Nkansah et al., *Cogent Chemistry* (2015), 1: 1119005
http://dx.doi.org/10.1080/23312009.2015.1119005

cogent chemistry

ANALYTICAL CHEMISTRY | RESEARCH ARTICLE

Determination of heavy metals in dust from selected nursery and kindergarten classrooms within the Kumasi metropolis of Ghana

Marian Asantewah Nkansah[1]*, Joseph Richmond Fianko[2], Stephen Mensah[1], Michael Debrah[1] and George William Francis[3]

Received: 16 October 2015
Accepted: 03 November 2015
Published: 14 December 2015

*Corresponding author: Marian Asantewah Nkansah, Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
E-mail: maan4gr@yahoo.co.uk

Reviewing editor:
Alexandra Martha Zoya Slawin, University of St. Andrews, UK

Additional information is available at the end of the article

Abstract: The exposure potential of children in nursery and kindergarten schools to metals in dust in the Kumasi Metropolis was studied. Dust samples from 20 selected schools were analyzed for heavy metal levels using atomic absorption spectrophotometry. The results showed that concentrations were in the range of below detection −9.710 µg/g for cobalt, below detection to 33.291 µg/g for chromium, below detection to 41.909 µg/g for lead, below detection to 1.383 µg/g for mercury, while cadmium levels were below detection for all samples. The mean levels of metals therefore decreased in the order: Cr > Pb > Co > Hg and Cd. Geographical variation correlated with heavy metal load. Health risk assessment using hazard quotient (HQ) and hazard index (HI) calculations indicated that ingestion contributed more to exposure than dermal contact. However, the values obtained by HQ and HI do not pose any immediate health risk but the cumulative effect is a matter of concern.

Subjects: Earth Sciences; Environment & Agriculture; Environmental Studies & Management

Keywords: dust; classroom; heavy metals; health risk

1. Introduction

Dust composition has a potential effect on human health. Urban surfaces receive deposits from sources such as vehicular emissions, industrial discharges, domestic heating, waste incineration, and other

ABOUT THE AUTHORS

Marian Asantewah Nkansah, Stephen Mensah and Michael Debrah belong to the same work group at KNUST. Our research interest spans varied areas of environmental chemistry; including pollution studies and remediation. This current work is part of a nation-wide survey of dust from streets, classrooms, and other public places and their potential impact on public health.

Joseph Richmond Fianko is an active member of the nuclear and environmental research center of the Ghana Atomic Energy Commission and collaborates with the University on various environmental research projects including the current work.

George William Francis is an astute professor of chemistry at the University of Bergen with interest in organic and environmental chemistry and has published extensively in a wide range of areas. He also collaborates with our work as part of the North-South Collaboration.

PUBLIC INTEREST STATEMENT

Children love to play on the ground and in sand. In most pre-school classrooms in developing countries, there is the likelihood of finding dust particles either carried from footpaths on the way to school or from the playing ground. The nature of constituents of this dust and the potential harm to children is not a subject of everyday discussion. This work brings to the fore, the potential of the classroom environment causing harm to children due to the presence of toxic metals in dust.

anthropogenic activities through atmospheric transport and local activities (Bris et al., 1999; Christoforidis & Stamatis, 2009; Glorennec, Lucas, Mandin, & Le Bot, 2012; Mingkui & Hao, 2009). Both outdoor and indoor dust have different compositions and are likely to pose health problems through direct inhalation (principally the finest particle sizes e.g. <10 μm) and unintentional consumption due to hand-to-mouth contact by children. Consumption of poorly washed fruits and vegetables are also ingestion routes of dust exposure (<250 μm) (Lorenzi, Entwisie, Cave, & Dean, 2011). Heavy metals are usually non-degradable and their homeostasis mechanism is not well understood. Thus, elevated levels of heavy metals are a potential threat to life. They may accumulate in the fatty tissues of the human body and affect the central nervous system. They may also disrupt the normal functioning of the body's internal organs and sometimes act as cofactors in other diseases (Tong & Lam, 2000). Metals released into the environment may find their way into classrooms possibly through wind action of dust within the school compounds as the kids play around and in dust on footpaths along which they walk to school (Kurt-Karakus, 2012). These metals in dust from kindergarten and nursery classrooms may further accumulate on the skins of the children and other teaching aids the children interact with (Darus, Nasir, Sumari, Ismail, & Omar, 2012). The interaction of children with their classroom environment results in direct interaction by dermal contact or through ingesting (Darus et al., 2012). Young children are more likely to ingest large quantities of dust than adults because of the behavior of licking non-food objects and repetitive hand/finger sucking. Children have a much higher absorption rate of heavy metals from the digestive system and higher hemoglobin sensitivity to heavy metals than adults (Meza-Figueroa, De la O-Villanueva, & De la Parra, 2007).

There is no record of research on the levels of metals in dust from nursery and kindergarten classrooms within the Kumasi metropolis. It is therefore necessary to determine the levels and assess the health implications of the metals on the pupils.

2. Materials and methods

2.1. Study area

2.1.1. Sampling and analysis

Dust samples were collected randomly from nursery and kindergarten schools in the Kumasi metropolis (Figure 1). A total of 20 samples were collected using a small plastic brush (20-cm long) and a small stainless steel (50 ml size) scoop and stored in labeled brown paper envelopes. The dust samples obtained were stored at room temperature in the laboratory.

2.1.2. Sample preparation

Dust samples were air dried at room temperature for 48 h, ground with mortar and pestle. The samples were then passed through a 250 μm sieve to remove the coarse dust components. A mass of 1.0 g of oven-dried lump-free dust samples were subjected to acid digestion using aqua regia, cooled, filtered through No. 42. Whatman filter paper, and analyzed using atomic absorption spectrophotometry (AAS).

2.1.3. Atomic absorption spectrophotometer (AAS) determination and quality assurance

Standard solutions of the heavy metals of interest (Sigma–Aldrich) were prepared and analyzed to obtain calibration curves. The analyte metals (Co, Cr, Hg, Pb, and Cd) were identified with the accurate detection of absorbance of standards. Quantification of heavy metals was obtained using the external calibration curves, and calculations of analyte concentrations were expressed as the dry weight of dust samples. For every sample, a procedural blank, a matrix-spiked sample consisting of all chemicals and matrix-spiked replicates were run to check the interference, and minimize any errors due to losses during the digestion procedure.

2.1.4. Pollution assessment indexes

Assessment of heavy metal contamination offers some insight into the levels of contamination of dust from selected nursery and kindergarten classrooms within the Kumasi Metropolis.

cogent chemistry

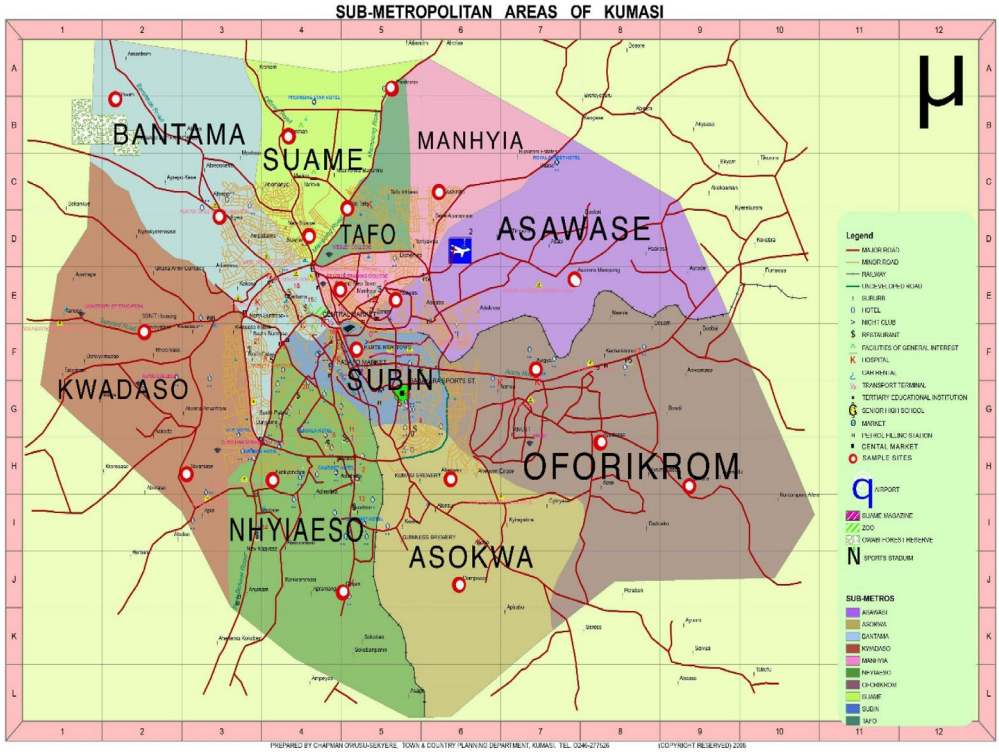

Figure 1. Map of the Kumasi Metropolis indicating sampling sites.

The pollution levels of heavy metals in the dust samples were assessed with geo-accumulation index (Igeo), contamination factor (CF), and pollution load index (PLI) as described below.

2.1.4.1. Geoaccumulation index (Igeo): The Igeo was introduced by Muller (1979) and has been used to evaluate the intensity of heavy metal pollution in dust. The Igeo was estimated with the equation below:

$$\text{Geoaccumulation index} = \log_2\left(\frac{C_m Sample}{1.5 \times C_{\text{ref}}}\right)$$

where C_m Sample is the concentration of the metal in the dust samples, C_{ref} is the concentration of the metal in the reference or background sample, and 1.5 is the background matrix correction factor due to lithogenic effects. The Igeo classification as proposed by Muller (1979) is summarized in Table 1.

2.1.4.2. Contamination factor. The level of contamination of the dust samples by metals was assessed with CF as proposed by Forstner and Wittmann (1983). CF was calculated as:

$$\text{Contamination factor} = \frac{C_m sample}{C_{\text{ref}}}$$

where C_m sample is the concentration of the metal in the dust and C_{ref} is the concentration of the metal in the reference or background sample (Forstner & Wittmann, 1983). Details on the formulae for calculation are presented in Table 2.

2.1.4.3. Pollution load index. PLI for the dust samples was evaluated by the equation below, as proposed by Tomilson, Wilson, Harris, and Jeffrey (1980).

$$PLI = (CF1 \times CF2 \times CF3 \times CF4 \times \ldots CF\eta)1/n$$

Table 1. Categories for geo-accumulation index (Igeo)

Igeo value	IgeoClass	Value of soil quality
Igeo < 0	0	Unpolluted
0 ≤ Igeo < 1	1	Unpolluted to moderately polluted
1 ≤ Igeo < 2	2	Moderately polluted
2 ≤ Igeo < 3	3	Moderately to strongly polluted
3 ≤ Igeo < 4	4	Strongly polluted
4 ≤ Igeo < 5	5	Strongly to very strongly polluted
Igeo ≥ 5	6	Very strongly polluted

Table 2. Classification of contamination factor

CF range	Pollution intensity
CF < 1	Low contamination
1 ≤ CF < 3	Moderate contamination
3 ≤ CF ≤ 6	Considerable contamination
CF > 6	High contamination

Table 3. Summary of the PLI classification

PLI range	Pollution intensity
PLI < 1	Denote perfection
PLI = 1	Present that only base line levels of pollutants are present
PLI > 1	Deterioration of site quality

where, *n* is the number of metals and CF is the contamination factor of each metal in the dust sample. Details on the classification are presented in Table 3.

3. Results and discussion

3.1. Heavy metal concentrations

The results of the analysis of the dust samples for Co, Cr, Hg, Pb, and Cd are presented in Table 4. Detection limits for the metals were 0.001 mg/g for Pb, Cr, Hg, and 0.005 mg/g for Co. Additional statistical distribution of the metals is presented in Tables 5a and 5b.

3.1.1. Concentration of cobalt in samples

The concentration of Co was below detection for 15 of the samples. However, the highest level of Co was 9.716 µg/g for sample FT. In addition to FT, only four schools AS, BY, EM, and DB contained cobalt. Calculation of the average cobalt concentration over the recorded values gave a concentration of 0.576 µg/g dry soil (Table 5a). This average concentration is higher than the levels obtained for all the other samples except FT. This result is in line with an earlier study by Gault et al. (2010), Gault et al. (2010)) who indicated that, exposure level for Co is generally very low. And it is normally throw food or skin contact with substances containing small amounts of cobalt (Gault et al., 2010). According to Tvermoes et al. (2013) the European Food Safety Authority guideline value for non-carcinogenic effects is maintained at 600 µg Co/day. This value was based on a lowest-observed-adverse-effect level of 23 mg Co/kg daily. This dose would represent a maximum lifetime daily Co dose that would be considered "safe" for all age groups and most potentially sensitive subpopulations. The maximum permissible level of cobalt in dust is found to be 20 mg/kg (AbdulRahman, Kusag, & Hassein, 2013). Therefore, it may be said that recorded values of cobalt in this study may not pose any harm.

Table 4. Concentration of heavy metals in samples in µg/g

Sample sites	Co	Pb	Cr	Hg	Cd
BK	b/d	3.530	11.406	0.0525	b/d
NW	b/d	b/d	2.419	0.996	b/d
AS	0.235	4.751	21.193	1.087	b/d
BY	0.927	0.360	5.149	1.383	b/d
AG	b/d	0.365	0.357	1.139	b/d
PK	b/d	3.717	21.211	1.225	b/d
OT	b/d	3.651	33.291	0.910	b/d
AH	b/d	0.607	b/d	0.087	b/d
AM	b/d	b/d	5.173	0.138	b/d
DP	b/d	0.847	b/d	0.035	b/d
BR	b/d	1.218	11.406	b/d	b/d
AT	b/d	9.602	2.419	b/d	b/d
EM	0.353	1.22	21.193	0.035	b/d
FB	b/d	4.268	5.149	0.088	b/d
AD	b/d	3.758	0.357	0.052	b/d
AY	b/d	6.457	21.211	0.088	b/d
SM	b/d	41.909	33.291	0.175	b/d
FT	9.716	6.917	b/d	0.262	b/d
OH	b/d	2.907	5.137	0.296	b/d
DB	0.293	0.243	b/d	0.105	b/d

Note: b/d denotes below detection.

Table 5a. Overall metropolitan statistical description concentration of heavy metal in µg/g

Metal	Co	Pb	Cr	Hg	Cd
Maximum	9.716	41.909	929.204	1.383	b/d
Minimum	b/d	b/d	b/d	b/d	b/d
Mean	0.576	4.816	381.302	0.407	b/d
Median	0.353	3.591	357.321	0.156	b/d
Stdev	3.714	9.219	280.682	0.486	b/d

3.1.2. Concentration of chromium in samples

Chromium concentrations ranged from below 0.001 mg/g (detection limit) to 33.291 µg/g (Table 4). The average concentration of chromium for all the samples in this study was determined to be 9.912 µg/g of dry soil (Table 5a). Comparing to a similar work done by Darus et al. (2012) in Shah Alam Malaysia, the average concentration in the current study was two times that recorded in Shah

Table 5b. Overall metropolitan statistical description concentration of heavy metal in µg/g

Metal	Range	Mean ± Std. Dev	Ref.
Co	0.24–9.72	2.30 ± 3.71	1.29
Pb	0.24–9.73	5.35 ± 9.22	7.91
Cr	0.36–33.29	12.52 ± 10.85	4.67
Hg	0.04–1.38	0.45 ± 0.49	0.26

Note: Ref. denotes concentration metals in reference samples.

Alam. From the results indicated in Table 4, it is obvious that the concentration of SM (33.291) is about 3.4 times greater than the average recorded in the entire study. According to Shanker, Cervantes, Lozatavera, and Avudainayagam (2005) naturally occurring Cr in soil ranges from 10 to 50 mg/kg depending on the parental material. From the results, therefore, it could be seen that the concentration of chromium measured in SM which is the highest concentration of chromium recorded is within the range of expected amounts occurring naturally in the environment. According to Christoforidis and Stamatis (2009), the source of Ni and chromium in street dust is believed to be corrosion of cars. Therefore, the concentration of chromium at SM may be attributed to the siting of automobile shops within 10 meters radius of the school premises. Since the pupils appear to share the same playground with the shop, the dust at the playground is greatly polluted with emissions from the activities of these shops.

3.1.3. Concentration of mercury in samples

The Hg concentrations in the classroom dust are displayed in Table 4. The mercury concentrations in the topsoil ranged from below detection to 1.383 µg/g, with a mean concentration of 0.408 µg/g. The average concentration of Hg in this study is four times lower when compared to a similar work by Sun et al. (2014) in 69 kindergartens in Wuhan China. Schools BR and AT however measured concentration below the detection limit of 0.001 mg/l with BY recording the highest concentration of 1.383 µg/g. Normal levels in soil range from 0.05 to 0.08 µg/g. Mercury concentrations in soil normally do not exceed 0.1 µg/g (European Union, 1998). It is obvious that sample sites AG, BY, AS, and PK recorded values over 10 times the expected amounts in soil. There was no clear link between the levels of Hg and the human activities close to the school.

3.1.4. Concentration of lead in samples

Lead concentration ranged from below detection limit to 41.909 µg/g dry soil according to the results of this study (Table 4). The average concentration of lead was found to be 4.816 µg/g of dry soil samples. Sample schools AM and NW recorded concentration below the detection limit of lead while SM recorded the highest value of 41.909 µg/g which is over eight times higher than the metropolitan average calculated from the study. From Table 4, it can also be observed that apart from AT with lead concentration of 9.602 µg/g, the remaining 18 samples recorded values lower than 10 µg/g, an indication that a concentration of 41.909 µg/g is an outlier. This very high concentration compared to the amounts measured in the other schools may be an indication of an enhancement in the release of lead into the school's environment. According to Karim, Qureshi, Mumtaza, and Qureshi (2013), engine exhausts produced by the fuel combustion, engine wear, the wear of tires, and the associated moving parts, leaks and spills from batteries and radiators greatly account for the release of lead into the environment. Therefore, the high concentration of lead recorded at SM may be partly due to activities of auto-mechanic shops sited just about 10 m away from the school such that these shops appear to share the school compound with the children.

Pupils in SM are at risk of the effect of Pb in the environment since the concentration of Pb measured is over two times the permissible levels of 20 mg/kg (AbdulRahman et al., 2013) in dust.

3.1.5. Concentration of cadmium in samples

From the results of the study, cadmium levels were all below the detection limit of 0.005 mg/l.

3.2. Correlation analysis

The relationship between heavy metal concentrations in dust samples were analyzed using Pearson's correlation coefficient and the results are presented in Table 3. Significant correlation was found to exist between Pb and Cr (R^2 = 0.521) at 0.01 levels (two tailed). This indicates that Pb and Cr might originate from similar pollution sources (Table 6). The other metals were however not correlated.

Table 6. Correlation analysis of heavy metals in dust samples

	Co	Pb	Cr	Hg
Co	1			
Pb	0.036	1		
Cr	−0.213	**0.521***	1	
Hg	−0.028	−0.162	0.184	**1**

*Correlation is significant at the 0.05 level (two tailed).

3.3. Assessment of metal pollution

Pollution measurement indicators used for the assessment of dust in the study area included geo-accumulation index, CF and PLI. Calculated values of the pollution indices are presented in Table 7.

CFs for all the heavy metals in the dust samples ranged from low contamination (CF < 1) for Co and Pb to moderate contamination (1 < CF < 3) for Cr and Hg.

All the dust samples (n = 20) recorded PLI value of 1.02 (PLI < 1) indicating that only baseline levels of pollutants are present. The geo-accumulation index (Igeo) of the metals in this study ranged from unpolluted with Co and Pb (Igeo < 0) to moderately polluted with Cr and Hg which were consistent with the previous results calculated for CF. The order of contamination with these heavy metals is; Cr > Hg > Pb > Co.

3.4. Health risk assessment

In this study, the exposures of students to heavy metal contamination through two pathways (i.e. ingestion and dermal contact) were examined.

The chronic daily intake (CDI) and non-carcinogenic risk (Hazard quotient, HQ) were calculated and the results are presented in Table 8.

From the results, the CDIingest and CDIdermal for all the metals were found to be less than unity (CDI < 1). The HQ values for ingestion and dermal contact were < 1 for Pb, Co, Cr, and Hg indicating

Table 7. Pollution indexes in dust samples

Metal	CF	CF classification	Igeo	Igeo classification
Co	0.45	Low contamination	−1.75	Unpolluted
Pb	0.61	Low contamination	−1.30	Unpolluted
Cr	2.12	Moderate contamination	0.50	Unpolluted to moderately polluted
Hg	1.56	Moderate contamination	0.06	Unpolluted to moderately polluted

Table 8. CDI, non-carcinogenic risks (HQ), and carcinogenic risk through two (2) exposure pathways

Metals	Mean	Chronic daily intake CDI		Non-carcinogenic risk (hazard quotient)	
		Ingestion	Dermal	Ingestion	Dermal
Pb	4.816	1.23E-5	9.80E-9	3.51E-3	2.80E-6
Co	0.576	1.46E-6	1.17E-9	*	*
Cr	9.912	2.52E-5	2.02E-8	1.69E-2	1.35E-5
Cd	b/d	b/d	b/d	b/d	b/d
Hg	0.407	1.03E-6	8.18E-10	6.4E-1	5.00E-4

*The reference dose could not be assessed at the time of the study.

that the students may not experience any significant health risk as indicated in Table 8. The hazard index (HI) is the sum of calculated HQs. HI value > 1 shows that there is a chance that non-carcinogenic effects may occur, whereas a value of HI < 1 shows no significant risk of non-carcinogenic effects. Therefore, the greater the HI values the higher the probability of non-carcinogenic effects (Kurt-Karakus, 2012; Liu et al., 2013). The HI value for the heavy metals through ingestion and dermal contact as a means of exposure was (0.623) and (0.0005), respectively. Heavy metals in dust from selected nursery and kindergarten classrooms in the Kumasi Metropolis poses no significant health risk but the cumulative effect is a matter of concern.

4. Conclusion

This study has provided data on levels of heavy metals in dust from classrooms in selected nurseries and kindergartens in the Kumasi Metropolis. Metal concentrations are quite consistent with concentrations reported for a series of locations worldwide. The mean values of the metals is in the order Pb > Cr > Co > Hg > Cd. Assessment of metal pollution indicated less contamination and health risk assessment revealed that the levels of the metals do not pose any risk to the exposed school children but the cumulative effect of continuous exposure may be harmful.

Acknowledgments
The researchers are grateful to the Department of Chemistry of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and the Nuclear Chemistry, and Environmental Research Center of the Ghana Atomic Energy Commission for the use of their facilities in conducting this research.

Funding
The authors received no direct funding for this research.

Author details
Marian Asantewah Nkansah[1]
E-mail: maan4gr@yahoo.co.uk
Joseph Richmond Fianko[2]
E-mail: jrfianko@yahoo.com
Stephen Mensah[1]
E-mail: skmens27@gmail.com
Michael Debrah[1]
E-mail: abrogates.debrah@gmail.com
George William Francis[3]
E-mail: George.Francis@uib.no
[1] Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
[2] Nuclear Chemistry and Environmental Research Center, Ghana Atomic Energy Commission, Accra, Ghana.
[3] Department of Chemistry, University of Bergen-Norway, Bergen, Norway.

Citation information
Cite this article as: Determination of heavy metals in dust from selected nursery and kindergarten classrooms within the Kumasi metropolis of Ghana, Marian Asantewah Nkansah, Joseph Richmond Fianko, Stephen Mensah, Michael Debrah & George William Francis, *Cogent Chemistry* (2015), 1: 1119005.

References

AbdulRahman, I. Q., Kusag, A. D., & Hassein, A. T. (2013). Measuring the concentrations of some heavy elements indoor and outdoor during dust storms in Anbar province in Iraq. *International Journal of Emerging Technology and Advanced Engineering* (ISSN 2250-2459, ISO 9001:2008 Certified Journal), *3*, 578–582.

Bris, F.-J., Garnaud, S., Apperry, N., Gonzalez, A., Mouchel, J.-M., Chebbo, G., & Thévenot, D. R. (1999). A street deposit sampling method for metal and hydrocarbon contamination assessment. *Science of The Total Environment, 235*, 211–220. http://dx.doi.org/10.1016/S0048-9697(99)00192-8

Christoforidis, A., & Stamatis, N. (2009). Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece. *Geoderma, 151*, 257–263. http://dx.doi.org/10.1016/j.geoderma.2009.04.016

Darus, F. M., Nasir, R. A., Sumari, S. M., Ismail, Z. S., & Omar, N. A. (2012). Heavy metals composition of indoor dust in nursery schools building. *Procedia - Social and Behavioral Sciences, 38*, 169–175. http://dx.doi.org/10.1016/j.sbspro.2012.03.337

European Union. (1998). *Mercury pollution prevention and abatement handbook* (pp. 219–222). World Bank Group.

Forstner, U., & Wittmann, G. T. W. (1983). *Metal pollution in aquatic environment*. New York, NY: Springer-Verlag.

Gault, N., Sandre, C., Poncy, J.-L., Moulin, C., Lefaix, J.-L., & Bresson, C. (2010). Cobalt toxicity: Chemical and radiological combined effects on HaCaT keratinocyte cell line. *Toxicology in Vitro, 24*, 92–98. http://dx.doi.org/10.1016/j.tiv.2009.08.027

Glorennec, P., Lucas, J.-P., Mandin, C., & Le Bot, B. (2012). French children's exposure to metals via ingestion of indoor dust, outdoor playground dust and soil: Contamination data. *Environment International, 45*, 129–134.

Karim, Z., Qureshi, B. A., Mumtaza, M., & Qureshi, S. (2013). Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi—A multivariate spatio-temporal analysis. *Ecological Indicators, 42*, 20–31.

Kurt-Karakus, P. B. (2012). Determination of heavy metals in indoor dust from Istanbul, Turkey: Estimation of the health risk. *Environment International, 50*, 47–55. http://dx.doi.org/10.1016/j.envint.2012.09.011

Liu, X., Song, Q., Tang, Y., Li, W., Xu, J., Wu, J., … Brookes, P. C. (2013). Human health risk assessment of heavy metals in soil–vegetable system: A multi-medium analysis. *Science of the Total Environment, 463–464*, 530–540. http://dx.doi.org/10.1016/j.scitotenv.2013.06.064

Lorenzi, D., Entwisie, J. A., Cave, M., & Dean, J. R. (2011). Determination of polycyclic aromatic hydrocarbons in urban street dust: Implications for human health. *Chemosphere, 83*, 970–977.

Meza-Figueroa, D., De la O-Villanueva, M., & De la Parra, L. M. (2007). Heavy metal distribution in dust from elementary schools in Hermosillo, Sonora, Mexico. *Atmospheric Environment, 41*, 276–288.

Mingkui, Z., & Hao, W. (2009). Concentrations and chemical forms of potentially toxic metals in road-deposited sediments from different zones of Hangzhou. *China. Journal of Environmental Sciences, 21*, 625–631.

Muller, G. (1979). Schwermetalle in den sediment des Rheins, Veranderungem Seit 1971. *Umschau, 79*, 778–783.

Shanker, A. K., Cervantes, C., Lozatavera, H., & Avudainayagam, S. (2005). Chromium toxicity in plants. *Environment International, 31*, 739–753. http://dx.doi.org/10.1016/j.envint.2005.02.003

Sun, J., Yu, M., Lu, Y., Thakur, C., Chen, B., Qiu, P., ... Chen, F. (2014). Carcinogenic metalloid arsenic induces expression of mdig oncogene through JNK and STATS activation. *Cancer Letters, 5*, 65–69.

Tomilson, D. C., Wilson, J. G., Harris, C. R., & Jeffrey, D. W. (1980). Problems in assessment of heavy metals in estuaries and the formation of pollution index. *Helgol Meeresunlters, 33*, 566–575.

Tong, S. T. Y., & Lam, K. C. (2000). Home sweet home? A case study of household dust contamination in Hong Kong. *Science of The Total Environment, 256*, 115–123. http://dx.doi.org/10.1016/S0048-9697(00)00471-X

Tvermoes, B. E., Finley, B. L., Unice, K. M., Otani, J. M., Paustenbach, D. D., & Galbraith, D. A. (2013). Cobalt whole blood concentrations in healthy adult male volunteers following two-weeks of ingesting a cobalt supplement. *Food and Chemical Toxicology, 53*, 432–439. http://dx.doi.org/10.1016/j.fct.2012.11.033