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Assessment of Levels of Heavy Metals in Paints from Interior Walls and Indoor Dust from Residential Houses in Nairobi City County, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author JKO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AOO, AMS and AOY managed the analyses of the study. Author JKO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study assessed the levels of Pb, Cr, Cd and Zn in settled indoor dust and paint chips.
Study Design: Samples were obtained from twelve selected residential houses within Nairobi County, Kenya.
Place and Duration of Study: GoK Laboratories, Department of Chemistry, JKUAT between February 2016 and November 2016.
Methodology: A modified version of EPA method SW846 3050B was used to digest the samples, and Flame Atomic Absorption Spectrophotometer (Shimadzu AAS-6200) used to analyze samples for the metals. Pearson correlation coefficient was determined for the various metal pairs in paint chips as well as in the dust samples. Also, it was calculated for the given metals in the dust and paint chips samples from a particular sampling point.

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Results: The mean concentration of the metals in both the dust and paint chip samples were in the order Zn>Pb>Cr>Cd. The mean concentrations of Zn, Pb, Cr and Cd were 366.14 µg/g, 129.12 µg/g, 82.65 µg/g, and 27.40 µg/g for the dust samples and 321.77 µg/g, 289.59 µg/g, 77.54 µg/g, and 73.45 µg/g for the paint chip samples respectively. Pb, Cd, and Zn in the paint chips showed a negative relationship while Cr had a positive correlation.
Conclusion: The metals in the paint chips were found to be of common origin while the correlation of the various metal pairs in the dust suggested more diverse sources. Paint from interior walls is not the only contributor of heavy metals in the settled indoor dust.

Keywords: Paint; settled indoor dust; heavy metals; FAAS; residential houses; Nairobi.

1. INTRODUCTION

Pollution within the indoor environment is gradually becoming a concern since people spend most of their time indoors [1,2]. There are numerous potential sources of pollutants that can lead to the indoor human exposure to heavy metals which on accumulation will put the health of the occupants at risk. The availability of the heavy metals within the environment is widespread [3] due to the numerous sources which are either natural or anthropogenic [4]. Of late, the impact of the anthropogenic activities on the levels of the heavy metals has been on the rise [5,6]. The heavy metals resulting from the various sources will eventually end up in the air, water, as well as soil and dust [7]. As a result, indoor pollution remains a vital challenge to the environmental health [8].

The heavy metals exist naturally in the earth's crust [4] in the form of various compounds thus heavy metal pollution will result from natural incidences emanating from geological activities, erosion, and weathering [9]. Anthropogenic activities that either lead to production or consumption of the heavy metals have contributed significantly to heavy metal pollution due to processes such as waste incineration [10], mining, smelting [11], agricultural activities, refineries, petroleum and coal combustion [7], and domestic activities [6]. Most of these activities are more prominent in the urban centers. Consequently, in the urban areas, the heavy metals are currently critical environmental pollutants causing serious public health concerns [12,13] as they are of acute toxicity and carcinogenic especially at elevated levels. Exposure to these elements leads to negative health impacts such ill conditions of the respiratory [14], cardiovascular [1] and gastrointestinal tissues as they interfere with various physiological and biochemical processes. In the long term, some lead to the behavioral problem as they negatively impact neurodevelopment in children [15].

Heavy metal pollution in the indoors can be attributed to non-point source pollution as various activities such as vehicular emissions, atmospheric deposition, construction activities and remains, and outdoor contaminated soils. Therefore, the settled indoor dust is a mixture of particulate matter emanating from both exterior and interior sources [16] hence it functions as a reservoir of pollutants [2]. Inhalation, ingestion and dermal contact with the dust are pathways of the heavy metals into the human body making household dust a significant source of heavy metal pollution [17,18].

Paints are one of the outstanding sources of lead in the environment [19] with the use of lead-based additives during paint manufacture as the major contributor to lead in paints [20]. However, the additives used in paint manufacturing contain not only lead but also other heavy metals [21]. However, lead in paints has attracted a considerable number of studies due to its pronounced negative effects on children in particular [22] with relatively less attention paid to other heavy metals. The exposure to the heavy metals occurs after paint on the walls dry, becoming susceptible to peeling off [19] due to contact with any object unintended or intended as during renovations [23] or construction work [24]. When the paint peels off, it gets mixed with dust within the house likely to enhance the accumulation of heavy metals in the dust [24]. Young children often tend to put their hands into the mouth [25] and in the process, they are prone to chew directly [22] paint bits that have fallen from the walls.

Nairobi City is the leading urban center in Kenya with a population estimate of 3.915 million in 2015 [26] leading to a demand for housing. However, no study has been done to assess the level of heavy metals in the indoor spaces of the residential houses. A study done 2012, established that household paints sold Kenya had an average lead concentration of 14900 ppm [27] but did not cover any other element.

Therefore, this study was designed to determine the levels of four heavy metals: lead (Pb), zinc (Zn), chromium (Cr) and cadmium (Cd) in paint chips from interior walls and also the settled indoor dust in selected residential houses.

2. MATERIALS AND METHODS

2.1 Sampling Procedure

The paint samples were collected through chipping off paint from interior painted walls of 12 randomly picked residential houses in various estates within the Nairobi City County as shown in Fig. 1. The dust samples were collected using a brush and a dustpan. An area of the floor was swept, and the dustpan was used to collect the dust. The areas considered were places with a tendency to accumulate dust which included places such as beneath furniture. Both the paint samples and dust samples were collected from the same room. The collected samples were then stored in polythene bags with seals, and labeled accordingly.

2.2 Sample Preparation

The paint samples were cut into small pieces using a razor. The dust samples were sieved through a 200-micrometer sieve. Approximately 0.5 grams of the samples were weighed and digested using a modified method from the EPA SW 3050B method [28]. Initially, 10 mL of 50% (volume by volume) of nitric acid was added to the sample. The sample was heated for 15 minutes at a temperature of 95℃. It was allowed to cool before 5 mL of nitric acid was added and heating done for 30 minutes. The contents of the flask were allowed to cool. The addition of the 5 mL of nitric acid was repeatedly done until there were no more brown fumes produced. The samples were then heated at 95℃ for 2 hours then cooled. 2 mL of water and 3 mL of 30% hydrogen peroxide was then added to the sample. The mixture was then warmed to start off the reaction. The mixture was then heated at 95℃ until only about 5 mL of the digestate was left. Finally, 10 mL of hydrochloric acid was added and the sampled heated for another 20 minutes at 95℃. The resulting digestate was filtered into 100 mL volumetric flask and topped up to the mark using distilled water. A reagent blank was also prepared. $Zn(NO_3)_2.6H_2O$ (Loba Chemie), $Pb(NO_3)_2$ (Calbiochem-Novabiochem Corporation), $Cd(NO_3)_2.4H_2O$ (Calbiochem-Novabiochem Corporation), and $CrCl_3.6H_2O$ (Griffchem Fine Chemicals) salts were used to prepare Zn, Pb, Cd and Cr calibration standards respectively. The concentration ranges of the working standards were 0.4000-2.5000 ppm for Pb and Cd standards and 0.1000-2.0000 ppm for Cr and Zn. Flame Atomic Absorption Spectrometer (Shimadzu model AA-6200) was used to determine the concentration of the various metal analytes present in the samples.

2.3 Data Analysis

The experimental data was analyzed using the Statistical Package for Social Sciences (IBM SPSS Statistics v.23). Pearson's correlation coefficient was calculated to determine the relationship between the elemental concentrations of a particular metal in the dust and paint chip samples, and also the relationship of metal pairs in the samples.

3. RESULTS AND DISCUSSION

3.1 Metals in Paint Chip Samples

The paint chip samples all recorded the presence of Pb, Zn, Cd, and Cr as shown in Table 1 (mean ± standard deviation). Six of the sampling points had Pb concentrations greater than 90 ppm standard set by WHO. It was established that the household paints sold in Kenya by 2012 are lead-based which explains the presence of Pb in all the samples [27]. For the paint chip samples, there was a considerable range of the concentrations of Pb, Zn, Cr, and Cd. For Pb, the minimum concentration in the dust samples was 22.99 ± 1.98 µg/g (SP11) while the highest concentration was 1638.32 ± 54.93 µg/g (SP10). For Zn, the range was from 228.82 ± 17.48 µg/g (SP5) to 532.47 ± 29.16 µg/g (SP4) while Cr concentrations were in the range of 31.70 ± 3.68 µg/g (SP1 0) to 254.39 ± 16.53 µg/g (SP9). Cd concentrations were in the range 10.51 ± 0.71 µg/g (SP8) to 70.23 ± 2.65 µg/g (SP12). The variations could be due to different locations of the sampling points thus impacting on the contribution of various sources of contamination. SP1 is a few meters from the busy Nairobi – Thika Highway, SP3 and SP4 are in estates with considerable vehicle traffic, while SP5 and SP6 are residential estates with relatively reduced traffic. Therefore, contamination from vehicular emission will vary between these points.

3.2 Metal in Indoor Dust

The mean elemental concentrations of the dust samples are shown in Table 2. Just like the dust samples, there was a considerable range in the concentrations of Pb, Zn, Cr and Cd in the paint chip samples. For Pb, the minimum concentration in the dust samples was 11.04 ± 2.94 µg/g (SP9) while the highest concentration was 740.52 ± 6.75 µg/g (SP10). The concentration ranges for Zn were 38.63 ± 2.94 µg/g (SP6) to 1056.37 ± 52.58 µg/g (SP7), Cr 12.39 ± 1.25 µg/g (SP4) to 189.01 ± 13.12 µg/g (SP8) and Cd 3.07 ± 0.34 µg/g (SP7) to 89.87 ± 8.13 µg/g (SP12). The variation of elemental concentrations in the paint chip could be attributed to the difference in the types of paints and also the various manufacturers. Houses in which emulsion paints are used are expected to have lower levels as opposed to houses in which oil paints were used since the oil paints use pigments based on heavy metals. Also, the level of the heavy metals will be heavily reliant on the manufacturer or brand [29] since the various brands have been established to have substantially different concentrations of the metals. Moreover, the levels of the heavy metals could have been influenced by the number of paint layers from the walls that were sampled. Since the various colour pigments used are of different metals, the colour of the paint sampled could also considerably influence the quantity of the metals present [29].

In some cases, the levels of the heavy metals in the dust samples were higher in comparison to the levels determined in the paint chips (Tables 1 and 2). However, as in Table 3, the mean elemental concentrations of the metals were in the order Zn>Pb>Cr>Cd for both the dust and paint chip samples. The average concentrations of Pb, Zn, and Cd were relatively higher in the paint chips samples compared to dust samples expect for Cr in which the mean concentration of the dust samples was higher. For Pb, 8 out of the 12 sampling sites had higher concentrations in the paint chips in comparison to the dust samples. The cleaning done in the various rooms will impact the levels of the elements in the settled dust, with frequent cleaning ensuring that the accumulation of heavy metals is reduced. The age of the building influences the extent of the deterioration of the interior wall paints which impact on contribution to the heavy metal accumulation in the dust [19].

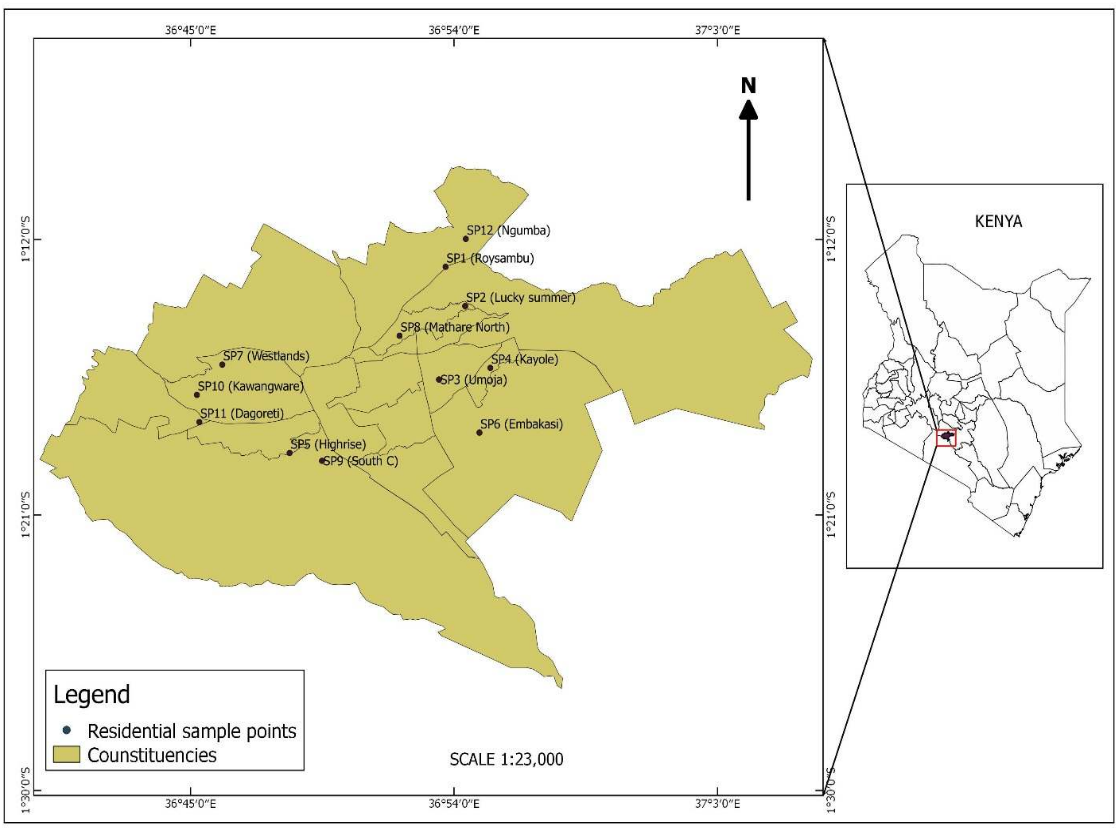

Fig. 1. A map showing the sampling points

Table 1. Concentrations of Pb, Zn, Cr, and Cd in paint chip samples

	Pb	Zn	Cr	Cd
	µg/g	µg/g	µg/g	µg/g
SP1	83.23 ± 3.67	387.79 ± 29.93	19.09 ± 2.54	24.59 ± 2.79
SP2	69.03 ± 9.19	252.84 ± 18.26	49.39 ± 5.59	23.14 ± 1.36
SP3	55.29 ± 7.91	433.88 ± 34.80	52.53 ± 9.36	13.94 ± 1.84
SP4	53.28 ± 3.33	532.47 ± 29.16	97.54 ± 4.99	12.01 ± 1.24
SP5	266.54 ± 7.85	228.82 ± 17.48	111.45 ± 9.74	12.28 ± 0.65
SP6	164.46 ± 5.35	317.08 ± 23.61	75.36 ± 14.22	10.71 ± 0.07
SP7	97.58 ± 7.36	323.36 ± 19.06	44.76 ± 7.14	27.10 ± 3.28
SP8	210.97 ± 14.15	278.26 ± 20.75	160.38 ± 15.29	10.51 ± 0.71
SP9	83.83 ± 3.64	422.80 ± 25.65	254.39 ± 16.53	18.89 ± 0.80
SP10	1638.32 ± 54.93	444.43 ± 15.27	31.70 ± 3.68	11.63 ± 1.22
SP11	22.99 ± 1.98	247.84 ± 16.50	79.83 ± 5.48	15.98 ± 0.99
SP12	95.77 ± 20.38	419.55 ± 29.67	46.69 ± 5.65	70.23 ± 2.65

Table 2. Concentrations of Pb, Zn, Cr and Cd in dust samples

	Pb	Zn	Cr	Cd
	µg/g	µg/g	µg/g	µg/g
SP1	188.90 ± 8.04	65.59 ± 9.19	80.81 ± 9.86	10.48 ± 0.71
SP2	116.34 ± 12.16	51.68 ± 7.99	77.60 ± 8.42	3.82 ± 0.15
SP3	380.34 ± 3.24	156.25 ± 12.45	75.21 ± 7.59	8.06 ± 10.79
SP4	131.70 ± 5.20	157.14 ± 7.91	12.39 ± 1.25	3.73 ± 0.26
SP5	38.25 ± 7.40	47.68 ± 1.83	47.74 ± 7.51	25.15 ± 4.05
SP6	28.95 ± 1.89	38.63 ± 2.94	70.97 ± 6.16	17.66 ± 2.99
SP7	294.15 ± 27.69	1056.37 ± 52.58	161.72 ± 9.78	3.07 ± 0.34
SP8	76.24 ± 2.96	939.43 ± 34.89	189.01 ± 13.12	11.39 ± 0.58
SP9	16.86 ± 1.83	44.29 ± 5.61	106.70 ± 10.02	8.62 ± 0.94
SP10	740.52 ± 6.75	75.50 ± 1.50	29.06 ± 1.30	84.34 ± 2.91
SP11	11.04 ± 2.94	57.35 ± 8.64	118.28 ± 9.94	9.42 ± 0.42
SP12	159.77 ± 9.94	112.37 ± 6.61	137.98 ± 5.05	89.87 ± 8.13

Table 3. The mean concentrations in paint chip and dust samples

Element	Dust sample	Paint chip samples
	µg/g	µg/g
Pb	129.12	289.59
Cr	82.65	77.54
Cd	27.40	73.45
Zn	321.77	366.14

3.3 Pearson Correlation

The Pearson correlation coefficient for the levels of metals between the paint chip and dust samples were showed a negative correlation for Pb (r = - .404), Cd (r = -.030) and Zn (r = -.193) while a positive correlation was found in Cr (r = .163). The relationship between the metals in the paint chips and dust was not significant (p≤0.05). This suggests that Pb, Cd, Cr, and Zn in the paints are not the only source of the metals in the dust [30]. Therefore, the contribution from vehicular emissions, street dust, the number of occupants, housekeeping, and other exterior sources cannot be sidelined. For the paint chip samples, all metal pairs had a positive correlation with varying degree of association. Pb-Cr (r = .677) and Cr-Zn (r = .461) have strong correlation while Pb-Cd (r = .223), Cr-Cd (r = .332), and Pb-Zn (r = .226) have moderate correlations with Cd-Zn (r = .142) having a very weak correlation. This indicates a common origin for the heavy metals [7,31] in the paint chips which could be due to the manufacturers. On the other hand, for the dust samples positive correlation was in Pb-Zn (r = .397) of weak correlation and Cr-Zn (r = .165) very weak correlation with the other pairs giving a negative weak correlation Cd-Zn (r = -384), Cr-Cd (r = -.355), Pb-Cd (r = -.247), and Pb-Cr (r = -.232). The weak to very weak strength of the correlation between the elemental pairs is due to possible independent varying sources of each element [3] in the environment such as Pb-based paints for Pb, galvanized steel materials for Zn [31], road surface wears for Cd, Pb and Zn and deterioration of vehicular parts for Cr [3].

4. CONCLUSION

In this study, it was found that heavy metals are present in both dust and paint chip samples from residential houses which should be a point of concern, in particular, Pb as WHO recommends a lead-free environment. For the dust samples, the elemental concentrations were in the range Zn (228.82 to 532.47 µg/g), Pb (22.99 to 1638.32 µg/g), Cr (31.70 to 254.39 µg/g), and Cd (10.51 to 70.23 µg/g) while for the paint chip samples, it was Zn (38.63 to 1056.37 µg/g), Pb (16.86 to 740.52 µg/g), Cr (12.39 to 189.01 µg/g), and Cd (3.07 to 89.87 µg/g). The interior walls have heavy metals thus posing health risks to young children. The elemental levels of the metals in the settled indoor dust are due to diverse sources making source mitigation challenging, hence frequently cleaning of the rooms should be encouraged to minimize the accumulation of lead in the settled dust in the houses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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