categories			
		Infant (0–1 yr)	Child (2–5 yrs)	Child (6–12 yrs)	Adult (19–75yr)
C	Mean concentration of PM2.5 in ambient air (μg/m^3)				
IngR	Ingestion rate (mg/day)	60	60	60	30
EF	Exposure frequency (days/year)	350	350	350	350
ED	Exposure duration (years)	1	6	12	30
ET	Exposure time (h)	1	8	6	3
AT	Averaging time (days); AT=ED × 365 days	365	2190	4380	10950
BW	Body weight (kg)	11.3	22.6	45.3	71.8
SA	Skin surface area (cm^2)	2800	2800	2800	5700
AF	Adherence factor of soil to skin (mg/cm^2/event)	0.2	0.2	0.2	0.07
ABS	Dermal absorption fraction	0.001	0.001	0.001	0.001
InhR	Inhalation rate (m^3/day)	9.2	16.74	21.02	21.4

Source:[21] [20].

However, to estimate the possible non-cancer effects that could arise from exposure to the synergistic effects of numerous trace metals, the sum of HQ values of all the metals were computed and expressed as a hazard index (HI). The formula for the HI is presented in Equation (5).

$$HI = \sum_{i=1}^{n} HQ1 + HQ2 + \cdots + HQi \qquad (5)$$

HI is the Hazard Index and HQ is the Hazard quotient.

3. RESULTS AND DISCUSSION

Table 4 presents the average seasonal concentration of trace metals bounded to $PM_{2.5}$ in the study area. Different seasonal patterns were observed in each of the analysed trace metals in the different study locations. The observed results showed that the concentration of the trace metals varied above the trace metal limit in ambient air as recommended by WHO and the EU. The highest concentration of these trace metals recorded were Pb (0.528 mg/m^3) in the raining season while the lowest concentration was observed in the dry season Cr (0.001mg/m^3). The unusually high concentration of trace metals observed during the rainy season in the air could be ascribed primarily to the illegal refining of petroleum product within the environ of Port Harcourt metropolis. The finding from this study was consistent with findings from; [2] [18] who reported higher concentration of $PM_{2.5}$ in Port Harcourt metropolis.

Table 4: Average concentration of trace metals in $PM_{2.5}$

	Raining Season				Dry Season			
Parameters	WJI	CHB	OPT	OWR	WJI	CHB	OPT	OWR
Pb	0.513	0.528	0.437	0.019	0.512	0.455	0.417	0.005
Cd	0.024	0.022	0.037	0.02	0.03	0.004	0.012	0.002
Cr	0.007	0.002	0.005	0.006	0.001	0.001	0.001	0.003
Ni	0.04	0.002	0.025	0.028	0.006	0.008	0.007	0.008

3.1 Cancer Risk Assessment of $PM_{2.5}$-Bound Trace Metals

The EPA considers cancer risks between 1×10^{-6} (i.e., 1 in 1,000,000) and 1×10^{-4} (i.e., 1 in 10,000) to be acceptable [30]. Findings from this study showed that the total average value of the ELCR for trace metals in $PM_{2.5}$ across the four (4) study locations exceeded the EPA threshold. From Table 4.16 the sum of the cumulative lifetime cancer risks across all investigated carcinogens due to inhalation exposures at each study site ranged as follows: WJI - Infant (3.05 x $10^{\wedge-2}$), Child (2.77 x $10^{\wedge-4}$), Young Adult (1.74 x $10^{\wedge-4}$), Adult (1.12 x $10^{\wedge-4}$). CHB: Infant (1.04 x $10^{\wedge-2}$), Child (9.61 x $10^{\wedge-5}$), Young Adult (6.02 x $10^{\wedge-5}$), Adult (3.87 x $10^{\wedge-5}$), OPT: Infant (2.32 x $10^{\wedge-4}$), Child (2.11 x $10^{\wedge-4}$), Young Adult (1.32 x $10^{\wedge-4}$), Adult (8.50 x $10^{\wedge-5}$) and OWR: Infant (2.98 x $10^{\wedge-4}$), Child (2.71 x $10^{\wedge-4}$), Young Adult (1.70 x $10^{\wedge-4}$), Adult (1.09 x $10^{\wedge-4}$).

The carcinogenic risk from As, Cd, Cr, Ni, and Pb were higher than the acceptable limit for all age groups. This implies that prolonged stay in this environment without abatement of this condition will likely induce cancerous effects in infants, child, young adults and adults. The risk levels for the carcinogenic trace metals were higher in Infants. The finding from this study is similar to epidemiological studies have reported higher cancer risks in infants than in Adults [13] [25] [33]

Table 5: Carcinogenic risks via inhalation exposure to heavy metals in $PM_{2.5}$.

Trace Metal / Location		**ADD_{inh}**				**IUR (mg/m3)□1**	**ELCR**			
		Infant	**Child**	**Young Adult**	**Adult**		**Infant**	**Child**	**Young Adult**	**Adult**
WJI	Pb	4.00E-01	3.64E-01	2.28E-01	1.46E-01	1.20E-05	4.80E-06	4.37E-06	2.74E-06	1.76E-06
	Cd	2.09E-02	1.90E-02	1.19E-02	7.65E-03	1.80E-03	3.76E-05	3.42E-05	2.14E-05	1.38E-05
	Cr	3.07E-03	2.79E-03	1.75E-03	1.12E-03	8.40E-02	2.58E-04	2.35E-04	1.47E-04	9.44E-05
	Ni	1.78E-02	1.62E-02	1.02E-02	6.52E-03	2.40E-04	4.28E-06	3.89E-06	2.44E-06	1.57E-06
					Total ELCR		**3.05E-04**	**2.77E-04**	**1.74E-04**	**1.12E-04**
CHB	Pb	3.84E-01	3.49E-01	2.19E-01	1.40E-01	1.20E-05	4.60E-06	4.19E-06	2.62E-06	1.69E-06
	Cd	1.01E-02	9.20E-03	5.76E-03	3.70E-03	1.80E-03	1.82E-05	1.66E-05	1.04E-05	6.66E-06
	Cr	9.76E-04	8.88E-04	5.56E-04	3.57E-04	8.40E-02	8.20E-05	7.46E-05	4.67E-05	3.00E-05
	Ni	3.70E-03	3.36E-03	2.11E-03	1.35E-03	2.40E-04	8.87E-07	8.07E-07	5.05E-07	3.25E-07
					Total ELCR		**1.06E-04**	**9.61E-05**	**6.02E-05**	**3.87E-05**

OPT	Pb	3.34E-01	3.03E-01	1.90E-01	1.22E-01	1.20E-05	4.00E-06	3.64E-06	2.28E-06	1.47E-06
	Cd	1.89E-02	1.72E-02	1.08E-02	6.92E-03	1.80E-03	3.40E-05	3.10E-05	1.94E-05	1.25E-05
	Cr	2.28E-03	2.07E-03	1.30E-03	8.34E-04	8.40E-02	1.91E-04	1.74E-04	1.09E-04	7.00E-05
	Ni	1.25E-02	1.14E-02	7.13E-03	4.58E-03	2.40E-04	3.00E-06	2.73E-06	1.71E-06	1.10E-06
						Total ELCR	**2.32E-04**	**2.11E-04**	**1.32E-04**	**8.50E-05**
OWR	Pb	9.17E-03	8.35E-03	5.23E-03	3.36E-03	1.20E-05	1.10E-07	1.00E-07	6.27E-08	4.03E-08
	Cd	8.81E-03	8.01E-03	5.02E-03	3.22E-03	1.80E-03	1.59E-05	1.44E-05	9.04E-06	5.80E-06
	Cr	3.32E-03	3.02E-03	1.89E-03	1.21E-03	8.40E-02	2.79E-04	2.54E-04	1.59E-04	1.02E-04
	Ni	1.40E-02	1.27E-02	7.98E-03	5.13E-03	2.40E-04	3.36E-06	3.06E-06	1.92E-06	1.23E-06
						Total ELCR	**2.98E-04**	**2.71E-04**	**1.70E-04**	**1.09E-04**

3.2 Non-carcinogenic risk assessment of $PM_{2.5}$-Bound Trace Metals

The results of the analysis for non-cancer risk for WJI presented in the Table shows a hazard index greater than 1 for all the categories including infants, child, young adult, and adult. While the results for CHB as shown in Table shows that the hazard index for infant (1.28) and child (1.17) where greater than the threshold while young adult (0.732) and adult (0.470) where less than the threshold.

The non-cancer risk assessment for the exposure to trace metals for OPT shows that the hazard index across all the groups were greater than the threshold limit. Infant (2.81), child (2.55), young adult (1.60) and adult (1.03). The result for OWR show that calculated values for the hazard index for infant (1.91), child (1.74) and young adult (1.09) were above the threshold limit of 1 while for adult (0.701) the calculated value was less the threshold.

Findings from this study showed that the probability for exposure to trace metal through the inhalation routes to induce non cancer effect was high for all age groups across the study location as Hazard Index (HI) recorded for all the age groups varied above the recommend threshold limit (HI>1) except for the young adult (0.732) and adult (0.470) in CHB, and adult (0.701) in OWR which had HI less than 1 (HI<1), This result indicates that there is high potential for exposure to Pb, Cr, Cd and Ni to induce non-cancer effects through the inhalation in infants, child and young adult.

Studies [16] [17] [19] conducted in recent years has shown a link between cardiovascular disease markers and exposure to high levels of certain metals such Ni, Cd, Cu, and As in $PM_{2.5}$. it has been reported in literatures that there is a strong relationship between the occurrence of hypertension and exposure to Cadmium and Chromium. It has also been noted that prolonged exposure to Nickel results to incidence of hyperglycemia, insulin resistance and glycemic deregulation [8] [31] [19]. In this study, children are more prone to the non-cancer effect of exposure to TM in $PM_{2.5}$ than adults. This finding is consistent with similar findings reported by [11] [12]. This could be since the immune system of the children is properly developed to manage environmental contaminants, and that they take in more air per unit body weight compared to the adults [3] [15].

Table 7: Non-carcinogenic risks of HMs in $PM_{2.5}$ via inhalation exposure pathways

Trace Metal / Location		ADDinh				RfC (mg/m3)	HQ			
		Infant	Child	Young Adult	Adult		Infant	Child	Young Adult	Adult
WJI	Pb	4.00E-01	3.64E-01	2.28E-01	1.46E-01					
	Cd	2.09E-02	1.90E-02	1.19E-02	7.65E-03	1.00E-05	2.09E+00	1.90E+00	1.19E+00	7.65E-01
	Cr	3.07E-03	2.79E-03	1.75E-03	1.12E-03	1.00E-04	3.07E-02	2.79E-02	1.75E-02	1.12E-02
	Ni	1.78E-02	1.62E-02	1.02E-02	6.52E-03	1.40E-05	1.27E+00	1.16E+00	7.25E-01	4.66E-01
						Hazard Index	**3.39E+00**	**3.09E+00**	**1.93E+00**	**1.24E+00**
CHB	Pb	3.84E-01	3.49E-01	2.19E-01	1.40E-01					
	Cd	1.01E-02	9.20E-03	5.76E-03	3.70E-03	1.00E-05	1.01E+00	9.20E-01	5.76E-01	3.70E-01
	Cr	9.76E-04	8.88E-04	5.56E-04	3.57E-04	1.00E-04	9.76E-03	8.88E-03	5.56E-03	3.57E-03
	Ni	3.70E-03	3.36E-03	2.11E-03	1.35E-03	1.40E-05	2.64E-01	2.40E-01	1.50E-01	9.66E-02
						Hazard Index	**1.28E+00**	**1.17E+00**	**7.32E-01**	**4.70E-01**

OPT	Pb	3.34E-01	3.03E-01	1.90E-01	1.22E-01					
	Cd	1.89E-02	1.72E-02	1.08E-02	6.92E-03	1.00E-05	1.89E+00	1.72E+00	1.08E+00	6.92E-01
	Cr	2.28E-03	2.07E-03	1.30E-03	8.34E-04	1.00E-04	2.28E-02	2.07E-02	1.30E-02	8.34E-03
	Ni	1.25E-02	1.14E-02	7.13E-03	4.58E-03	1.40E-05	8.94E-01	8.13E-01	5.10E-01	3.27E-01
						Hazard Index	**2.81E+00**	**2.55E+00**	**1.60E+00**	**1.03E+00**
OWR	Pb	9.17E-03	8.35E-03	5.23E-03	3.36E-03					
	Cd	8.81E-03	8.01E-03	5.02E-03	3.22E-03	1.00E-05	8.81E-01	8.01E-01	5.02E-01	3.22E-01
	Cr	3.32E-03	3.02E-03	1.89E-03	1.21E-03	1.00E-04	3.32E-02	3.02E-02	1.89E-02	1.21E-02
	Ni	1.40E-02	1.27E-02	7.98E-03	5.13E-03	1.40E-05	1.00E+00	9.10E-01	5.70E-01	3.66E-01
						Hazard Index	**1.91E+00**	**1.74E+00**	**1.09E+00**	**7.01E-01**

4. CONCLUSIONS

The result of this study showed that for all age groups there is the likelihood that As, Cd, Cr, Ni, and Pb will induce non-cancer effect through inhalation if the environmental condition in the area is unabated. Study location with hazard index greater than 1 (HI>1) demonstrates that the total non-cancer risk exceeds the safe limit, this indicates that there is a high potential health risk associated with a prolonged stay in this area. The cancer risk from As, Cd, Cr, Ni, and Pb were higher than the acceptable limit for all age groups and could induce cancer effects in infants, children, young adults and adults. The risk levels for the carcinogenic trace metals were higher in Infants. The findings showed that the levels of trace metals (TM) in the studied area might pose a risk to people's health. It also provided new information on the pollution problems in the research area and serves as a reminder of the necessity for stricter emission control methods. Policymakers and other key stakeholders could utilize these data to develop strategies to reduce the levels of trace metals in PM. It is time for the Nigeria Government to create standards for TM air quality.

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