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Health risk assessment of cadmium, chromium and nickel from car paint dust from used automobiles at auto-panel workshops in Nigeria

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ABSTRACT

Nigeria's economic problems which inhibited local production has resulted in massive importation of used automobiles. Most of these automobiles need some repairs and reworking, having outlived their lifespan in the manufacturer's country. This study centers on the human carcinogenic and non-carcinogenic health risk assessment of cadmium, chromium and nickel exposures from reworking of imported used vehicles. Scraped car paint dusts from 56 Japanese made cars were collected from 8 different panel beating (body works) workshops (A–H) in Southeastern Nigeria. They were homogenized, mixed, divided into fine particles, filtered and digested by standard method. The filtrates were assayed for cadmium, chromium and nickel with atomic absorption spectrophotometry (AAS, 200A), workshops F and D have the highest concentration (mg/kg) of Cd (3.58 ± 0.02) and (3.36 ± 0.04) and higher than levels in workshops A, B, C, E, G and H. Chromium (mg/kg) in workshops F and G were (2.87 ± 0.04) and (2.95 ± 0.06) and higher than the other workshops. Nickel in workshop A (3.84 ± 0.04) is close to other workshop values. The highest hazard quotients for adults were cadmium in workshops B (1.37E-01), D (1.69E-01), E (1.79E-01) (inhalation), chromium [workshops G (5.45E-02), F (5.29E-02) and C (5.24E-02) inhalation]. Nickel -workshop A (5.9E-03) for children (inhalation). HQ in children through ingestion is cadmium (3.72E-04) workshop F and ingestion- 3.21E-01(workshop F) while nickel is 1.06E-02 (workshop A).The highest cancer risks were in exponents -4,-7 and -8 (adult) and -3, -6 and -9 (children) for workshops A–H through inhalation, ingestion and dermal contact, exposures to scrap car paint dust may be of significant public health importance in Nigeria as it can add to body burden of some carcinogenic heavy metals.

1. Introduction

Environmental heavy metal contamination is a worldwide phenomenon, but the associated ecological and health risks are not yet matters of priority to the authorities in Nigeria. Low level and unspecialized industrial and manufacturing concern have given rise to high artisanal activities in Nigeria. Nigeria imports large quantities of old vehicles and the figure continues to increase [1] and their repair fits into artisanal (unregulated) activities. Components of automobiles include mechanical components, electronic and electrical devices, polymeric and sundry components that may contain toxic substances, examples include vehicular crankshaft, engine block and connecting rod, which contains steel, chromium, nickel, titanium, copper [2,3] while switches, batteries, headlamp bulbs, break light, data tapes, floppy disk, power supply boxes, car stereo equipment etc. contains cadmium, chromium and nickel etc., when these vehicles age and decompose, they constitute environmental and public health menace [4,5]. In an attempt to repair these vehicles, the artisans at the workshops are exposed to heavy metal pollution through scrapped car paint dust by a number of subtle ways such as contact with workshop tools, handshake, body hug, sharing of personal items, inhalation of and contact with microscopic air suspensions at the workshops. These workshops are cited mainly along busy but congested roads inter mixed with other business activities in Nigeria, hence human contact with heavy metals through paint dusts is possible. These metals cause array of symptoms and chronic diseases, studies has suggested that cadmium at low environmental exposures as currently found in industrialized countries, may result to subtle renal effects leadin3g to noticeable level in urinary excretion of micro-proteins [6,7]. Cadmium is hazardous both by inhalation and ingestion and can cause acute and chronic intoxications in

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humans with exceptional long half-life and accumulation in kidney, lungs and liver [8], very toxic, can disrupt biological systems, even at very low concentrations than most toxic metals [9]. Chronic exposure leads to ulcerations and perforations of the nasal septum, chronic bronchitis, decreased pulmonary function, pneumonia and other respiratory effects [10]. The cancer causing properties of chromium (VI) is known [11]. The acute toxicity of chromium (VI) is due to oxidation properties, hemolysis and organ failures [12].

Human exposure to nickel causes a variety of pathologic effects but adverse health effects is dependent on exposure route (inhalation, oral or dermal) and classification based on systemic, immunologic, neurologic, reproductive, distorted developmental or carcinogenic effects following acute (01 day), sub-chronic (10–100 days) and chronic (100 days or more) exposure periods [13]. Kidney is the actual organ of accumulation for nickel but inflammation in the bronchioles, alveolar congestion, alveolar cell hyperplasia and congestion in the lumen do occur [14]. Heavy metals act antagonistically disrupting trace elements in the body, inhibit and compete with protein and enzyme for binding sites and impair immune system. Unachukwu and co-workers [15] reported that non-communicable diseases (NCDs) such as cardiovascular disease, diabetes mellitus, cancer, renal diseases, liver failure and so on, which may be associated with heavy metal toxicity are now highly diagnosed and reported in Nigerian hospitals and may be more pronounced amongst artisans [16–18]. This work authenticates heavy metal poisoning through occupational routes. Therefore, illiteracy and engagement in non specialty occupation predisposes individuals (exposed subjects) to heavy metal poisoning. The aim of this work is to show that artisans can be exposed to carcinogenic heavy metals like cadmium, chromium and nickel through scraped car paint dust. It will assist in public health policy formulation and aid diagnostic skills of medical and public health workers in Nigeria.

2. Materials and methods

56 cars were selected from 8 different auto-panel workshops (workshops A–H) located in Awka, Nnewi, Onitsha and Enugu all in the Southeastern part of Nigeria. Fig. 1. Workshops A and B were from Awka, C and D from Nnewi, E and F from Onitsha and G and H were from Enugu. Seven Japanese cars of over 10 years old were identified in each of the auto-panel workshops. (Japanese cars were mostly available at the time of visit to the workshops (sampling) and most Nigerian middle class and those at the lower rung of the economy prefer Japanese cars because they have both second hand value and fuel efficiency. The paint flakes/dusts were collected from them and stored in black polythene bags before digestion and analyses. The samples were ground and sieved using meshes (metric test sieve BS 410 WS Tyler) with geometric diameters of 100 μm and 45 μm on a mechanical shaker (Retsch AS 200) for 15 min at amplitude of 10 mm/g to separate them into two particle size fractions [19]. 2 g of paint dust was weighed into a conical flask, adding 15 ml of concentrated nitric and perchloric acid at a ratio 1:1 and heating in a fume cupboard at a temperature of 105 °C near to dryness, it was allowed to cool, and 10 ml of distilled, de-ionized water was added, stirred, filtered and made up in a standard volumetric flask. Standard solutions of cadmium, chromium and nickel were prepared and assayed at their respective wavelengths with atomic absorption spectrophotometry (AAS 200A), with a detection limit set at 0.001 mg/l, and blank values reading as 0.00 mg/l in de-ionized water, electrical conductivity value lower than 5 μs/cm, standard graphs were plotted, samples of the filtrates were extrapolated from the graphs, analyzed in triplicates and results reported as Mean ± SD. The calibration curves were prepared for each of the metals investigated using the least square fitting method. Soil samples from the workshops were also analyzed using the same method, soil control samples were collected 200 m away from the workshops while water samples were collected within 500 m away from each workshop. The accuracies of this method have been evaluated by analysis of NBS standard reference materials and were better than ± 10%. A quality control program, including reagent blanks, replicate samples and standard reference materials, was used to access data precision and accuracy. Blanks were prepared in a procedure similar to that used for the dust samples and routinely analyzed before each measurement as we have reported before (20)

3. Exposure and risk assessment method

The US Environmental Protection Agency [21] and Dutch National Institute of Public Health and Environmental Protection exposure and risk assessment model for paint dusts were employed [22,23].The haphazardly situated workshops are without safety and public health regulation. The exposure to pollutants is through inhalation, dermal and ingestion, calculated using Eqs. ((1)–(3)) (21)

$$CDI_{inh} = \frac{C\times R_{inh} \times F_{exp} \times T_{exp}}{PBF_{\times} ABW_{\times} T_{avrg}} \quad (1)$$

$$CDI_{dermal} = \frac{C\times SAF \times A_{skin} \times DAF \times F_{exp} \times T_{exp}}{PBF_{\times} ABW_{\times} T_{avrg}} \quad (2)$$

$$CDI_{ingestion} = \frac{C\times R_{ing} \times F_{exp} \times T_{exp} \times 10^{-6}}{ABW \times T_{avrg}} \quad (3)$$

The CDI is the chronic daily intake (mg kg^{-1} day^{-1}); R_{ing} is the ingestion rate at 60 mg dust day^{-1} for children (1–6 years) and 30 mg day^{-1} for adults [22,23]; R_{inh} is the inhalation rate at 20 m^3 day^{-1} for adults and 7.6 m^3 for children [24]; F_{exp} is the exposure frequency, in this study, 180 day $year^{-1}$ [25,26]; T_{exp} is the exposure duration, in this study, 24 years for adults and 6 years for children [27]; A_{skin} is the skin area, in the study, 5700 cm^2 for adults and 2800 cm^2 for children [27]; SAF is the skin adherence factor, in this study, 0.7 mg cm^{-2} h^{-1} for adults and 0.07 mg cm^{-2} h^{-1} for children [26–29]; DAF is the dermal absorption factor (unitless), in our study, 0.001 for both children and adults; PEF is the particle emission factor, in the present study, 1.36×10^9 m^3 kg^{-1} for both cases [27], body weight (ABW) at 15 kg for children and 70 kg for adults [26,30,31]; and $T_{avrg} = T_{exp} \times 365$ days is the averaging time for non-carcinogens.

The non-carcinogenic risk (Hazard Quotient) from the metals is expressed as:

$$HQ = (CDI \times BAF)/RFD \quad (4)$$

Where CDI (E) = chronic daily intake (exposure), 'RFDs' = reference dose of the metals (mg kg^{-1} day^{-1}) and BAF = bio-accumulation factor.

$$\text{Hazard index} = \sum_{k=1}^{n} CDI(E)k/RFD \quad (5)$$

Hazard index (HI) = = sum total of more than one hazard quotient if multiple substances or multiple exposure pathways, this study involves exposure from different vehicles and three exposure pathways (ingestion, inhalation and dermal contact) [32], where HI > 1, means non- cancer risk is likely but when HI < 1, non-cancer may be impossible (32).

When a multiple pathways, total exposure hazard index (HIt) could be used to communicate non-cancer risks expressed thus [22]:

$$HIt = \sum_{1}^{n} HI(\text{Exposure Pathway 1}) \quad (6)$$

HIt ≤ 1, the assumption is that no chronic risks will occur, but HIt > 1, non-cancer risks are possible.

The Incremental Lifetime Cancer Risk (ILCR) is the probability of an individual developing cancer in his lifetime when exposed to potential carcinogens. Calculated with [22]:

$$\text{Incremental lifetime cancer risk} = CD_{(ing\ /\ inh\ /\ dermal)} \times SLF \quad (7)$$

Where SLF is known as the cancer slope factor, in this study,

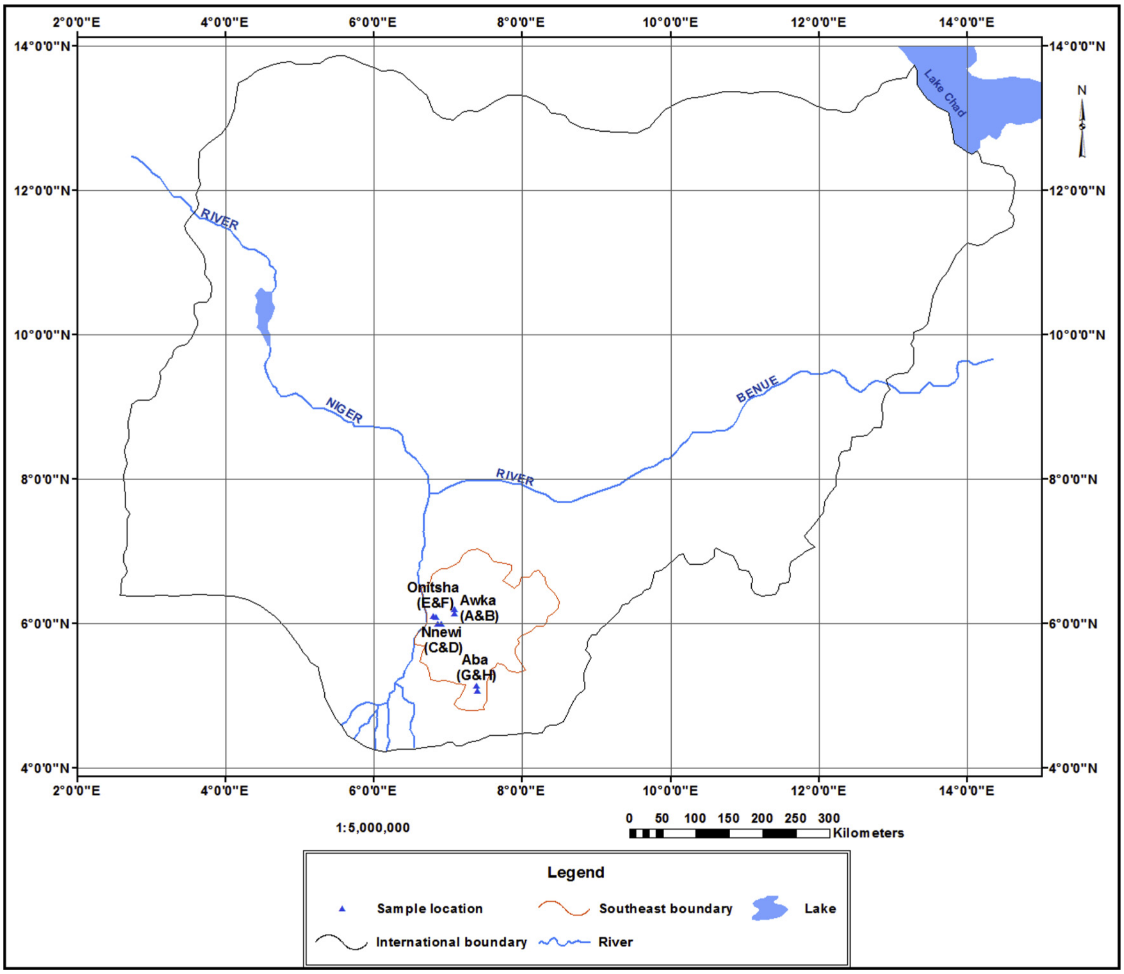

Fig. 1. Showing location of the workshops in municipal cities of Southeastern Nigeria.

cadmium, chromium and nickel has SLF of 0.38; 0.5 and 0.00 respectively [33].

4. Results

The heavy metal concentration (mg/kg) in Table 1 shows the level of cadmium, chromium and nickel from scrapped car paint in different workshop in the Southeastern Nigeria as follows: workshop F has the highest concentration of Cd (3.58 ± 0.02), followed by workshop D (3.36 ± 0.04), that of workshop B (2.27 ± 0.07), workshops E, G, A, C and H are as follows (2.54 ± 0.04, 2.37 ± 0.08, 2.25 ± 0.003, 2.03 ± 0.10 and 1.95 ± 0.03) respectively. The concentration (mg/kg) of chromium in workshops G (2.95 ± 0.06), F (2.87 ± 0.04), C (2.84 ± 0.03), D (2.63 ± 0.03) which were higher than those of workshops E (2.48 ± 0.04), B (2.45 ± 0.03), A (2.43 ± 0.02) and H (2.29 ± 0.02) while the highest concentration (mg/kg) of nickel is from workshop A (3.84 ± 0.04), followed by workshops F (3.52 ± 0.01), D (3.34 ± 0.03), B (3.30 ± 0.02), C (3.23 ± 0.07). The least values were in workshops G (2.88 ± 0.02), H (2.78 ± 0.04) and E (2.75 ± 0.03). Table 1 also shows the highest soil cadmium values of 3.63 ± 0.03 and 3.93 ± 0.01 (mg/kg) at workshops D and F, highest soil chromium values of 3.53 ± 0.02 and 3.45 ± 0.02 in workshops F and G. Highest soil nickel concentration of 4.31 ± 0.01 and 4.57 ± 0.01 (mg/kg) were in workshops A and F. Range of heavy metal in surface water were Cd (Nd-0.03), Cr (Nd-0.05), Ni (Nd-0.03) while that of borehole water were Cd (Nd-0.02), Cr (Nd-0.01) and Ni (Nd-0.02)

Table 2 shows the chronic daily intake from exposure to cadmium, chromium and nickel through ingestion, inhalation and dermal contact exposures in adults and also the hazard quotient from the different exposure pathways. The highest exposure pathway for the three metals (cadmium, chromium and nickel) is through inhalation with a range (1.85E-03 – 3.65E-03), ingestion (4.11E-07 -8.10E-07) and dermal (9.86E-08 –1.0E-07).The highest hazard quotient through ingestion, inhalation and dermal exposures in adults were workshop F (3.98E-05), workshop F (1.79E-01) and workshop F (5.29E-06).

Table 3 shows the chronic daily exposure to Cd, Cr and Ni in children through inhalation, ingestion and dermal routes. The highest exposure pathway in children is through inhalation with a range of (3.32E-03 – 6.53E), ingestion (3.84E-06 – 7.56E-06) and dermal (1.26E-08 – 2.47E-08). The highest values for hazard quotient through ingestion, inhalation and dermal exposures in children were 3.72E – 04 (workshop F), 3.21E – 01 (workshop F) and 1.61E-06 (workshop F).

Table 4 shows hazard index for cadmium for both adult and children through inhalation were 1.043 and 1.869 respectively, when cadmium, chromium and nickel are added (linear summation), the values were 1.469 and 2.631, and these values were above one [1], thereby making exposure through inhalation very hazardous. Total linear exposure for adult (children) through ingestion and dermal routes were 3.263E-04 (3.036E-03) and 4.335E-05 (1.967E-05), these were below one [1] and does not constitute health hazard.

Table 5 the total hazard index (HI) of the three heavy metal from exposure to scrap car paint dusts. The adult is highest in the range of 4.82E-06 –.1.64E-01, that of children1.11E-06 – 2.93E-01 (workshop A). Adult and children range were 5.53E-06 – 1.88E-01 and 1.27E-06 – 3.36E-01 (workshop B). The highest for adult and children in workshop

Table 1
Showing Metals Levels (mg/kg; mg/l) of Scrapped Car Paint Dust, Workshop Soil and Water Samples.

		Heavy metals from scrapped car paint dust						Heavy metals from the workshop soil						Heavy metals in water (SFW) and (BHW)		
WKS	Bearing	Cd	SD	Cr	SD	Ni	SD	Cd	SD	Cr	SD	Ni	SD	Cd	Cr	Ni
A	$6^0$21.12 [1]0 [11]N	2.25	0.03	2.43	0.02	3.84	0.04	2.63	0.04	2.69	0.03	4.31	0.01	0.02 (s f)	ND (sf)	0.20 (sf)
	$7^0$80.21 [1]0 [11]E							(0.01)		(0.03)		(0.04)		0.001 (b h)	ND (bh)	0.002 (bh)
B	$6^0$09.81 [1]0 [11]N	2.74	0.07	2.45	0.03	3.30	0.02	2.93	0.14	2.72	0.04	3.84	0.01	0.03 (s f)	0.03(sf)	0.01(sf)
	$7^0$07.22 [1]0 [11]E							(0.03)		(0.04)		(0.12)		0.01 (b h)	0.01(bh)	0.002 (bh)
C	$6^0$02.96 [1]0 [11]N	2.03	0.10	2.84	0.03	3.23	0.07	2.81	0.02	3.11	0.03	3.56	0.06	0.001 (s f)	0.02 (sf)	0.03 (sf)
	$6^0$91.73 [1]0 [11]E							(0.04)		(0.06)		(0.02)		ND (b h)	0.01(bh)	ND (bh)
D	$6^0$01.96 [1]0 [11]N	3.36	0.04	2.63	0.03	3.34	0.03	3.63	0.05	2.80	0.03	2.80	0.03	0.02 (s f)	ND (sf)	ND (sf)
	$7^0$43.32 [1]0 [11]E							(0.01)		(0.01)		(0.03)		0.001 (b h)	ND (bh)	ND (bh)
E	$6^0$16.67 [1]0 [11]N	2.54	0.04	2.48	0.04	2.75	0.03	3.58	0.07	3.00	0.05	3.68	0.05	0.02 (s f)	0.01(sf)	0.02 (sf)
	$6^0$97.83 [1]0 [11]E							(0.01)		(0.04)		(0.14)		0.002 (b h)	ND(bh)	ND (bh)
F	$6^0$67.22 [1]0 [11]N	3.58	0.02	2.87	0.04	3.52	0.01	3.93	0.03	(3.53)	0.07	4.57	0.01	ND (s f)	0.05(sf)	0.01(sf)
	$6^0$78.34 [1]0 [11]E							(0.02)		0.03		(0.11)		ND (b h)	0.01(bh)	ND (bh)
G	$6^0$92.22 [1]0 [11]N	2.37	0.08	2.95	0.06	2.88	0.02	2.82	0.16	3.45	0.02	3.56	0.02	0.03 (s f)	0.01(sf)	ND (sf)
	$7^0$89.32 [1]0 [11]E							(0.08)		(0.11)		(0.07)		0.002 (b h)	ND (bh)	0.01(bh)
H	$6^0$45.94 [1]]0 [11]N $7^0$54.84 [1]]0 [11]E	1.95	0.03	2.29	0.02	2.78	0.04	2.04 (0.03)	0.02	2.63 (0.05)	0.03	3.32 (0.03)	0.08	0.01 (s f) ND (b h)	ND (sf) ND(bh)	0.03 (sf) 0.001(bh)

WKS = Workshops; [N = 3]; SD = standard deviation; values in parenthesis are control of workshop soil; ND = not detected; SFW = surface water; BHW = borehole water.

C were 4.69E-06 – 1.59E – 01 and 1.08E-06 – 2.55E-01, for workshop D, adult highest range from 6.55E-06 – 2.22E-01 and children 1.51E-06 – 3.98E-01.

The highest range of 5.23E-06 – 1.77E-01 (adult) and (children) 1.2E-06 – 3.1E-01 (workshop E).In workshop F, adult ranged from 7.10E-06 – 2.38E-01 while children ranged from1.61E-06 to 4.26E-01. Adult and children total exposure range for workshop G were 5.24E-06 – 1.78E-01 and 1.21E06 - 3.18E-01. In workshop H, adult exposure ranged from 4.25E-06 – 1.44E-01 while that of children ranged from 9.79E-07 – 2.58E-01. In all the workshops, inhalational route had the highest metal exposure dose of total hazard index while dermal contact had the least.

The carcinogenic risk of Cd and Cr were calculated as seen in Table 6, that of nickel tended to zero (0), since cancer slope factor (SLF) for nickel is zero (0). For children, the highest carcinogenic cadmium risk levels were 2.17E-03, 2.68E-06 and 8.78E-09 for inhalation, ingestion and dermal exposure respectively for workshops D and F. The highest cadmium carcinogenic risks for adult were 9.88E-04, 2.87E-07 and 3.80E-8 for inhalation, ingestion and dermal exposures for workshops B and F. The highest carcinogenic chromium risk levels for children were 2.51E-03, 2.91E-06 and 9.25E-9 for inhalation, ingestion and dermal exposures all in workshop G. The highest carcinogenic chromium risk levels for adults were 1.41E-03, 3.11E-07 and 4.13-08 for inhalation, ingestion and dermal exposures respectively, all in workshop G.

5. Discussions

In our first attempt at chronicling hazardous effect of non-cancer causing metals from scraped car paint dust in Nigeria [20], literature search using PubMed, Scopus, Google Scholar and other online search engines show that our work may be first of its kind. The high concentration of carcinogenic heavy metals in this study is an important public health concern (Table 1). A careful look at Table 1, is evident that our work can add Cd, Cr and Ni to the environment. The health and environmental effect of heavy metals with regard to their concentration makes this important, for toxicity of heavy metals is mainly a function of concentration [34].

Global public health issue has led to restrictions in environmental protection in developed countries [35,36], but in Nigeria auto-panel workshops which has created direct and indirect job opportunities for self-employed young artisans through fairly used vehicular spare parts sales and repair, battery chargers, auto-painters, body work (panel-beating), auto-electricians, engine oil and diesel sales, car wash, tire pumping and repair, wheel balancing, taxi cab etc., implying that auto-artisans may be exposed to carcinogenic heavy metals (Cd, Cr and Ni) are not regulated.

By inspection, it is evident that metal values of soil from all the workshops were higher than that of paint dust matrix (Table 1), this is despite the fact that soil heavy metal can percolate into the soil or may be affected by dilution factor from rain or redistribution by flood, this can be attributed to the fact that as vehicles are repaired and taken away, more are brought into the workshops for the same purpose, the workshop soil therefore keep accumulating these metals as against control samples taken 200 m away from the workshops, though with insignificant metal value. In water samples, in which heavy metals were detected, the levels in surface water were slightly higher than that of borehole (underground water), this may be attributed to the high filtering capacity of clay soil underlying the geologic formation of the study area [37]. Established cadmium, chromium, and nickel are contacted from scrapped paint dust through ingestion, nose inhalation of mobile particles of paint dust and absorption of these heavy metals by skin adhered dust/particles (CDI_{ing}, CDI_{inh}, CDI_{dermal}). Literatures of exposure pathway that could be used to compare with our study include: ingestion exposure [38–41]; skin and dermal exposures [42], inhalational (nose) exposure [43,44], and the findings of this study can

Table 2
Health risk from heavy metals exposure in adults from scrapped car paint dust (n = 56 samples, n = 7 samples from each workshop).

Workshops		CDI	Mg/kg day^{-1}	HAZARD	QUOTIENT	(HQ)
A	Cadmium	Chromium	Nickel	Cadmium	Chromium	Nickel
Inhalation	2.14 E-03	2.31 E-03	3.65 E-03	1.13 E-01	4.49 E-02	5.9 E-03
Ingestion	4.75 E-07	5.13 E-07	8.10 E-07	2.51 E-05	9.96 E-06	1.31 E-06
Dermal	6.3 E-08	6.80 E-08	1.08 E-07	3.36 E-06	1.32 E-06	1.74 E-07
B						
Inhalation	2.6 E-03	2.32 E-03	3.14 E-03	1.37 E-01	4.52 E-02	5.08 E-03
Ingestion	5.78 E-07	5.17 E-07	6.96 E-07	3.05 E-05	1.0 E-05	1.12 E-06
Dermal	7.67 E-08	6.86 E-08	9.24 E-08	4.05 E-06	1.33 E-06	1.49 E-07
C						
Inhalation	1.93 E-03	2.69 E-03	3.07 E-03	1.01 E-01	5.24 E-02	4.97 E-03
Ingestion	4.28 E-07	5.99 E-07	6.82 E-07	2.26 E-05	1.16 E-05	1.1 E-06
Dermal	5.68 E-08	7.95 E-08	9.04 E-08	3.0 E-06	1.55 E-06	1.47 E-07
D						
Inhalation	3.19 E-03	2.49 E-03	3.17 E-03	1.69 E-01	4.85 E-02	5.14 E-03
Ingestion	7.09 E-07	5.55 E-07	7.05 E-07	3.74 E-05	1.08 E-05	1.14 E-06
Dermal	9.41 E-08	7.36 E-08	9.35 E-08	4.97 E-06	1.43 E-06	1.52 E-07
E						
Inhalation	2.41 E-03	2.36 E-03	2.61 E-03	1.27 E-01	4.58 E-02	4.23 E-03
Ingestion	5.36 E-07	5.23 E-07	5.8 E-07	2.83 E-05	1.02 E-05	9.4 E-07
Dermal	7.11 E-08	6.94 E-08	7.70 E-08	3.76 E-06	1.34 E-06	1.25 E-07
F						
Inhalation	3.4 E-03	2.73 E-03	3.34 E-03	1.79 E-01	5.29 E-02	5.42 E-03
Ingestion	7.55 E-07	6.05 E-07	7.43 E-07	3.98 E-05	1.17 E-05	1.2 E-06
Dermal	1.0 E-07	8.04 E-08	9.86 E-08	5.29 E-06	1.56 E-06	1.59 E-07
G						
Inhalation	2.25 E-03	2.81 E-03	2.74 E-03	1.19 E-01	5.45 E-02	4.43 E-03
Ingestion	5.0 E-07	6.22 E-07	6.08 E-07	2.64 E-05	1.21 E-05	9.84 E-07
Dermal	6.64 E-08	8.26 E-08	8.06 E-08	3.50 E-06	1.60 E-06	1.31 E-07
H						
Inhalation	1.85 E-03	2.18 E-03	2.64 E-03	9.78 E-02	4.23 E-02	4.28 E-03
Ingestion	4.11 E-07	4.83 E-07	5.87 E-07	2.17 E-05	9.39 E-06	9.5 E-07
Dermal	5.46 E-08	6.41 E-08	7.78 E-08	2.88 E-06	1.25 E-06	1.26 E-07

RfD_O = Cd (0.0005); Cr (0.005); Ni (0.02); BAF = Cd (52.8); Cr (5.83); Ni (32.4).

Table 3
Health risk from heavy metals exposure in Children from scrapped car paint dust (n = 56 samples, n = 7 samples from each workshop).

Workshops		CDI	Mg/kg day^{-1}	HAZARD	QUOTIENT	(HQ)
A	Cadmium	Chromium	Nickel	Cadmium	Chromium	Nickel
Inhalation	3.83 E-03	4.13 E-03	6.53 E-03	2.02 E-01	8.03 E-02	1.06 E-02
Ingestion	4.43 E-06	4.79 E-06	7.56 E-06	2.34 E-04	9.3 E-05	1.23 E-05
Dermal	1.44 E-08	1.57 E-08	2.47 E-08	7.65 E-07	3.04 E-07	1.11 E-06
B						
Inhalation	4.66 E-03	4.17 E-03	5.61 E-03	2.46 E-01	8.09 E-02	9.09 E-03
Ingestion	5.39 E-06	4.83 E-06	6.5 E-06	2.85 E-04	9.4 E-05	1.05 E-05
Dermal	1.77 E-08	1.58 E-08	2.13 E-08	9.32 E-07	3.07 E-07	1.27 E-06
C						
Inhalation	3.45 E-03	4.83 E-03	5.49 E-03	1.82 E-01	9.38 E-02	8.89 E-03
Ingestion	3.99 E-06	5.59 E-06	6.36 E-06	2.11 E-04	1.08 E-04	1.03 E-05
Dermal	1.31 E-08	1.83 E-08	2.08 E-08	6.9 E-07	3.55 E-07	1.08 E-06
D						
Inhalation	5.71 E-03	4.47 E-03	5.68 E-03	3.02 E-01	8.69 E-02	9.19 E-03
Ingestion	6.62 E-06	5.18 E-06	6.58 E-06	3.49 E-04	1.0 E-04	1.07 E-05
Dermal	2.16 E-08	1.69 E-08	2.15 E-08	1.14 E-06	3.29 E-07	1.51 E-06
E						
Inhalation	4.32 E-03	4.22 E-03	4.68 E-03	2.28 E-01	8.19 E-02	7.57 E-03
Ingestion	5.0 E-06	4.89 E-06	5.42 E-06	2.64 E-04	9.49 E-05	8.78 E-06
Dermal	1.64 E-08	1.59 E-08	1.77 E-08	8.64 E-07	3.1 E-07	1.20 E-06
F						
Inhalation	6.09 E-03	4.88 E-03	5.98 E-03	3.21 E-01	9.48 E-02	9.69 E-03
Ingestion	7.05 E-06	5.65 E-06	6.93 E-06	3.72 E-04	1.09 E-04	1.12 E-05
Dermal	2.31 E-08	1.85 E-08	2.27 E-08	1.22 E-06	3.59 E-07	1.61 E-06
G						
Inhalation	4.03 E-03	5.02 E-03	4.89 E-03	2.13 E-01	9.74 E-02	7.93 E-03
Ingestion	4.67 E-06	5.81 E-06	5.67 E-06	2.47 E-04	1.13 E-04	9.19 E-06
Dermal	1.53 E-08	1.89 E-08	1.85 E-08	8.06 E-07	3.69 E-07	1.21 E-06
H						
Inhalation	3.32 E-03	3.89 E-03	4.73 E-03	1.75 E-01	7.56 E-02	7.66 E-03
Ingestion	3.84 E-06	4.51 E-06	5.48 E-06	2.03 E-04	8.77 E-05	8.87E-06
Dermal	1.26 E-08	1.47 E-08	1.79 E-08	6.63 E-07	2.87 E-07	9.79 E-07

Table 4
Hazard index (HI) from individual heavy metal exposure to scrapped car paint dust.

	Cd	Cr	Ni	Total Hazard Index (THI)
Inhalation				
Adult	1.043	0.387	3.945E-02	1.469
Children	1.869	0.692	7.062E-02	2.631
Ingestion				
Adult	2.318E-04	8.575E-05	8.744E-06	3.263E-04
Children	2.165E-03	7.996E-04	7.176E-05	3.036E-03
Dermal				
Adult	3.081E-05	1.138E-05	1.163E-06	4.335E-05
Children	7.08E-06	2.62E-06	9.969E-06	1.967E-05

Table 5
Total hazard index (HI) of three heavy metals from exposure to car paint dust.

Workshops	Inhalation	Ingestion	Dermal
A			
Adult	1.64 E-01	3.63 E-05	4.82 E-06
Children	2.93 E-01	3.39 E-04	1.11 E-06
B			
Adult	1.88 E-01	4.17 E-05	5.53 E-06
Children	3.36 E-01	3.89 E-04	1.27 E-06
C			
Adult	1.59 E-01	3.54 E-05	4.69 E-06
Children	2.85 E-01	3.3 E-04	1.08 E-06
D			
Adult	2.22 E-01	4.94 E-05	6.55 E-06
Children	3.98 E-01	4.61 E-04	1.51 E-06
E			
Adult	1.77 E-01	3.94 E-05	5.23 E-06
Children	3.17 E-01	3.68 E-04	1.2 E-06
F			
Adult	2.38 E-01	5.29 E-05	7.01 E-06
Children	4.26 E-01	4.93 E-04	1.61 E-06
G			
Adult	1.78 E-01	3.95 E-05	5.24 E-06
Children	3.18 E-01	3.69 E-04	1.21 E-06
H			
Adult	1.44 E-01	3.21 E-05	4.25 E-06
Children	2.58 E-01	2.99 E-04	9.79 E-07

compromise body immunity (Tables 1–3). Heavy metals can accumulate and build up in cells, bones, glands and hair [45]. Scrap car paint dusts, soil aerosols and fugitive dust laden heavy metals less than 10μml been tiny, microscopic and less dense than air can travel far and wide (distance covered is dependent on meteorological condition of geographical area) and when inhaled can be trapped in the trachea-bronchial and alveolar-bronchial system, but infiltration of inhaled particles into air-track has an inverse relation with particle size for those greater than 0.5 μm [46]. Biologic and physic-chemical factors influence the movement of settled particulates in the respiratory tract coupled with dissolution and movement into body fluid and blood by phagocytosis and simultaneous mobility with mucus [47], adhesion and dispersion process of accumulated particles differs at different section of the respiratory track [48].

The hazard indices of cadmium for children and adults through inhalation were 1.869 and 1.043, inferring health risk associated with scrap car paint dust. Total non-carcinogenic hazard indices (adult and children) for both ingestion and dermal contact are below the hazard threshold value of one [1] set by the US EPA [22,23] (Table 4). Although the values are minimal and suggest insignificant risk when singly considered but when the three exposure routes are summed up, as they may occur simultaneously, the effect can compromise public health.

The total hazard indices (Table 5) of the three heavy metal from scrap car paint dust reveal there may be reasonable level of toxicity through inhalation mostly in children followed by adult than through ingestion and dermal contact, this agrees with the work of Orisakwe and co-workers [18] wherein the respiratory abnormalities associated with occupational exposure to particulate insults in "Okada" (motorcycle) operators in Nigeria reveal serious health implications. Cadmium has no healthy body function but has been recognized as an endocrine disruptor for its adverse effect on reproduction [49], disruption of spermatogenesis in vivo and in laboratory animals [50] and binding with androgen and estrogen receptors [51], prostrate and testicular toxicity and infertility [52,53]. There are reported cases of cognitive reduction with osteoporotic effect in aged sick resulting from presence of lead, a metal of charge similarity with cadmium, nickel, calcium (Pb^{+2}, Cd^{+2}, Ni^{+2}, Ca^{+2}) in the bloodstream implies bone defect [54,55]. Chromium (Cr^{+3}) is not very toxic, hexavalent chromium (Cr^{+6}) is carcinogenic, corrodes skin and causes denaturation and precipitation of tissue proteins [56]. Occupational exposure to chromium is mostly by inhalation, but gastrointestinal tract and skin can occur [57], hence respiratory tract is the primary target organ for Cr^{+6} and its compounds. Nickel is absorbed through the lungs [58,59], gastrointestinal tract [60] and skin [61], but excreted in the urine [62]. A careful look at our work, shows that it may be significant in public health issues through occupational exposure considering the work of

Table 6
Incremental Lifetime Cancer Risk (ILCR) for adult and children from three metals in scrapped car paints in Southeastern Nigeria.

Carcinogenic metal	Route of exposure	Workshops							
		A	B	C	D	E	F	G	H
Cadmium	Inhalation								
	Adult	8.31E-4	9.88E-4	7.33E-4	1.21E-3	9.16E-4	1.29E-3	8.55E-4	7.03E-4
	Children	1.46E-3	1.77E-3	1.31E-3	2.17E-3	1.64E-3	2.31E-3	1.53E-3	1.26E-3
	Ingestion								
	Adult	1.81E-7	2.19E-7	1.63E-7	2.69E-7	2.04E-7	2.87E-7	1.90E-7	1.56E-7
	Children	1.68E-6	2.05E-6	1.52E-6	2.52E-6	1.90E-6	2.68E-6	1.77E-6	1.46E-6
	Dermal								
	Adult	2.39E-8	2.91E-8	2.16E-8	3.58E-8	2.70E-8	3.8E-8	2.52E-8	2.07E-8
	Children	5.47E-9	6.73E-9	4.98E-9	8.21E-9	6.23E-9	8.78E-9	5.81E-9	4.79E-9
Chromium	Inhalation								
	Adult	1.16E-3	1.16E-3	1.35E-3	1.25E-3	1.18E-3	1.37E-3	1.41E-3	1.09E-3
	Children	2.07E-3	2.09E-3	2.42E-3	2.24E-3	2.11E-3	2.44E-3	2.51E-3	1.95E-3
	Ingestion								
	Adult	2.57E-7	2.59E-7	2.99E-7	2.78E-7	2.62E-7	3.03E-7	3.11E-7	2.42E-7
	Children	2.39E-6	2.42E-6	2.79E-6	2.57E-6	2.45E-6	2.83E-6	2.91E-6	2.26E-6
	Dermal								
	Adult	3.40E-8	3.43E-8	3.98E-7	3.68E-8	3.47E-8	4.02E-8	4.13E-8	3.21E-8
	Children	7.85E-9	7.90E-9	9.15E-9	8.45E-9	7.95E-9	9.25E-9	9.45E-9	7.35E-9

Orisakwe et al [17] and that of Vitayavirasuk et al [63] which shows that subjects exposed to heavy metal in a paint factory and automobile paint spray may have compromised health status.

Table 6 shows the possibility of exposed subjects developing cancer from lifetime exposure to carcinogenic metals. Cadmium and chromium in children and adult are at a higher risk through inhalation but children are marginally at risk than adult through ingestion, dermal contact does not constitute threat been below the regulatory range of 1×10^{-6} to 1×10^{-4} [32]. Hazard index (HI) is the total calculated hazard quotients (HQ) and greater than 1 show that non-carcinogenic effects may occur but lower than one [1] shows no significant risk of non-carcinogenic effect, higher HI value means the occurrence of non-cancer effect [27], several studies have linked cadmium, chromium, arsenic, lead and other heavy metals to cancer, diabetes, osteoporosis, bronchitis, respiratory and pulmonary symptoms, allergenic effect, nephrotoxicity, keratoconjunctivitis, cardiovascular disease, neuroendocrine disruption, hypertension and infertility [6–10,12,49,64].

In comparison, some study proves that inhaled particles exhibit synonymic health effects as ingested ones [65,21]. HQ value below 1×10^{-6} is a negligible cancer risk but HQ values greater than 1×10^{-4} is high. Cancer risks equal or above 1×10^{-4} is a health threat [31], cadmium, chromium and nickel exposures for children through inhalation for workshops A–H are in exponents of 10^{-1}, 10^{-2} and 10^{-3} while that of adults are 10^{-1}, 10^{-2} and 10^{-3}, is a serious health issue (Tables 2 and 3). That of adults through ingestion and dermal contact varied exponentially from 10^{-7} to 10^{-5} and 10^{-7} to 10^{-6} while that of children ranged from 10^{-6} to 10^{-4} and 10^{-7} to 10^{-6} · These may not be regarded as public health catastrophe. Zhao et al [66] posit that short time but reasonable dose exposure to heavy metal may not be the only cause of cancer but persistent low dose exposure possibly as seen in scrap auto- paint dust plays key role in tumor formation, as Cr, Cd, As, Pb and Hg were found in tissues of lung, liver and gastric cancer sufferers.

In this study, cancer risk for cadmium through inhalation were in the high risk range of 1.26×10^{-3} – 2.31×10^{-3}, and 9.88×10^{-4} - 1.29×10^{-3} (children and adult) and that of chromium is in the range of 1.95×10^{-3} – 2.51×10^{-3} and 1.09×10^{-3} – 1.41×10^{-3} for children and adult respectively (Table 6), all above the US EPA regulatory value (1×10^{-6} to 1×10^{-4}). Exposure of cadmium through ingestion and dermal contact were in the lower risk range of 1.46×10^{-6} - 2.68×10^{-6} and 4.79×10^{-9} - 8.78×10^{-9} for children and that of adults were in the range of 1.56×10^{-7} - 2.87×10^{-7} and 2.07×10^{-8} - 3.58×10^{-8}. Chromium exposure through ingestion and dermal routes were in the range of 2.26×10^{-6} - 2.91×10^{-6} and 7.35×10^{-9} - 9.45×10^{-9} for children while both routes for adults were in the range of 2.42×10^{-7} – 3.11×10^{-7} and 3.21×10^{-8} – 4.13×10^{-8} (Table 6). This implies negligible risk for cadmium and chromium for the exposed subjects within the study area. For nickel every value tended to zero because its cancer slope factor is zero. Apart from heavy metals (Cd, Cr and Ni) contained in the paint, paint aerosols can be hazardous posing similar effect as microscopic welding particles which can extremely compromise human health [67]. The findings here correlates with other literature [68,69] that despite advantages automobile transportation offers to the populace, it surely has negative public health impact. This work amongst others [16,18] is an indication that occupational and direct local exposures [70] is the most self-evident scenario of heavy metal or chemical risk, that may be associated with scrap car paint dust.

In Conclusion, the artisans and the resident population working or residing near auto-panel workshops may be exposed to heavy metal risks, from car paint dust matrix and this can compromise their body immunity.

Conflict of interest

The authors hereby state that they do not have any conflict of interest with regards to research article.

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