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Health Risk Assessment of Toxic Trace Metals in Private Car Dusts from Pretoria, South Africa

J. O. Olowoyo*†, O. O. Agboola and A. E. Alaba***
*Department of Biology, Sefako Makgatho Health Sciences University, Medunsa, Pretoria, 0204, South Africa
**Department of Botany, University of Lagos, Akoka, Nigeria
†Corresponding author: J. O. Olowoyo

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ABSTRACT

Concentration of trace metals from car dust have not been examined from private cars in South Africa. The present study investigated the concentrations of trace metals from selected car dust from three car washing centres in Pretoria, South Africa. Different private cars were selected at three prominent car washing centres in Pretoria, South Africa. Dust samples were collected from these cars and analysed for trace metal concentrations using ICP-MS. The highest mean concentrations for the trace metals were recorded for Mn (862.9 ± 14.65 µg/g). The concentrations of Mn, Zn, Cu and Cr were the highest from all the dust samples. A positive correlation was also noticed for elements such as Pb and Cu, Cu and Zn, Mn and Pb, Cr and Pb and Mn and Cu suggesting a common source for these elements. The geo-accumulation revealed extreme contamination for trace metals Cr, Ni and Zn with values greater than 7. The carcinogenic and non-carcinogenic risk calculated showed that the exposure route was in the order: ingestion > dermal absorption > inhalation. Both the non-carcinogenic and carcinogenic risk calculated for the drivers are less than 1. However, continuous ingestion with an increase in the concentration of these metals may pose serious carcinogenic risk over time. It will therefore be necessary for future research to investigate the relationship between the trace metals in blood of these drivers.

INTRODUCTION

Report from published literature has suggested that there are high levels of trace metals in urban soils of Pretoria, South Africa, due to various factors such as industrialization, vehicular emission and urbanization (Olowoyo et al. 2013, Okonkwo et al. 2009, Lion et al. 2016). The country is currently witnessing a tremendous increase in various developmental projects, which have been linked to an increase in different types of pollutants. Among these pollutants are trace metals, which have been known to be non-biodegradable, capable of resuspension and could be persistent for a very long term in the environment (Amorello et al. 2015, Lau et al. 2014, Chen 2014). Some of these trace metals could be carcinogenic, but have been linked to various diseases in humans ranging from lung diseases, brain damage especially in children, kidney failure and bone diseases (Adgate et al. 2003, IARC 2011, Gao et al. 2015).

Dust has been known to be the main source and sink of atmospheric particulates containing high concentrations of both toxic trace metals and other organic pollutants such as polychlorinated biphenyl (PCBs), polycyclic aromatic hydrocarbons (PAHs) and polyfluorinated compounds (PFCs) (Zhu et al. 2013, Fraser et al. 2013). Gao et al. (2015) stated that dust is the most pervasive factor affecting human health and wellbeing due to its composition. Exposure to polluted dust over a long period of time may cause chronic diseases as a result of inhalation, ingestion and through dermal absorption (Wang et al. 2008).

Generally, the inner environment of cars may be contaminated by polluted dust samples containing trace metals in different ways. These different pathways may include infiltration of dust from outside sources when the car windows are down, vehicular emissions, transfer of particles by wind and adherence to shoes (Popoola et al. 2012, Amorello et al. 2015, Olowoyo et al. 2016). Report from the study of Amorello et al. (2015) showed high concentrations for platinum from settled car dust and were classified as been “extremely contaminated dust”. The study further showed that indoor dust in cars may consist of settled dust on the surface of dashboards, carpets and soil particles that have been tracked or blown into the indoor environment from outdoor.

Pretoria is one of the country’s three capital cities, serving as the seat of the executive branch of government and as a result, the city has witnessed an influx of people from all over the world for the past few years. The population in the city ranged from 700,000 to 2.95 million. There are several means of transportation in the city such as railway, buses and private cars. Weakley & Bickford (2015) noted in a study from Johannesburg South Africa, that private cars (including their use as a passenger or in a lift club) make up almost one-third of regular trips in the city of Johannesburg, and this may be similar to Pretoria. Reports from other studies have shown that settled bus dust may contain high concentration of toxic trace metals such as Pb and that teenager and children are mostly at risk (Gao et al. 2015). It should be noted in South Africa that buses and other forms of transportation are owned by cooperate bodies or government. The cleaning is mostly done by the government or cooperate bodies that own the business, and hence may be uncontrolled by an individual. Since private cars are used as means of transportation daily in the city and given that a sizable number of residents in the city use their private cars daily, exposure to toxic trace metals may have significant effect on their health. The present study therefore seeks to investigate the concentrations of trace metals in some settled car dust brought to car washing centres for cleaning with a view to determine the health risk associated with this exposure.

MATERIALS AND METHODS

Sampling and data collection: The study was carried out from three major car washing centres in Pretoria, South Africa. The three car washing centres were selected based on the numbers of vehicles patronizing the car wash centres in three different major areas of Pretoria namely: Pretoria West, Pretoria Central and Pretoria North. From each of the car washing centres, 10 cars were selected at random with a total of 30 private cars. All the cars, that were selected, were not cleaned or washed for a period of six days and those where the owners/occupants do not use air conditioners but rely on fresh air coming through the car windows. Dust samples were collected before each car wash using a brush. Brushing was done carefully on the surfaces of the dashboards, car mats and car seats. Settled dust samples were collected from the car dashboards, carpets and on the car seats. Coarse particles such as sticks, papers and non-other dust particles were removed manually. Only cars that were using unleaded petrol were used in the study. About 10 g of the settled dust samples were collected from all the cars. The dust samples were then transferred in a sealed container to the laboratory for determination of trace metal content.

For the acid digestion procedure, Supra pure and analytical grade of nitric, hydrochloric, perchloric acids and deionized water were used. To 0.5 g of the dust samples, 5 mL of nitric acid, 3 mL of hydrochloric acid and 2 mL of perchloric acid were added. The samples were then acid digested in a microwave oven express plus 16 vessel Teflon containers. The resulting solution was later made to 50 mL volume with deionized water and analysed for trace metals using ICP-MS.

Data analysis and health risk assessment: All data analysis was done using SPSS 23.0 for windows. Significant differences in the concentrations of trace metals from the three different car washing centres were carried out using analysis of variance (ANOVA). Correlation coefficient was used to determine the relationships that exist among the trace metals determined.

Pollution assessment: Pollution assessment of the dust samples was calculated using the pollution index (Pi) (Snyman & Herselman 2006) method and the geo-accumulation index (I-geo) (Muller 1996). The pollution index was calculated using the formula:

$$\mathrm{P}i = \mathrm{C}i \,/\, \mathrm{S}i \qquad \text{...(1)}$$

Where, Ci represents the concentration of heavy metal i in dust, while Si indicates the relevant standard value for this metal. The Si values for the metals calculated were: 3 mg/kg (Cd), 350 µg/g (Cr), 150 µg/g (Ni), 100 µg/g (Pb) and 200 µg/g (Zn).

The geo-accumulation index was determined using the model:

$$\text{I-geo} = \log_2 (\mathrm{C}i / 1.5\mathrm{B}i) \qquad \text{...(2)}$$

Where, Bi is the soil background concentration of heavy metal i in South African soils and 1.5 is the correction factor. Soil contamination levels using Pi were classified into four grades: $\mathrm{P}i < 1$ unpolluted, $1 \leq \mathrm{P}i < 2$ slight pollution, $2 \leq \mathrm{P}i < 3$ medium pollution, and $\mathrm{P}i \geq 3$ heavy pollution. With the geo-accumulation index, the I-geo was classified into seven grades: I-geo ≤ 0 uncontaminated, $0 <$ I-geo ≤ 1 slightly moderately contaminated, $1 <$ I-geo ≤ 2 moderately contaminated, $2 <$ I-geo ≤ 3 moderately severely contaminated, $3 <$ I-geo ≤ 4 severely contaminated, $4 <$ I-geo ≤ 5 severely extremely contaminated, and I-geo > 5 extremely contaminated.

The health risk assessment was calculated using three pathways namely: dermal, inhalation and ingestion using the formula described by:

$$\text{Ingestion: } \mathrm{ADD}_{\mathrm{ING}} = \frac{\mathrm{CS} \times \mathrm{IR} \times \mathrm{CF} \times \mathrm{FI} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \qquad \text{...(3)}$$

Where, $\mathrm{ADD}_{\mathrm{ING}}$ is average daily doses in ingestion exposure pathway, CS is chemical concentration in dust (µg/g), IR is ingestion rate (200 mg/d^{-1}), CF is conversion factor (10^{-6} kg/mg^{-1}), EF is exposure frequency (230 days/year), ED is exposure duration (3 years), BW is body weight (65 kg), and AT is averaging time (ED × 365 days for non-carcinogens and 70 × 365 days for carcinogens (Van den Berg 1995).

$$\text{Dermal: } ADD_{dermal} = \frac{CS \times AF \times CF \times SA \times ABS \times EF \times ED}{BW \times AT} \quad ...(4)$$

Where, ADD_{DER} is average daily doses in skin contact exposure pathway, CS is chemical concentration in dust (µg/g), AF is soil to skin adherence factor (0.2 mg/cm^2), CF is conversion factor (10^{-6} kg/mg^{-1}), SA is the skin area available for contact (732 cm^2), ABS is absorption factor (0.001) and for arsenic is 0.03 (De Miguel et al. 2007), EF is exposure frequency (230 days/year), ED is exposure duration (3 years), BW is body weight (kg), and AT is averaging time (ED × 365 days for non-carcinogens and 70 × 365 days for carcinogens (Van den Berg 1995).

$$\text{Inhalation: } ADD_{inh} = \frac{CS \times DAIR \times CF \times ED}{PEF \times BW \times AT} \quad ...(5)$$

Where, ADD_{INH} is average daily doses in inhalation exposure pathway, CS is chemical concentration in dust (µg/g), DAIR is daily air inhalation rate (7.6 m^3/day), PEF is the particle emission factor (1.36×10^9 m^3/kg), CF is conversion factor (10^{-6} kg/mg^{-1}), EF is exposure frequency (230 days/year), ED is exposure duration (3 years), BW is body weight (65 kg), and AT is averaging time (ED × 365 days for non-carcinogens and 70 × 365 days for carcinogens (Van den Berg 1995).

RESULTS AND DISCUSSION

The concentrations of the trace metals from all the dust samples collected from all the cars are presented in Tables 1-3. The highest mean concentration for all the trace metals was recorded from one of the cars from the Pretoria Central car washing centre. The highest mean concentrations were recorded for Mn with a mean value of 862.9 ± 14.65 µg/g. The lowest mean concentration for this metal was, however, recorded from Pretoria North with a mean value of 130.2 ± 2.27 µg/g. Observed differences in the concentrations of this metal from the three car washing centres were significant ($p<0.05$). Okonkwo et al. (2009) reported that the level of total Mn concentrations in street dust of Pretoria ranged from 329.1-863.9 µg/g, and the major source of Mn determined was mainly from the combustion of vehicular methylcyclopentadienyl manganese tricarbonyl (MMT) which is used in unleaded gasoline to increase the octane rating.

Concentrations of Pb ranged from 0.81 ± 0.02-59.93 ± 1.56 µg/g. Hg ranged from 0.16 ± 0.07-62.27 ± 1.20 µg/g. Ba was in the range of 0.02 ± 0.01-150.3 ± 10.12 µg/g, and Mo in the range of 0.03 ± 0.01-3.35 ± 0.13 µg/g. The concentration for arsenic was below detection limit of 0.02 µg/g in some of the car dusts, but the concentrations from other cars, where it was detected, was in the range of 0.74 ± 0.18 µg/g-4.92 ± 0.38 µg/g. Zn ranged between 12.27 ± 0.20-498.9 ± 3.00 µg/g. The values for Cu ranged between 5.06 ± 0.07-642.9 ± 3.19 µg/g. Nickel was in the range of 0.57 ± 0.11-83.72 ± 8.75 µg/g, Cr in the range of 0.03 ± 0.00-133.4 ± 4.2 µg/g, and V in the range of 0.31 ± 0.03-173.8 ± 0.40 µg/g.

From the car washing centres from Pretoria North, the mean highest concentrations of the trace metals were in the order Mn > Zn > Ba > Cr > Cu > V > Ni > Pb > As > Hg > Mo, from Pretoria West, the highest mean concentrations was in the order Cu > Zn > Mn > Cr > V > Ni > Ba > Pb >As > Mo > Hg and the order of the highest mean trace metals from Pretoria Central was Mn > Zn > Cu > Cr > Ba > Ni > Pb > V > As > Mo. Generally, trace elements such as Mn, Zn, Cu and Cr were those with the highest concentrations from all the car washing centres. Pearson correlation showed positive correlation for elements such as Pb and Cu, Cu and Zn, Mn and Pb, Cr and Pb, Mn and Cu from each of the car washing centres. Sources of these metals in the environment have been linked previously to vehicular emission and pollution from industries among others. The study of Olowoyo et al. (2013) suggested that the positive correlation found among trace metals associated with vehicular emission might be an indication of anthropogenic source for all these trace metals. This is also followed by a long history of metal contamination in urban environment due to re-suspension which may in turn account for the presence of trace metals in the present study.

The exposure assessment estimated for Cr, Ni, Zn, Cd and Pb are given in Table 4. The health risk assessments were calculated for ingestion, inhalation and dermal absorption. The ADDs were calculated for the minimum, median and maximum concentrations for the metals. The parameters used were stated under the methodology section. The assessment in this study may basically be used for the most frequent car driver. The classification from the International Agency for Research on Cancer (IARC) grouped Cr, Cd and Ni among others as Group 1 carcinogens that may cause lung cancer and to some extent cancers of the nose and nasal sinuses (IARC 2011, Chervona et al. 2012). Pb and Zn may be non-carcinogenic but have been linked to an increased risk of different types of diseases including cardiovascular diseases and neurological diseases both in children and adults. Pb is of major concern because of its ability to cause injury to the central nervous system and also adverse neurobehavioural outcomes if ingested at a toxic level and bioaccumulated in the body over a prolonged period (Changming & Jie 2011, Gagan et al. 2012). Based on the IARC model, our results showed that the most

Table 1: Concentrations of trace metals (μg/g) in cars from a car washing entre in Pretoria North.

	Trace Metals											
Cars	V	Cr	Mn	Ni	Cu	Zn	As	Mo	Ba	Hg	Pb	Cd
1	28.14± 0.77	50.25±1.35	161.8±3.01	14.65±0.48	9.235±0.17	26.55±0.33	3.114±0.08	0.719±0.02	74.79±1.32	0.251±0.02	9.137±0.14	0.129
2	74.63±1.27	41.36±0.75	130.2±2.27	11.84±0.37	11.41±0.02	31.73±0.86	1.281±0.12	0.557±0.11	46.26±0.56	0.137±0.01	12.56±0.28	0.114
3	51.83±0.11	41.72±0.11	373.8±0.68	14.35±0.11	14.12±0.04	37.99±0.36	0.752±0.06	0.16±0.002	21.18±0.08	0.134±0.01	6.308±0.01	0.059
4	22.39±0.57	31.06±1.13	240.1±6.0	13.67±0.26	9.806±0.16	38.79±1.27	0.98±0.8	0.24±0.02	15.45±0.50	0.096±0.16	9.299±0.16	0.045
5	79.48±2.64	67.3±0.64	620.4±9.60	35.12±0.21	89.23±2.75	151.3±1.10	1.298±0.05	0.77±0.03	62.27±1.20	0.104±1.20	12.59±0.09	0.272
6	32.95±0.58	67.15±1.16	297.2±7.44	21.71±0.45	19.38±0.39	113.8±2.17	4.507±0.12	0.558±0.04	22.24±0.46	0.091±0.008	15.35±0.35	0.243
7	39.61±2.58	91.64±6.30	514.4±32.7	30.27±0.84	29.93±1.79	217±13.90	2.198±0.22	0.842±0.06	150.3±10.12	0.112±0.02	21.62±1.40	0.162
8	22.01±1.14	101.1±5.48	284±18.53	61.15±4.04	18.35±1.07	68.3±3.63	0.747±0.18	0.393±0.05	17.04±1.04	0.23±0.023	7.551±0.04	0.169
9	22.07±0.73	89.62±2.61	204±6.50	9.697±0.1	57.85±1.90	136.3±3.61	1.26±0.15	0.395±0.02	16.35±0.41	0.074±0.03	22.69±0.82	0.066
10	23.96±0.14	46.44±0.19	133.4±0.36	9.291±0.20	8.927±0.08	32.93±0.22	1.323±0.10	0.77±0.006	34.17±0.35	0.035±0.007	9.95±0.06	0.115

Table 2: Concentrations of trace metals (μg/g) in cars from a car washing entre in Pretoria West.

	Trace Metals											
Cars	V	Cr	Mn	Ni	Cu	Zn	As	Mo	Ba	Hg	Pb	Cd
1	17.49±0.23	58.17±2.39	250.9±0.56	18.62±0.25	233.2±3.23	671.5±26.1	1.867±0.21	0.957±0.07	74.63±2.77	0.098±0.02	32.8±0.43	0.367
2	36.88±0.75	133.4±4.2	569.9±11.37	36.95±0.63	23.36±0.65	165.4±4.57	2.081±0.07	0.596±0.04	29.65±1.18	0.07±0.01	59.93±1.56	0.188
3	173.8±0.40	42.23±0.95	203.0±1.62	28.53±0.46	34.5±0.33	53.42±1.06	0.506±0.08	0.183±0.02	14.64±0.13	0.06±0.02	7.897±0.07	0.104
4	115.4±4.75	32.41±1.56	301.8±10.90	15.48±0.75	40.43±1.51	99.05±4.72	1.031±0.07	0.728±0.02	30.29±1.59	0.049±0.013	14.01±0.58	0.326
5	81.23±1.83	40.47±3.53	382.7±9.05	18.29±0.90	41.42±1.88	361.30±24.14	1.708±0.20	0.748±0.10	28.68±2.73	0.307±0.13	18.06±0.98	0.257
6	15.8±2.22	48.09±5.57	396.7±48.91	83.72±8.75	24.16±3.14	224.3±25.34	1.203±0.96	0.875±0.14	27.04±3.78	0.465±0.08	13.89±1.65	1.058
7	24.78±1.86	60.99±4.67	313.10±26.41	15.55±0.72	119.50±8.0	187.7±16.75	1.78±0.11	1.897±0.06	23.94±1.73	0.165±0.002	34.65±2.67	0.199
8	20.13±0.71	62.41±3.01	422.9±12.04	17.09±0.48	642.9±31.97	223.9±4.84	2.427±0.66	0.654±0.06	34.0±1.58	0.119±0.04	22.82±0.55	0.175
9	29.31±0.12	65.32±0.17	462.5±5.77	27.19±0.78	157.7±2.06	296.1±4.68	0.839±0.66	0.55±0.02	24.3±0.57	0.11±0.02	11.83±0.21	0.203
10	25.87±0.09	52.89±0.32	512.7±11.44	21.73±0.38	704.4±11.93	316.0±5.48	1.478±0.08	0.661±0.08	22.73±0.07	0.047±0.09	12.01±0.28	0.227

Table 3: Concentrations of trace metals (μg/g) in cars from a car washing entre in Pretoria Central.

	Trace Metals											
Cars	V	Cr	Mn	Ni	Cu	Zn	As	Mo	Ba	Hg	Pb	Cd
1	16.15±0.08	40.56±0.8	204.3±1.39	14.8±0.46	14.89±0.52	186.1±0.64	1.356±1.08	1.33±0.33	13.41±0.35	0.099±0.05	17.58±0.23	0.204
2	33.51±0.03	103.8±0.02	862.9±14.65	38.72±0.61	324.4±6.43	498.9±3.00	4.915±0.38	1.191±0.07	29.77±0.49	0.301±0.06	38.55±0.35	0.343
3	33.51±1.14	103.8±1.91	862.9±14.65	38.72±0.61	324.4±6.42	498.9±3.00	4.915±0.39	1.191±0.07	29.77±0.49	0.301±0.06	38.55±0.35	0.343
4	24.66±0.49	75.53±3.45	350.7±3.34	33.94±1.58	177.5±4.2	239.6±12.11	0.949±0.08	3.357±0.13	50.59±3.03	0.197±0.05	24.95±0.64	0.192
5	20.23±1.12	47.94±0.85	102.0±1.36	11.29±0.13	13.41±0.53	63.77±0.90	<0.02	0.701±0.17	10.55±0.13	0.165±0.07	4.757±0.13	0.106
6	0.035±0.007	0.035±0.003	0.271±0.002	0.573±0.11	0.065±0.007	0.278±0.20	<0.02	0.03±0.01	0.027±0.01	0.171±0.04	0.021±0.002	0.006
7	15.18±0.40	80.69±0.68	184.2±2.57	24.97±0.98	151.3±3.86	256.1±4.49	<0.02	0.968±0.08	18.35±0.37	0.122±0.07	6.157±0.12	0.662
8	6.6987±.28	127.5±6.52	138.0±5.67	37.67±1.33	6.525±0.73	17.58±1.40	<0.02	0.737±0.21	3.28±0.25	0.089±0.008	3.294±0.21	0.092

Table 4: The ADD for ingestion, inhalation and dermal absorption from all the three sites.

		PTA North/Trace Metals					PTA Central/Trace Metals					PTA West/Trace Metals				
		Cr	Ni	Zn	Cd	Pb	Cr	Ni	Zn	Cd	Pb	Cr	Ni	Zn	Cd	Pb
Ing	Min	5.3E-05	1.6E-05	4.55E-05	6.8E-08	1.65E-06	5.14E-08	9.78E-07	4.63E-07	1.72E-08	3.48E-08	5.56E-05	2.66E-05	9.16E-05	1.72E-07	1.35E-05
	Median	1.15E-04	7.09E-05	4.40E-04	2.06E-07	1.08E-05	1.3E-04	4.28E-05	4.39E-04	3.26E-07	3.02E-05	9.98E-05	4.66E-05	3.85E-04	3.95E-07	3.10E-05
	Max	1.7E-04	1.05E-04	3.72E-04	4.63E-07	2.15E-05	2.19E-04	6.64E-05	8.56E-04	1.13E-06	6.61E-05	2.29E-04	1.44E-04	1.15E-03	1.80E-06	1.03E-04
Inh	Min	4.38E-08	1.30E-08	3.70E-08	5.58E-11	1.34E-09	4.18E-11	7.09E-10	3.77E-10	1.39E-11	2.79E-11	4.21E-08	2.01E-08	6.94E-08	1.30E-10	1.10E-08
	Median	9.39E-08	2.0E-08	6.58E-08	1.67E-10	1.75E-08	1.05E-07	3.48E-08	3.57E-07	2.65E-10	2.45E-08	7.56E-08	3.53E-08	2.91E-07	2.99E-10	2.52E-08
	Max	1.4E-07	8.53E-08	3.03E-07	3.77E-10	3.16E-08	1.78E-09	5.40E-08	6.96E-07	9.20E-10	5.38E-08	1.75E-07	0.09E-07	8.73E-09	1.36E-09	8.36E-08
Der	Min	2.66E-06	7.97E-06	2.28E-06	3.43E-09	2.23E-08	2.57E-09	4.89E-08	2.32E-08	8.58E-10	1.72E-09	2.78E-06	1.33E-06	4.58E-06	4.29E-09	6.67E-07
	Median	5.77E-06	1.23E-06	5.89E-06	1.03E-08	1.08E-06	6.48E-09	2.14E-06	2.20E-05	1.63E-08	1.515-06	4.99E-06	2.33E-06	1.92E-05	8.58E-09	1.55E-06
	Max	8.67E-06	5.24E-06	1.86E-05	2.32E-08	1.95E-06	1.09E-05	3.32E-06	4.28E-05	5.66E-08	3.31E-06	1.14E-05	7.18E-06	5.66E-08	1.97E-08	5.14E-06

Min: Minimum value for the trace elements from the different centres, **Med:** Medium values obtained for the trace elements from the different centres and **Max**: maximum value obtained for the trace elements from the different centres; **Ing**: Ingestion, **Inh**: Inhalation and **Der**: Dermal absorption

Table 5: Geo-accumulation index for Cr, Ni and Zn from dust samples collected in cars from the three car washing centres in Pretoria, South Africa.

	PTA North			PTA Central			PTA West		
	Cr	Ni	Zn	Cr	Ni	Zn	Cr	Ni	Zn
1	8.73	7.61	6.54	8.42	7.62	9.35	8.94	7.96	11.20
2	8.45	7.30	6.80	9.77	9.01	10.77	10.14	8.94	9.18
3	8.46	7.58	7.06	9.78	9.01	10.77	8.48	8.57	7.55
4	8.03	7.51	7.09	9.31	8.82	9.71	8.10	7.69	8.44
5	9.15	8.87	9.05	8.66	7.23	7.80	8.41	7.93	10.31
6	9.15	8.18	8.64	1.98	2.92	0.08	8.66	10.12	9.62
7	9.60	8.66	9.57	9.41	8.37	9.81	9.00	7.70	9.36
8	9.74	9.67	7.91	10.07	8.97	5.95	9.41	7.83	9.62
9	9.56	7.01	8.90				9.11	8.50	10.02
10	8.61	7.00	6.85				8.80	8.17	10.11

Table 6: Pollution index for Cr, Ni, Zn, Cd and Pb from dust samples collected in cars from the three car washing centres in Pretoria, South Africa.

	PTA North					PTA Central					PTA West				
	Cr	Ni	Zn	Cd	Pb	Cr	Ni	Zn	Cd	Pb	Cr	Ni	Zn	Cd	Pb
1	0.14	0.10	0.13	0.04	0.09	0.12	0.99	0.93	0.07	0.18	0.17	0.12	3.36	0.12	0.23
2	0.12	0.08	0.15	0.04	0.13	0.30	0.26	2.50	0.11	0.39	0.38	0.24	0.83	0.06	0.60
3	0.11	0.10	0.19	0.02	0.06	0.30	0.26	2.50	0.11	0.39	0.12	0.19	0.27	0.03	0.08
4	0.09	0.09	0.19	0.01	0.01	0.22	0.23	1.20	0.06	0.25	0.09	0.10	0.49	0.11	0.14
5	0.19	0.23	0.75	0.09	0.13	0.14	0.75	0.32	0.04	0.05	0.12	0.12	1.81	0.08	0.18
6	0.19	0.15	0.57	0.08	0.15	8.57E-05	3.8E-03	1.35E-03	3.33E-03	0.01	0.14	0.56	1.12	0.35	0.14
7	0.26	0.20	1.08	0.05	0.22	0.23	0.17	1.28	0.22	0.06	0.17	0.10	0.94	0.63	0.35
8	0.28	0.41	0.34	0.05	0.08	0.36	0.25	0.09	0.03	0.03	0.18	0.11	1.12	0.06	0.23
9	0.26	0.07	0.68	0.02	0.23						0.19	0.18	1.48	0.07	0.12
10	0.13	0.06	0.17	0.04	0.10						0.15	0.15	1.58	0.08	0.12

probable carcinogenic and non-carcinogenic exposure for Cr, Ni, Zn, Cd and Pb from all the sites will be through ingestion followed by dermal absorption and inhalation. The present study only takes into consideration the adult drivers using cars on a daily basis, and the selected parameters used for calculation might not be applicable to the children. However, the major carcinogenic and non-carcinogenic risk will be through the ingestion of dust particles rich in Zn, Cr and Ni from this study. Previous studies have shown that ingestion is the major exposure pathway that may cause cancer when compared with other pathways. Excessive accumulation of these trace metals in the body may cause cancer. For instance, Cr may accumulate in the body tissues leading to pathological changes causing gastrointestinal cancer (Lei et al. 2016). Generally, the exposure routes considered here are < 1 (USEPA 2011) which shows that the pathways considered here are still safe for the drivers, but an increase in the concentration of the metals and exposure may increase the risk.

The pollution index and geo-accumulation index presented in Tables 5 and 6 were only calculated for Cr, Ni, Pb and Zn. The background values for other trace elements determined were not available at the time of writing this paper. The result for the geo-accumulation index revealed that the dust samples collected from the cars from the three car washing centres were extremely contaminated with Cr, Ni and Zn, while the pollution index revealed that the dust samples collected from cars from the car washing centres in Pretoria Central and Pretoria West were slightly polluted with Zn. The report of our study is similar to that reported by Saeedi et al. (2012) where it was noted that the soil and dust samples have elevated concentrations of elements such as Cu, Cr, Pb, Ni, Cd, Zn, Fe and Mn. Similar observation was also made by Keshavarzi et al. (2015) where they evaluated the pollution and chemical speciation of selected heavy metals and noted that Hg, Pb, Zn and Mn are the most toxic elements in street dust samples. The mobility of these metals is important in soils and increases with the pollution level (Dumoulin et al. 2017).

CONCLUSION

The present study determined the levels of trace metals in dust samples collected from cars that are due for washing from three main washing centres in Pretoria. The result of this study suggested an elevated level of Mn in the dust samples collected from all the cars. Mn, Zn, Cu and Cr were the highest trace elements in the study and the positive correlation found with these metals suggested the impact of anthropogenic input. This might be attributed to the replacement of leaded petrol to unleaded petrol introduced in the country since 2005. However, there are considerable amounts of Pb in the environment which may suggest the result of re-suspension of this metal over time. The geo-accumulation and pollution index calculated for some elements such as Cr, Ni and Zn showed that the dust samples were extremely contaminated with these metals and continuous ingestion with an increase in the concentrations of these metals may pose serious carcinogenic risk over time. It will therefore be necessary for future research to investigate the relationship between the trace metals in the blood of these drivers.

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