Heavy metal concentration in classroom dust samples and its relationship with childhood asthma: a study from Shiraz, Islamic Republic of Iran

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Abstract

Background: Classrooms are an important environment for young children as this is where they spend a large part of their time.

Aims: This study was designed to quantify the levels of heavy metals in classroom dusts in Shiraz, a city southwestern Iran. The potential association between heavy metal levels and childhood asthma was also investigated.

Methods: We selected 32 schools for collecting classroom dust samples during September–November 2016. The concentration of 10 heavy metals was measured in these dust samples by optical emission spectrometry. The diagnosis of childhood asthma was made using both the medical chart of each student and examination by an allergist. The data were analysed using *SPSS*, version 21.0.

Results: The concentration of heavy metals in classroom dust samples ranged from 7559 to 53 723.0 mg/kg (mean: 16 945.5 mg/kg) for Fe, 169.0 to 952.0 mg/kg (mean 288.9 mg/kg) for Mn, and 9.0 to 971.0 mg/kg (mean 258.8 mg/kg) for Pb. We found no correlation between heavy metals in classroom dust and childhood asthma.

Conclusion: In comparison with studies reported elsewhere, the maximum levels of lead in our study were greater. A potential explanation for the lack of correlation with childhood asthma is the large mass of the particles, preventing them from reaching the lower airways. Nevertheless, special attention should be paid to reducing high levels of heavy metals in classroom dust in this area.

Keywords: asthma, dust, heavy metals, environment, schoolchildren

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Introduction

Heavy metals (HMs) are metals with specific densities greater than 5 g/cm^3 which are found naturally on the earth in very small amounts. Many of these HMs, such as copper, chromium, iron, manganese and zinc, are essential to health. However, if they accumulate in the body in concentrations exceeding a certain threshold, they can cause serious damage to various organs. Soil is the major source for HMs released to the environment; they can enter the human body via direct ingestion of soil via contaminated hands, inhalation of dust and eating polluted plants grown close to roads with heavy traffic or contaminating industries (*1–5*).

Epidemiological and experimental studies have provided evidence for the adverse effects of HMs on respiratory diseases and allergic sensitization (*6,7*). Among these, the metals most commonly associated with allergic diseases of humans are arsenic, cadmium, lead, nickel, chromium and manganese (*8,9*). Human exposure to HMs has been studied mainly by monitoring the concentrations in body fluids such as blood or urine, or by studying their concentrations in ambient air. Chronic exposure to arsenic by drinking groundwater contaminated with low levels of arsenic can be harmful for the respiratory system (*10*), and a high blood level of arsenic is a risk factor for nasal polyposis (*11*). A recent study reported that the concentration of cadmium in the blood was significantly associated with asthma, but not with high total IgE levels (*12*). A high blood lead level in children with asthma has been identified as a risk factor for increasing asthma severity, eosinophilia and elevated immunoglobulin E levels (*13*). A Chinese study reported that the prevalence of asthma and cough was associated with high blood levels of chromium and manganese (*14*). Recent studies have also reported on environmental exposure to several HMs and their adverse effects on the respiratory system. A higher level of ambient nickel was associated with increased respiratory symptoms and wheezing in young children. The rate of emergency department visits and hospitalization for paediatric asthma has increased in areas with higher levels of ambient zinc (*15,16*).

Dust, the main source of HMs, is the preferred non-invasive matrix for metal monitoring. However, information is limited concerning the association between HMs in dust or soil and health care utilization for respiratory diseases, especially among children.

Childhood asthma is increasing and environmental changes due to exposure to more pollutants in outdoor and indoor air are suspected as possible causes. The prevalence of asthma among Iranian children varied from 1.26% to 11.60% by all the studies in an Iranian meta-analysis (*17*). In 2015, a study showed increasing trends in air pollutants and patient admissions due to asthma in Shiraz (*18*). Young children spend much of their time at school, and are therefore exposed to classroom dusts. Dust contaminated with HMs potentially affects the students' health and induces respiratory diseases by inflammation, sensitization and even scar formation in the lung tissues (*19,20*). Few studies have been conducted on the association between asthma and the level of heavy metals in the classroom.

The aim of this study was to measure the levels of 10 HMs, including arsenic (As), cadmium (Cd), chromium (Cr),cobalt (Co),copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) in classroom dust of 4 districts of Shiraz. The potential association between HM levels and childhood asthma was also investigated.

Methods

Study area

Shiraz, the capital of Fars province, has a total area 240 km^2 and a population of around 1.5 million. It is located in the Zagros mountain range in southwestern Islamic Republic of Iran at an elevation of 1486 m above sea level. The city has a moderate climate and an average annual rainfall of about 300 mm. Industrial activities in the city include an oil refinery, a cement factory and a thermal power plant. Shiraz is also one of the major centres for electronic industries: about 50% of the country's electronic investment is concentrated here.

Winds are the principal transport mechanism of dust particles; this city has been affected by dust storms coming from Iraq in warm seasons in recent years. Moreover, gaseous wastes from primitive forms of heating and automobile exhaust along with factory chemicals are the main cause of air pollution in the area studied. In addition to high population growth, the rate of urbanization has also increased: it is now a highly urbanized area.

Sample collection

Sampling was carried out in the main area of the city, which was divided into 4 educational districts based on geographical area. Moshir crossing is the central point of the division: the 1st district is the north-western, 2nd north-eastern, 3rd south-western and 4th south-eastern sectors of the city. We randomly selected 2 primary schools and 6 high schools in each of the subdomains. From each school, 4 dust samples were collected from 2 classrooms and they were mixed to form a single sample for examination. Thus, 8 dust samples were collected from the primary schools (children aged 6–11 years) and 24 from the high schools (children aged 12–17 years) during September–November 2016. The principals of schools were asked not to clean the classrooms for 1 week prior to dust collection. Dust samples were collected from window sills, bookshelves, and corners in the classrooms using a clean plastic brush, tray and containers. The study protocol was approved by the ethics committee of Shiraz University of Medical Sciences (approval number: 12988).

Sample preparation and analysis

The samples were immediately put in polythene bags, labelled and transported to the laboratory. Large pieces of grit and dirt were removed from the dried dust samples and then they were passed through a 2 mm stainless steel sieve. The fraction < 2 mm was ground using an agate mortar and pestle, and passed through a 63 micron sieve. In order to determine the concentration of metals (As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb and Zn), we carried out complete dissolution of dust samples (approximately 1 g of each), using a mixture of HF, HNO_3, $HClO_4$ and H_2O_2 in a Teflon beaker in a sand bath at atmospheric pressure. The concentrations of the 10 heavy metals were determined by an accredited commercial laboratory (Zar Azma Laboratory, Tehran) using inductively coupled plasma mass spectrometry (ICP-MS) methods (Agilent 7700x, Agilent Technologies, Santa Clara, California). Detection limit for the analysed metals was: As 0.1 mg/kg, Cd 0.1 mg/kg, Co 1 mg/kg, Cr 1 mg/kg, Cu 1 mg/kg, Fe 100 mg/kg, Mn 5 mg/kg, Ni 1 mg/kg, Pb 1 mg/kg and Zn 1 mg/kg.

Subjects and environmental questionnaire

We used 2-stage cluster sampling; in the first stage, all schools in each of the 4 subdomains were considered a cluster and 8 schools were randomly selected. In the second stage all classes in the selected schools were considered a cluster and 2 classrooms were randomly selected. We considered all students in these selected classes as our sample.

All students at the time of entering the school have a health record which is completed free by a different general practitioner every year. Collection of data from the medical records of students was authorized by the Department of Education in Shiraz and the principal of each school.The same allergist examined the student health records, completed the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire by interview and carried out a physical examination of all students in 2 random classes of each school for diagnosis of childhood asthma (*21*).

A school environment questionnaire was created for this study by the authors; it was completed by the principal of the school to obtain information about the education level (primary school or high school), the surface area of school, age of school building, number of students in each class, number of students in school, air conditioning (heating and cooling elements), mechanical ventilation and the number of trees in the school yard. Information about HMs in street dust related to this area (Shiraz) was taken from a 2015 study for comparison with our data (*22*).

Statistical analysis

<body1>The Mann–Whitney U-test and analysis of variance (ANOVA) were used to compare the level of heavy metals in the sample schools and other areas. Pearson correlation was done for assessing the association between heavy metals in classroom dusts with the area of the school, age of the school building, number of students in each class, number of students in school and the number of trees. We used independent sample *t*-test for comparing the means. Analyses were performed using *SPSS*, version 22, and statistical significance was set at $P < 0.05$.

Results

A total of 32 schools were selected for classroom dust sampling, 8 (25%) primary schools and 24 (75%) high schools. Out of 11 001 students in the selected schools, 856 (7.78%) had asthma. Descriptive data of the schools are shown in Table 1.

The mean, minimum and maximum concentrations of 10 HMs across the sampling sites are shown in Table 2. Descriptive statistics showed, in decreasing order of concentration, Fe> Mn > Pb > Zn >Cr >Cu >Ni > Co > As > Cd in the classroom dusts; the concentration of Fe, which had the highest level (mean 16 945.5 mg/kg), was more than 5 times greater than the concentration of Mn (2nd highest level; mean 288.9 mg/kg).

The results of the Mann–Whitney U-test showed there was no difference between the level of heavy metals in dusts of classrooms in primary schools and high schools ($P = 0.1$).

Sampling was done in 4 districts; the results of the Kruskal–Wallis test showed that levels of Zn ($P = 0.007$) and As ($P = 0.005$) were significantly higher in the 3rd district. We found no correlation between the surface area of the school, age of the school building and the number of trees in the school with the concentration of HMs in classroom dusts.

Comparison of the mean content of 10 heavy metals in this study with urban street dust of previous study (*21*) in this area is shown in Table 2. The levels of chromium and lead in classroom dusts were significantly higher than in street dust in Shiraz. All selected schools had air conditioning, including heating and cooling devices; mechanical ventilation was not found in any school.

There was no correlation between single HMs in the classroom dusts and childhood asthma (Table 3). The sum of 10 heavy metal variables was assessed as a single variable. Pearson correlation showed that there was a negative relationship between the sum of HM levels and number of students diagnosed as having asthma, but this was not statistically significant (r = –0.18, P = 0.30).

Discussion

This study presents the concentration of HMs in classroom dust in selected primary and high schools in Shiraz. The mean values of the metals were Fe > Mn > Pb > Zn > Cr > Cu > Ni > Co > As > Cd in our classroom dusts. Sources of HMs in schools could be natural outdoor sources, including industrialization, vehicle emissions and street soil, or via indoor activities carried out within the building by the students.

Consistent with our findings, a study in Malaysia showed a high Fe concentration in indoor floor dust in 3 nursery schools and another Malaysian study found elevated levels of Fe in dust samples from 10 preschools (*23,24*). Iron is abundant in the Earth's crust and motor vehicle emissions are also a main source of ambient Fe (*25,26*). It may be transmitted to schools via airflow stream and wind. Small amounts of iron are required for maintaining good health, but large amounts lead to cellular damage, mutation and other diseases (*27*).

In a study on the dusts of 51 French classrooms at 17 nurseries and primary schools, the highest metal loadings were for Mn and Cu, however, Fe was not measured (*28*). Manganese is the 12th most abundant HM on earth and is often found in combination with Fe; it was the second most common HM in our study. Automobile traffic density is strongly correlated with increased atmospheric Mn concentrations. It is an essential metal for health, however, excessive exposure can cause neurodegenerative disorders in humans (*29*).

Comparison of HM concentrations between our classroom dust samples with the findings of a study from classrooms in Ghana showed that the levels of Fe, Co and Pb were several-fold greater in the our study (Fe 16 945.5 mg/kg vs 4.8, Co 6.3 mg/kg vs 0.5, Pb 258.8 mg/kg vs 31.2) (*30*). The mean concentration of Co was 12.5 times greater in our study than in the Ghana study; nevertheless, a dose of ≤ 23 mg/kg of Co is considered safe for all age groups (*31*). Cobalt compounds have been used for centuries to impart a rich blue colour, and more recently cobalt has been mostly used in batteries for mobile devices.

Lead concentration ranged from 9 to 971 mg/kg according to our results; perhaps this wide range was because some schools are near and some far from the main streets. In indoor dust in areas with heavy traffic, Pb concentration has been reported to be in the range of 5.80–639.10 mg/kg (*5*): the range of Pb in our classroom dust was much greater than that. There has been heavier traffic in recent years. According to the Shiraz Traffic Organization report, the number of vehicles increased from 250 000 in 2007 to 700 000 in 2014 (*32*). An effective way of maintaining a clean classroom is certainly by installing mechanical ventilation systems to reduce the level of indoor HMs, but costs and energy expenditure are often high.

The concentration of HMs in indoor dust varies depending on the location. We did not find any relationship between the concentrations of HMs in the dust of classrooms with school demographics; only the level of metals was shown to be significantly higher in the 3rd district. Rahmat Highway is a main road in the 3rd district, running from Motahari Boulevard east to Modarres Boulevard, where it becomes Sardaran Boulevard. The schools in this district are located in the old centre of Shiraz, an area subject to heavy traffic and automobile emissions, which highlights the need to pay attention to HM contamination in children's schools.

The concentrations of HMs in Shiraz classroom dust were compared with data reported for street dusts in the same area. The level of Cr and Pb in classroom dusts was significantly higher than that in street dust; it may be an indication of an increase in the release of Cr and Pb into the school environment. Chromiu is extensively used in paper production industries, and Cr in the school dust might be attributed to the use of paper and books in classrooms. Lead, as an indoor pollutant, could be generated from such sources as building materials, cleaning and hygiene products, computers and printers (*33*). The range and mean concentration of As, Cu, Mn, Ni and Zn were greater in the street dust than the classrooms dust; without doubt, street dust is much more easily polluted by outdoor particles in this area.

Indoor pollutants inside such buildings as home, the work environment, and school have been well recognized as influencing human health due to the chronic nature of the exposure. Despite this, our findings showed that none of HMs in classroom dusts correlated with the symptoms of childhood asthma. A study from Glasgow, Scotland, reported a strong association between soil Ni levels ≥ 1038 mg/kg and respiratory cases (*34*). The maximum level of Ni was 117 mg/kg in our study; therefore, the low quantity of Ni particles in dusts may be the reason for low level of asthma in our children. There are insufficient data in previous research for comparison of classrooms dust HM content with respiratory diseases and asthma.

A number of studies have shown the effect of airborne HM concentration on respiratory health. A study in Japan evaluated the association between changes in airborne HM levels including Fe, Mn, Cd and Cr with increasing cough (*20*). In a study from New York, increased probability of wheezing was associated significantly with increased level of ambient Ni and V (vanadium) (*15*). A recent study has shown that exposure to ambient Mn, Ni and Cr might be associated with adverse respiratory symptoms in Italian adolescents (*35*).

Particle penetration fractions into the deepest part of the respiratory system depend on the size, shape and quantity of elements. It appears that settled HM particles in dust are larger and heavier than airborne HMs and might not reach deeply into the airways. It may also related to the small diameter of the lower airways in children, making entrance of HM particles difficult in this age group.

In conclusion**,** the concentrations of Pb were higher in classroom dusts of Shiraz than the values now being reported in the more developed countries and in street dust. Improved ventilation and regular cleaning procedures in schools as well as control of air pollution can decrease the levels of HM loading in classroom dusts. Although we did not find any relationship between the concentrations of HMs in classroom dusts and asthma, large sample size and longitudinal studies are suggested to evaluate developing asthma in older age.

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References

1. Tóth G, Hermann T, Da Silva MR, Montanarella L. Heavy metals in agricultural soils of the European Union with implications for food safety. Environ Int. 2016;88:299–309. doi:10.1016/j.envint.2015.12.017.
2. Zhao Q, Wang Y, Cao Y, Chen A, Ren M, Ge Y, et al. Potential health risks of heavy metals in cultivated topsoil and grain, including correlations with human primary liver, lung and gastric cancer, in Anhui province, Eastern China. Sci Total Environ. 2014;470–1:340–7. doi:10.1016/j.scitotenv.2013.09.086
3. Soodan RK, Pakade YB, Nagpal A, Katnoria JK. Analytical techniques for estimation of heavy metals in soil ecosystem: a tabulated review. Talanta. 2014;125:405–10. doi:10.1016/j.talanta.2014.02.033
4. Moghtaderi T, Mahmoudi Sh, Shakeri A, Masihabadi MH. Heavy metals contamination and human health risk assessment in soils of an industrial area, Bandar Abbas – South Central Iran. Hum Ecol Risk Assess. 2018;24(4):1058–73. doi.org/10.1080/10807039.2017.1405723

5. Tan SY, Praveena SM, Abidin EZ, Cheema MS. A review of heavy metals in indoor dust and its human health-risk implications. Rev Environ Health. 2016 Dec;1;31(4):447–56. doi:10.1515/reveh-2016-002

6. Daisey JM, Angell WJ, Apte MG. Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. Indoor Air. 2003;13(1):53–64. doi:10.1515/reveh-2016-0026

7. Zhao Z, Zhang Z, Wang Z, Ferm M, Liang Y, Norbäck D. Asthmatic symptoms among pupils in relation to winter indoor and outdoor air pollution in schools in Taiyuan, China. Environ Health Perspect. 2008;116(1):90–7. 10.1289/ehp.10576

8. Corradi M, Mutti A. Metal ions affecting the pulmonary and cardiovascular systems. Met Ions Life Sci. 2011;8:81–105.

9. Jomova K, Valko M. Advances in metal-induced oxidative stress and human disease. Toxicology. 2011;10;283(2–3):65–87. doi:10.1016/j.tox.2011.03.001

10. Das D, Bindhani B, Mukherjee B, Saha H, Biswas P, Dutta K, et al. Chronic low-level arsenic exposure reduces lung function in male population without skin lesions. Int J Public Health. 2014;59(4):655–63. doi:10.1007/s00038-014-0567-5.

11. Khlifi R, Olmedo P, Gil F, Chakroun A, Hamza-Chaffai A. Association between blood arsenic levels and nasal polyposis disease risk in the Tunisian population. Environ Sci Pollut Res Int. 2015;22(18):14136–43. doi:10.1007/s11356-015-4666-5.

12. Park S, Lee EH, Kho Y. The association of asthma, total IgE, and blood lead and cadmium levels. J Allergy Clin Immunol. 2016;138(6):1701–3. 10.1016/j.jaci.2016.04.030.

13. Wang IJ, Karmaus WJJ, Yang CC. Lead exposure, IgE, and the risk of asthma in children. J Expo Sci Environ Epidemiol. 2017;27(5):478–83. doi:10.1038/jes.2017.5.

14. Zeng X, Xu X, Zheng X, Reponen T, Chen A, Huo X. Heavy metals in PM2.5 and in blood, and children's respiratory symptoms and asthma from an e-waste recycling area. Environ Pollut. 2016;210:346–53. doi:10.1016/j.envpol.2016.01.025.

15. Patel MM, Hoepner L, Garfinkel R, Chillrud S, Reyes A, Quinn JW, et al. Ambient metals, elemental carbon, and wheeze and cough in New York City children through 24 months of age. Am J Respir Crit Care Med. 2009;180(11):1107–1113. doi:10.1164/rccm.200901-0122OC.

16. Hirshon JM, Shardell M, Alles S, Powell JL, Squibb K, Ondov J, et al. Elevated ambient air zinc increases pediatric asthma morbidity. Environ Health Perspect. 2008;116(6):826–31. doi:10.1289/ehp.10759.

17. Hassanzadeh J, Mohammadbeigi A, Mousavizadeh A, Akbari M. Asthma prevalence in Iranian guidance school children, a descriptive meta-analysis. J Res Med Sci: Official J Isfahan University of Medical Sciences. 2012;17(3):293–7.

18. Moghtaderi M, Zarei M, Farjadian S, Shamsizadeh S. Prediction of the impact of air pollution on rates of hospitalization for asthma in Shiraz based on air pollution indices in 2007–2012. Open J Air Pollution. 2016;5(2):37–43.

19. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol. 2014;7(2):60–72. doi:10.2478/intox-2014-0009.

20. Nguyen TT, Higashi T, Kambayashi Y, Anyenda EO , Michigami Y, Hara J, et al. A longitudinal study of association between heavy metals and itchy eyes, coughing in chronic cough patients: related with non-Immunoglobulin E mediated mechanism. Int J Environ Res Public Health. 2016;7:13(1):110. doi:10.3390/ijerph13010110

21. Lukrafka JL, Fuchs SC, Moreira LB, Picon RV, Fischer GB, Fuchs FD. Performance of the ISAAC questionnaire to establish the prevalence of asthma in adolescents: a population-based study. J Asthma. 2010 Mar;47(2):166–9. doi:10.3109/02770900903483766

22. Keshavarzi B, Tazarvi Z, Rajabzadeh MA, Najmeddin A. Chemical speciation, human health risk assessment and pollution level of selected heavy metals in urban street dust of Shiraz, Iran. Atmospheric Environment.2015;119:1–10. doi.org/10.1016/j.atmosenv.2015.08.001

23. Darus FM, Nasir RA, Sumari SM, Ismail ZS, Omar NA. Heavy metals composition of indoor dust in nursery schools building. Procedia Soc Behav Sci 2012;38:169–75. doi:10.1016/j.sbspro.2012.03.337

24. Latif MT, Saw MY, Saad A, Mohamad N, Baharudin NH, Mokhtar MB, et al. . Composition of heavy metals in indoor dust and their possible exposure: a case study of preschool children in Malaysia. Air Qual Atmos Health 2014;7:181–93.

25. Lutgens FK, Tarbuck EJ. Essentials of Geology, 7th ed. Upper Saddle River, NJ. Prentice Hall, 2000.

26. Poulakis E, Theodosi C, Bressi M, Sciare J, Ghersi V, Mihalopoulos N. Airborne mineral components and trace metals in Paris region: spatial and temporal variability. Environ Sci Pollut Res Int. 2015;22(19):14663–72. doi:10.1007/s11356-015-4679-0

27. Grazuleviciene R, Nadisauskiene R, Buinauskiene J, Grazulevicius T. Effects of elevated levels of manganese and iron in drinking water on birth outcomes. Polish J Environ Stud.2009:18(5):819–25.

28. Canha, N, Mandin, C, Ramalho O, Wyart G, Ribéron J, Dassonville C,et al. Exposure assessment of allergens and metals in settled dust in French nursery and elementary schools. Atmosphere 2015;6, 1676–94. doi:10.3390/atmos6111676

29. Avila DS, Puntel RL, Aschner M. Manganese in health and disease. Met Ions Life Sci. 2013;13:199–227. doi:10.1007/978-94-007-7500-8_7

30. MA Nkansah, JR Fianko, S Mensah, M Debrah, GW Francis. Determination of heavy metals in dust from selected nursery and kindergarten classrooms within the Kumasi metropolis of Ghana. Cogent Chemistry. 2015;1(1):1–9.

31. Tvermoes BE, Finley BL, Unice KM, Otani JM, Paustenbach DJ, Galbraith DA. Cobalt whole blood concentrations in healthy adult male volunteers following two-weeks of ingesting a cobalt supplement. Food Chem Toxicol. 2013;53:432–9. doi:10.1016/j.fct.2012.11.033

32. Office of Transport and Traffic report. Shiraz: Shiraz Municipality; 2015.

33. Wright NJ, Thacher TD, Pfitzner MA, Fischer PR, Pettifor JM. Causes of lead toxicity in a Nigerian city. Arch Dis Child. 2005;90:262–6. doi:10.1136/adc.2003.043562

34. Morrison S, Fordyce FM, Scott EM. An initial assessment of spatial relationships between respiratory cases, soil metal content, air quality and deprivation indicators in Glasgow, Scotland, UK: relevance to the environmental justice agenda. Environ Geochem Health. 2014;36(2):319–32.

35. Rosa MJ, Benedetti C, Peli M, Donna F, Nazzaro M, Fedrighi C, et al. Association between personal exposure to ambient metals and respiratory disease in Italian adolescentsa cross-sectional study. BMC Pulm Med. 2016 Jan;12(16):6. doi:10.1186/s12890-016-0173-9.

Table 1. Descriptive data of 32 selected schools in Shiraz, 2016

Characteristic	**Minimum**	**Maximum**	**Mean**	**SD**
Area of school (m^2)	1900	20000	5443.7	4502.9
Age of school building (years)	2	54	22.8	15.1
No. of classrooms in the school	5	50	14.62	7.1
No. of trees in the school	5	150	26.8	34.5
No. of students in each school	64	700	343.7	153.1
No. (%) of asthma cases in each school	8 (3.3)	84 (15.0)	26.7 (9.1)	3.5

Table 2. Comparison of heavy metal concentrations in classroom dust samples in Shiraz (2016) and urban street dust reported in a 2015 study (*22*)

Metal	Mean (mg/kg)	SD	Minimum (mg/kg)	Maximum (mg/kg)	*P*-value
As					
Classroom dust	2.8	1.7	0.2	8.8	< 0.001
Street dust	6.6	0.8	5.3	8.6	
Cd					
Classroom dust	1.0	2.3	0.2	13.5	0.3042
Street dust	0.5	0.2	0.3	0.9	
Co					
Classroom dust	6.4	2.96	3.10	16.1	–
Cr					
Classroom dust	172.8	122.1	50.0	514	0.0007
Street dust	67.2	12.9	31.6	105.9	
Cu					
Classroom dust	40.0	22.4	14.0	118.0	
Street dust	136.3	51	49.8	232.5	< 0.001
Fe					
Classroom dust	16 945.5	8 691.1	7 559.0	53 723.0	0.0973
Street dust	20 254.6	2 636.3	16 300.0	24 900.0	
Mn					
Classroom dust	288.9	156.1	169.0	952.0	0.0002
Street dust	438.5	73.2	245.0	652.0	
Ni					
Classroom dust	50.1	22.5	25.0	117.0	< 0.001
Street dust	77.5	14.7	39.4	117.9	
Pb					
Classroom dust	258.8	268.2	9.0	971.0	0.0220
Street dust	115.7	56.3	36.8	234.3	
Zn					
Classroom dust	258.8	210.6	26.0	829.0	0.0142
Street dust	403.5	180.5	160.9	778.3	

SD = standard deviation.

Table 3. Correlation between heavy metal levels in classroom dusts and proportion of students who have asthma, Shiraz 2016

Metal	Students with asthma (%)	
	Pearson correlation	*P*-value
As	–0.049	0.788
Cd	–0.226	0.214
Co	–0.069	0.62
Cr	–0.005	0.979
Cu	–0.170	0.352
Fe	–0.102	0.578
Mn	–0.270	0.136
Ni	–0.122	0.505
Pb	–0.002	0.992
Zn	–0.078	0.673