International Journal of GEOMATE, Dec., 2018 Vol.15, Issue 52, pp.30 - 37
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.52.8197
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

CONCENTRATIONS OF METAL(LOID)S IN OUTDOOR AND INDOOR DUST FROM RUSSIAN CITY

*Tatyana G. Krupnova[1], Irina V. Mashkova[1], Svetlana V. Gavrilkina[2], Evgeniy D. Scalev[1] and Nikita O. Egorov[1]

[1]Chemistry Department, South Ural State University, Russia; [2] Ilmen State Reserve, Russian Academy of Sciences, Ural Branch, Russia

*Corresponding Author, Received: 05 Oct. 2018, Revised: 29 Jun. 2018, 03 Oct: 00 Dec. 2018

ABSTRACT: The metal(loid)s content in the environment is one of the important issues in the environmental management. The metal(loid)s may be present in the both from naturals like natural components of the Earth's crust and anthropogenic sources as human activity effects. Some metal(loid)s are toxic and dangerous for the environment. Chelyabinsk was chosen for researching as a typical industrial Russian city. Road dust and household dust were collected to investigate the contamination of metal(loid)s (Cr, Ni, Cu, Zn, As and Pb) in outdoor and indoor urban. A total of 32 road dust and 17 household dust samples were collected in the urban area during August 2017. The concentrations of metal(loid)s in the dust samples were determined using Analyst 400 (Perkin-Elmer) atomic absorption spectrometer with a flame atomization mode. The study shows that Zn has the highest content in road dust whilst in household dust, both As and Ni have the highest content. Cu, Pb, Zn and Cr contamination were significantly elevated in the outdoor and indoor dust.

Keywords: Metal(loid)s, road dust, household dust, urban area

1. INTRODUCTION

Dust is a common urban air pollutant. It plays an important role in human health. One of the most dangerous components of urban dust is heavy metals and metal(loid)s. There is a lot of research dealing with the contents of metal(loid)s in the street and household floor dusts [1]-[5].

The exposure to inhalable airborne particulate matter in the size range <10 μm (PM_{10}) and <2 μm ($PM_{2.5}$) emissions from roads is implicated as detrimental to human health [1], [6], [7]. Especially household dust is dangerous and associated with increased risk of respiratory illnesses [8] because It is reported that people have more than 70% of the daytime stay at indoor environment [9], [10].

Road dust is generated by many different sources and activities such as public transportation emission [11]-[13], industrial emission [13], [14], surface particles erosion of buildings and roads [14] and other human activities [14], [15]. It is known that the large number of PM_{10} is mechanically generated by studded tires and traction material during cold winter in regions as Russia, Nordic countries, the northern part of USA, Canada [16].

Also, metal(loid)s can transfer from the outdoor to the indoor by the soil or dust that stick to footwear [17] and by outdoor air drift in-house [18]. The concentrations of metal(loid)s in house dust depends on the chemical composition of the soil and outdoor dust [17], the height of the building, the frequency and time of windows opened [19], the number of residents and pets in house, smoking, sweeping frequency, the use of air conditioning and rubber carpet products, paint and cooking frequency [19], [20].

There is no study of metal(loid)s content in indoor dust and limited studies [21] of outdoors urban dust in Russia during recent years.

The aim of this work was to investigate contamination and distribution of metal(loid)s in outdoor and indoor dust collected from the Chelyabinsk urban area.

2. METHODS

2.1 Study area

Chelyabinsk is an industrial Russian city. It is located at the geographic coordinates of 55°N and 61°E (Fig. 1). The main sources of pollution in Chelyabinsk are equally industry and transport [22]. The population of Chelyabinsk is 1,199 thousand people [23] with more than 390 thousand registered motor vehicles [24].

Sampling was carried out in August 2017. A total of 17 indoor dust samples were collected from an urban area (12 residential and 5 office). Also, we collected 32 outdoor dust samples. Figure 2 shows the location of sampling sites in the study area.

2.2 Sampling

At the sampling sites, about 250-500 g of road dust sample was collected by vacuum cleaner from each site in August 2017.

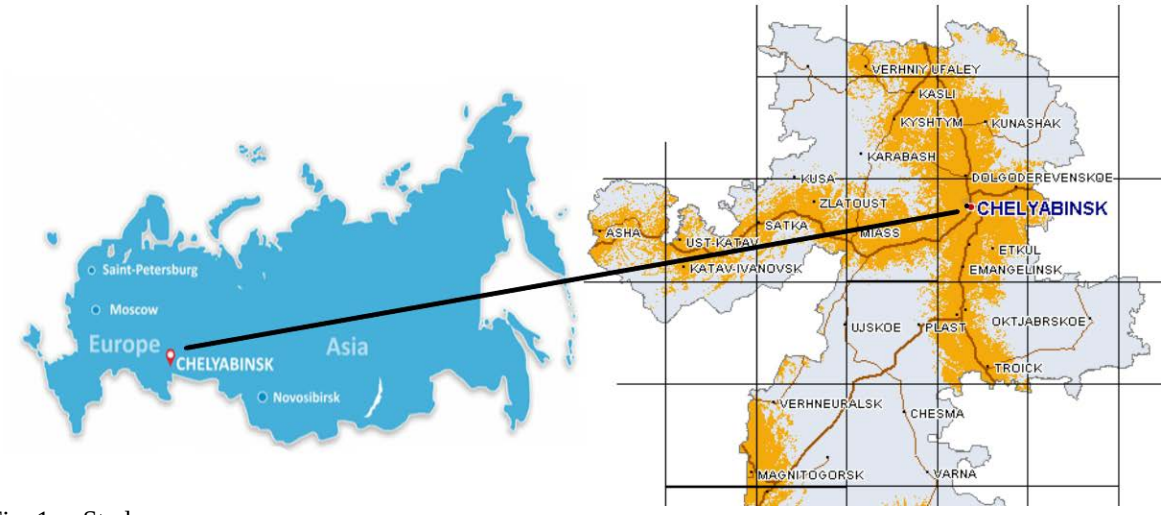


Fig. 1 Study area

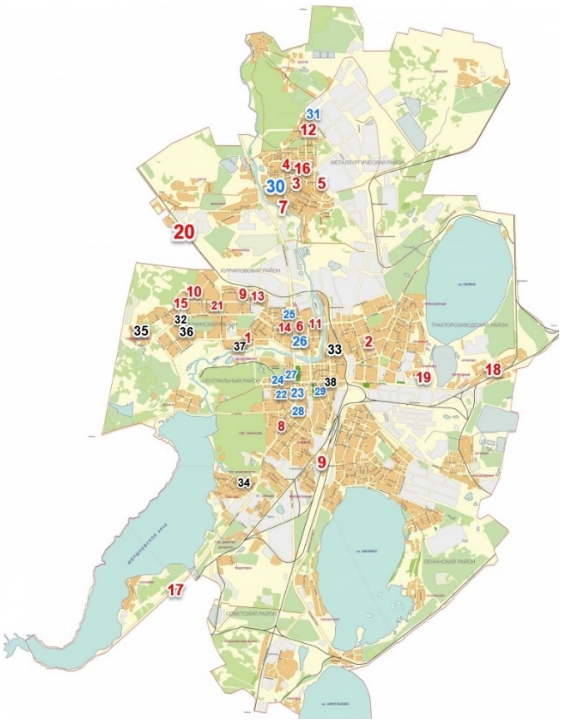


Fig. 2 The locations of all sampling sites. Red, blue and black numbers are sampling sites of outdoor dust, both indoor and outdoor dust, and indoor dust, respectively.

The road dust samples were stored in self-sealed polyethylene bags and carefully labeled. The samples were carefully air-dried in the laboratory for 1 week and sieved through a 2000 μm mesh nylon sieve to remove debris. The samples were then ground using a pulverizer and sieved through 63 μm nylon mesh sieve. We used < 63 μm dust fraction for analysis [20]. A minimum of three samples was collected.

Indoor dust samples were obtained from vacuum cleaner bags in regular use of participating students-volunteers for the purpose of cleaning homes or offices. The volunteers were asked to answer some questions about the general condition of the sampling location. The data covered the following information: age of the building, floor cover, smoking, number of occupants, floor level, cleaning frequency, air conditioning, walls, roof and floor cover, the time for last paint, cooking fuel, cooking frequency, and pet.

For the whole residential/office area and to facilitate, we used the indoor dust sampling method described by Kurt-Karakus [19]. We collected the vacuum cleaner bag dust containments of the respective homes/office. The bags from the homes/offices of volunteers dismantled, placed in a resealable bag, labeled and returned to the laboratory. In case of use of bagless vacuum cleaners, the content of the dust compartment of the vacuum cleaner was emptied into a plastic bag, sealed, labeled and returned to the laboratory. The dust samples were placed in a desiccator for 24 h, sieved through 63-mesh polystyrene sieve and then dust was dried at 105 °C for 24 h.

All outdoor and indoor dust samples were taken to the laboratories of the South-Ural Common Use Center of the Ilmen State Reserve UrB RAS for elemental analysis. Consequently, all concentrations reported in the current study are on a dry weight (dw) basis.

2.3 Sample analysis

Dust samples were microwave digested with 65% HNO_3 acid. After digestion, extracts were filtered through a 0.45-μm Millipore filter and diluted to a volume of 25 ml with Mili-Q water. The filtered supernatant was analyzed for metal(loid)s

determination (Cr, Ni, Cu, Zn, As and Pb) using Atomic Absorption Spectrophotometer (Perkin Elmer AAS Analyst 400).

2.4 QA/QC

All of the samples were tested in triplicate. Analytical blank and reference materials were included in every sequence. Certified reference material GSO 10413-2014 CO of structure (agrochemical indicators) of the soil of cespitose and podsolic srednesuglinisty (SADPP-10) was obtained from I BEND Rosselkhozakademiya's VNIIA (Russia) The recoveries for metal(loid)s ranged from 90% to 110% (Cr, Ni, Cu, Zn, As and Pb). The limits of quantification (LOQs) were calculated from the lowest concentration of the calibration curve. The LOQ of metal(loid)s analyzed in samples was 0.1 $mg \cdot kg^{-1}$

2.5 Statistical analysis

Microsoft Excel 2013 and SPSS 24.0 software were used to organize and analyze the data. The Kolmogorov–Smirnov test was used to test data normality. Non-normal distributions of concentration ($mg \cdot kg^{-1}$ dw) data were assumed for all heavy metals in both sampling environment. In the case of the presence of only two groups, the procedure reduces to the Mann–Whitney test, the nonparametric analog of the two-sample t-test to compare the means of two groups. The relationship between the data was determined using the Spearman rank-order correlation coefficient.

3. RESULTS AND DISCUSSION

3.1 Metal(loid)s in outdoor and indoor dust

The concentrations ($mg \cdot kg^{-1}$ dw) of metal(loid)s (Cr, Ni, Cu, Zn, As and Pb) on a dry weight basis in outdoor and indoor dust from Chelyabinsk were shown in Table 1. Zn showed the highest concentration (888±608 $mg \cdot kg^{-1}$) and (956±529 $mg \cdot kg^{-1}$) in outdoor and indoor dust, respectively. The concentrations of As were the lowest (2.5±1.6 $mg \cdot kg^{-1}$) and (7.1±3.2 $mg \cdot kg^{-1}$) in outdoor and indoor dust, respectively. The concentrations of metal(loid)s in outdoor dust may be arranged in the following order: As < Ni < Cu < Cr < Pb < Zn. While in indoor dust the ratio between the elements was As< Cu < Ni < Cr < Pb < Zn. The average contents of As and Ni were the higher in household dust than in street dust. Mann–Whitney test showed that Cu, Pb, Zn and Cr contamination was significantly elevated in the outdoor and indoor dust.

Concentrations of metal(loid)s in dust were much higher than the maximum allowable levels according to national standard for soil and natural geochemical background concentrations (Tables 1 and 2). For overall data set, concentrations of metal(loid)s in analyzed samples were within the mean values reported in the literature (Tables 1 and 2) or they showed concentrations lower mean values compared to values reported in the literature (Tables 1 and 2).

Table 1 The concentrations of metal(loid)s in outdoor (n=32) and indoor (n=17) dust from Chelyabinsk urban area ($mg \cdot kg^{-1}$ dw). Different letters indicate significant differences among the species according to the Mann–Whitney test ($p<0.05$)

Metal(loid)	As		Ni		Cu		Pb		Zn		Cr	
Outdoor (Out)/ Indoor (In)	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In
Mean	2.5a	7.1b	26a	34b	32a	29a	86a	129a	888a	956a	53a	44a
S (Dis)	1.6	3.2	11	11	8	10	51	137	608	529	22	15
Min	0.9	3.9	15.0	21.0	23.0	15.0	30	27	200	330	25	28
Max	5.6	15.9	65.0	57.0	45.0	45.0	250	520	2,200	2,240	89	71

Table 2 Mean national standard, natural geochemical background concentrations and global concentrations of metal(loid)s in the soil, indoor and outdoor dust ($mg \cdot kg^{-1}$ dw). n.a.: didn't report

Location	Type of dust/soil	As	Ni	Cu	Pb	Zn	Cr	Ref.
Russian National Standard	soil	2	4	3	32	23	6(III)/0.05(VI)	[25]
Chelyabinsk region	soil	n.a.	34.2	21.6	12.88	78.9	n.a.	[26]
Chengdu, China	indoor	n.a.	52.6	161	123	675	82.7	[20]
Istanbul, Turkey	indoor	n.a	282	200	30	984	89	[19]
Guangzhou, China	outdoor	20	41	192	387	1,777	176	[27]
Jeddah, Saudi Arabia	outdoor	21.55	51.29	139.11	140.73	487.5	65.43	[28]

Table 3 Correlation coefficients for outdoor dust samples

	As	Ni	Cu	Pb	Zn	Cr
As	1	0.42*	0.42**	0.51**	0.35*	0.10
Ni		1	0.39*	0.47**	0.32	0.16
Cu			1	0.67**	0.62**	0.27
Pb				1	0.50**	0.27
Zn					1	0.03
Cr						1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4 Correlation coefficients for indoor dust samples

	As	Ni	Cu	Pb	Zn	Cr
As	1	-0.189	0.717**	-0.079	-0.198	0.462*
Ni		1	0.112	-0.024	0.027	-0.020
Cu			1	-0.09	-0.106	0.564**
Pb				1	-0.098	-0.061
Zn					1	-0.063
Cr						1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

It was observed a high correlation between As and Cu, Pb. Ni; Zn and As, Cu, Pb; Pb and Cu, Ni in road dust (Table 3) and Zn, as and Pb in household dust (Table 4). The reason for these facts can be the common source of elements, particularly those metals coming from brake and tire wears [29]. Zn is a common element in motor vehicles, including tires, vehicle brake linings, metallic parts. Cu and Pb also are a part of tire [29]. Ni alloys in cars and yellow paint on roads [30]. The dust is mechanically generated by studded tires and traction material during cold winter in Russia [16].

3.2 The relations between metal(loid)s concentrations and household factors

The information gathered on household factors based on questionnaires showed that 80.95% and 19.05 of the houses were located in the urban and rural areas, respectively (Fig. 3a). And 76.19% and 23.81% of the studied apartments were home and office, respectively (Fig. 3a). Age of buildings was less than 10, 20, 30, 40, 50 and 60 years in 9.51%, 19.05%, 19.05%, 9.52%, 28.57% and 14.29% of cases, respectively.

And 85.71% of the houses had smokers and 23.81% of the houses had a pet (Fig. 3a). Previous studies reported that cooking and smoking may be other contributors to heavy metals in the urban household environment [25], [28]. The percentage of fuel types used for cooking was 61.9% and 14.29% for natural gas and electricity, respectively (Fig. 3a).

Moreover, people were cooking one, two and three times during the day in 4.76%, 28.57% and 38.10% of cases, respectively, and people were not cooking in 28.57% of the houses (Fig. 3b). 23.81% of the households were facing to a busy traffic street, 33.33% of the homes had conditioner (Fig. 3a), cleaning frequency was 1, 2, 3 and 7 times in a week for 42.86%, 14.29%, 19.05% and 23.81% of the houses (Fig. 3b).

The survey results also showed 4.76%, 38.1%, 33.33%, 14.29% and 9.52% of the houses had parquet, laminate, linoleum, wood and moquette, respectively. 52.38% of houses had wallpaper and those ones were water-emulsion paint, 9.52% of the house walls had MDF panels, and the time for last pain of 9.52% houses was less than 1 year (Fig. 3b).

Roof cover was white lime painted, latex painted and suspended ceiling in 47.62%, 23.81% and 28.57% of houses, respectively (Fig. 3b).

The results showed that the smoking was the important factor of heavy metals enriched in household dust, especially for Pb, Zn and AS, and the Spearman's correlation coefficient for smoking - Pb, smoking - Zn and smoking - As was 0.607 ($p < 0.01$), 0.449 ($p < 0.05$) and 0.584 ($p < 0.01$), respectively (Table 4). Those results could be explained by the amount of metal(loid)s in a cigarette. This result is similar to the previous study [20].

Also, the wall, floor and roof covers had the important effects on the concentrations of metals in the household dust (Table 5).

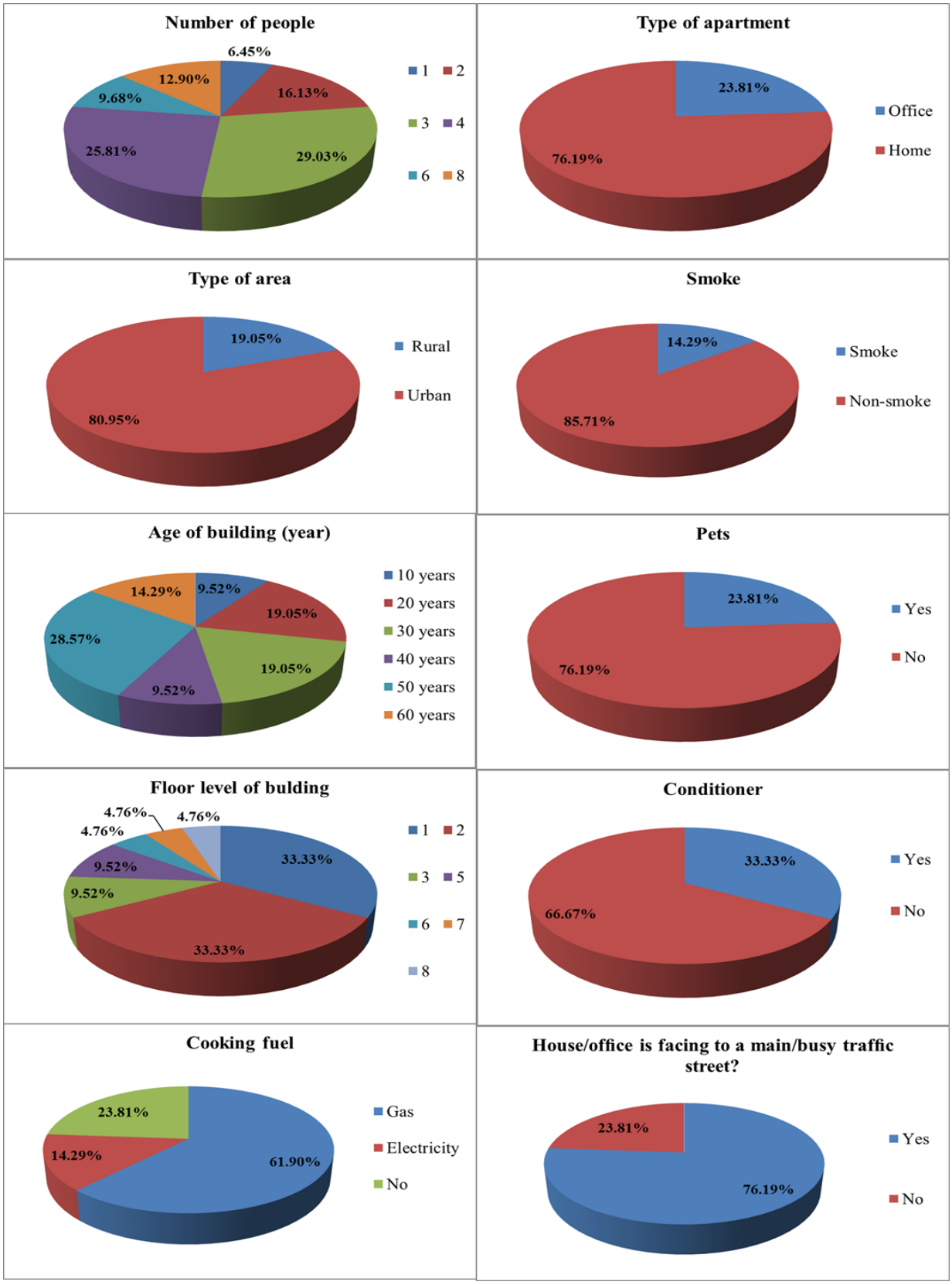


Fig. 3a House factors based on questionnaire results in Chelyabinsk households

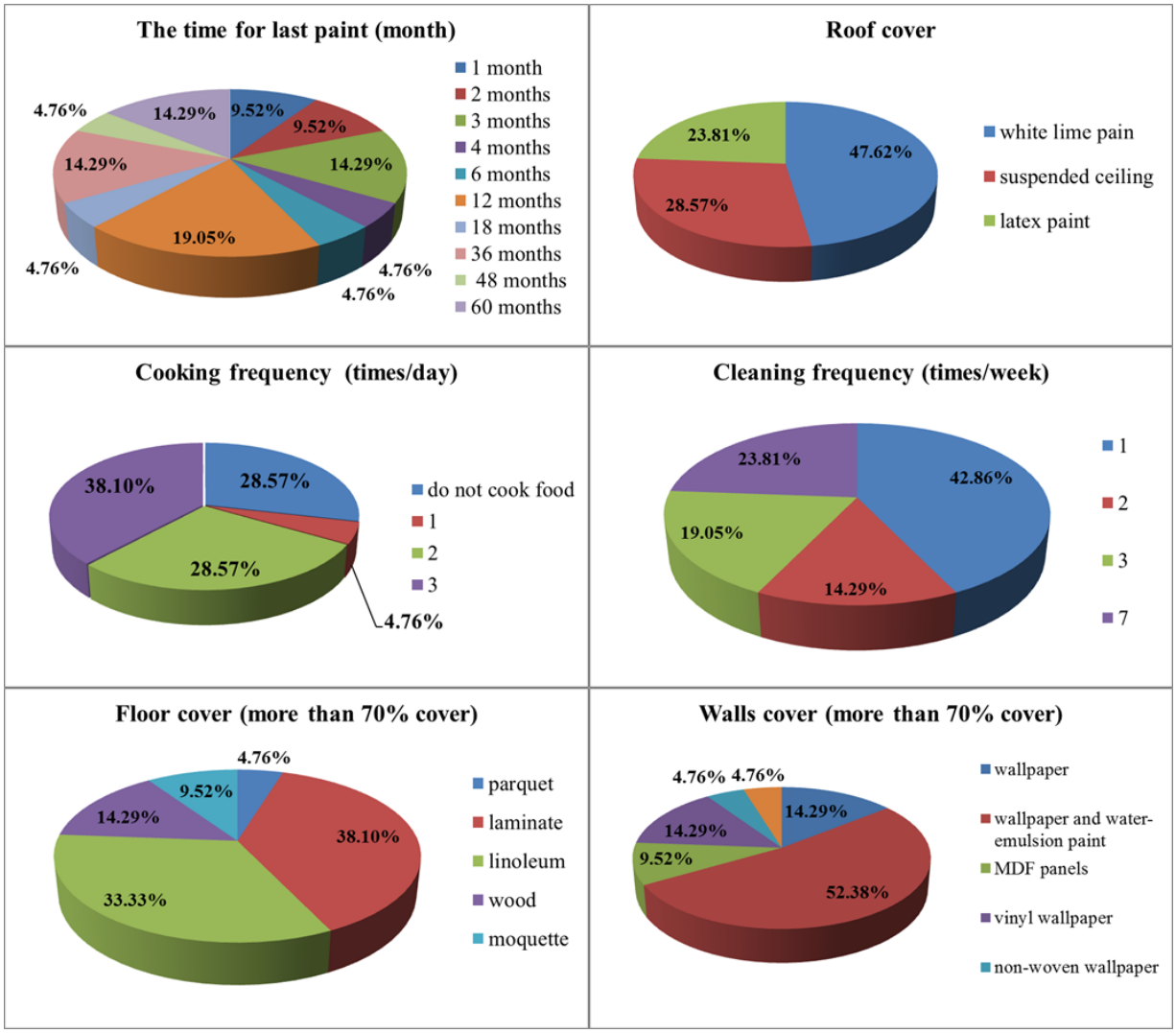


Fig. 3b House factors based on questionnaire results in Chelyabinsk households.

The Spearman's correlation analysis showed that As-wall cover, Pb -wall cover and Zn-roof cover were a significant correlation ($p < 0.05$), also As-floor cover, Zn-floor cover, Cu-wall cover and Pb-roof cover were a significant correlation ($p < 0.01$) (Table 5). There are some Zn^{2+} and $Cu2^{+}$ in the antibacterial fungicide of different building materials, as well as As and Pb can be part of the paints [3], [19], [20].

Furthermore, the Spearman's correlation coefficient for Zn-the time for last paint and As-age of the building were -0.562 ($p < 0.05$) and 0.441 ($p < 0.01$), respectively (Table 5), which could be due to the flaking of paint off the wall. The previous researchers have received similar results [20], [31].

There were significant correlations between As and the cooking fuel ($p < 0.05$). Also Cr-cooking frequency was significant correlation ($p < 0.01$). The previous study showed that the household cooking was one of the indoor pollution sources [3].

4. CONCLUSION

The present study investigated the concentrations of metal(loid)s (Cr, Ni, Cu, Zn, As and Pb) in outdoor and indoor dust from Chelyabinsk, Russia. The average content of Zn was the highest in road dust.

The average contents of As and Ni were the highest in household dust. Cu, Pb, Zn and Cr contamination were significantly elevated in the outdoor and indoor dust. Smoking, buildings' age, cooking fuel and frequency, the wall, floor and roof covers were the significant factors leading to differences in concentrations of metal(loid)s.

.

Table 5 The bivariate correlation analysis of metal(loid)s in household dust and the household factors

	As	Ni	Pb	Cr	Cu	Zn
Smoking	**0.584****	0.102	**0.607****	0.35	-0.35	**0.449***
Age of building	**0.441***	0.012	0.429	-0.156	0.075	0.29
Number of people	-0.141	0.112	-0.283	-0.023	0.278	-0.278
Pet	-0.452	0.056	-0.258	-0.074	-0.176	-0.48
Cooking fuel	**0.463***	-0.084	0.336	-0.087	0.148	0.042
Floor	-0.099	0.300	-0.036	-0.063	0.296	-0.119
House/office is facing to a main/busy traffic street?	-0.055	0.083	0.018	-0.306	0.12	-0.203
Cooking frequency	-0.57	-0.048	-0.431	**0.447***	0.272	-0.264
Cleaning frequency	0.361	-0.04	0.126	-0.248	0.134	0.057
Time for last paint	0.066	0.144	-0.191	0.206	-0.235	**-0.562****
Conditioner	-0.359	0.126	-0.284	0.017	-0.025	0.002
Wall cover	**0.540***	-0.014	**0.488***	0.312	-0.164	0.176
Floor cover	**0.558****	-0.039	0.393	-0.049	-0.273	**0.569****
Roof cover	0.376	-0.026	**0.592****	-0.062	0.059	**0.476***

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

5. ACKNOWLEDGMENTS

The authors would like to thank the support provided by Act 211 Government of the Russian Federation, contract № 02.A03.21.0011.

6. REFERENCES

[1] Huang M., Wanga W., Chan C.Y., Cheunga K.C., Mana Y.B., Wang X. and Wong M.H., Contamination and risk assessment (based on bioaccessibility via ingestion and inhalation) of metal(loid)s in outdoor and indoor particles from urban centers of Guangzhou, China, Science of the Total Environment, Vol. 479–480, 2014, pp. 117-124.

[2] Al-Khashman O., Heavy metal distribution in the dust, street dust and soils from the work place in Karak Industrial Estate, Jordan. Atmos. Environ., Vol. 38, 2004, pp. 6803-6812.

[3] Chattopadhyay G., Lin K.C.P. and Feitz A.J., Household dust metal levels in the Sydney metropolitan area. Environ. Res., Vol. 93, 2003, pp. 301-307.

[4] Hassan S., Metal concentrations and distribution in the household, stairs and entrywaydust of some Egyptian homes, Atmos. Environ., Vol. 54, 2012, pp. 207-215.

[5] Atiemo M.S., Ofosu G. F., Kuranchie-Mensah H., Tutu A.O., Palm N.D.M.L. and Blankson S.A., Contamination Assessment of Heavy Metals in Road Dust from Selected Roads in Accra, Ghana, Research Journal of Environmental and Earth Sciences, Vol. 3, Issue 5, 2011, pp. 473-480.

[6] Phetrawech T and Thepanondh S., Evaluation of resuspension of road dust in a cement industrial complex area, International Journal of GEOMATE, Vol.12, Issue 33, 2017, pp. 96-103.

[7] Apeagyei E., Bank M.S. and Spengler J.D., Distribution of heavy metals in road dust along an urban-rural gradient in Massachusetts, Atmospheric Environment, Vol. 45, 2011, pp. 2310-2323.

[8] Butte W. and Heinzow B., Pollutants in house dust as indicators of indoor contamination. Rev. Environ. Contam. Toxicol., Vol. 172-175, 2001, pp. 1-46.

[9] Maertens R.M., Bailey J., White PA., The mutagenic hazards of settled house dust: a review. Mutat. Res. Rev. Mutat. Res., Vol. 567, 2004, pp. 401–425.

[10] US EPA, Exposure factors handbook. National Center for Environmental Assessment. Office of Research and Development, Washington, D.C., 1997.

[11] Amato F., Alastuey A., de la Rosa .J, Gonzalez Castanedo Y., Sánchez de la Campa A.M., Pandolfi M., Lozano A., Contreras González J., and Querol X., Trends of road dust emissions contributions on ambient air particulate levels at rural, urban and industrial sites in southern Spain, Atmos. Chem. Phys., Vol. 14, 2014, pp. 3533-3544.

[12] Denier van der Gon H., Gerlofs-Nijland, M E., Gehrig R., Gustafsson M., Janssen N., Harrison R.M., Hulskott J., Johansson C., Jozwicka M., Keuken M., Krijgsheld K., Ntziachristos L., Riediker M., and Cassee F.R., The Policy Relevance of Wear Emissions from Road Transport, Now and in the Future, An International Workshop Report and Consensus Statement, J. Air. Waste Manage., Vol. 63, 2013, pp. 136-149.

[13] Zibret G., Van Tonder D. and Zibret L., Metal content in street dust as a reflection of atmospheric dust emissions from coal power plants, metal smelters, and traffic, Environ. Sci. Pollut. Res. Int., Vol. 20, Issue 7, 2013, pp. 4455-4468.

[14] Kuang C.1., Neumann T., Norra S. and Stüben D., Land use-related chemical composition of street sediments in Beijing, Environ. Sci. Pollut. Res. Int., Vol. 11, Issue 2, 2004, pp.73-83.

[15] Morton-Bermea O., Hernández-Álvarez E., González-Hernández G. and Romero F., Assessment of heavy metal pollution in urban topsoils from the metropolitan area of Mexico City, J, Geochem, Explore, Vol. 101, 2008, pp. 218-224.

[16] Gustafsson M., Blomqvist G., Gudmundsson A., Dahl A., Swietlicki E., Bohgard M., Lindbom J. and Ljungman A., Properties and toxicological effects of particles from the interaction between tyres, road pavement and winter traction material, Sci. Total Environ., Vol. 393, 2008, pp. 226–240.

[17] Hunt A., Johnson D.L. and Griffith D.A., Mass transfer of soil indoors by track-in on footwear. Sci. Total Environ. Vol. 370, 2006, pp. 360-371.

[18] Thatcher T.L., Layton D.W. and Deposition, resuspension, and penetration of particles with in a residence. Atmos. Environ. Vol. 29, 1997, pp. 1487-1497.

[19] Kurt-Karakus P.B., Determination of heavy metals in indoor dust from Istanbul, Turkey: estimation of the health risk, Environ. Int. Vol. 50, 2012, pp, 47-55.

[20] Cheng Z., Chen L.-J., Li H.-H., Lin Z.-B., Yang Y.Y-X, Xu X.-X., Xian J.-R., Shao J.-R. and Zhu X.-M., Characteristics and health risk assessment of heavy metals exposure via household dust from an urban area in Chengdu, China, Sci. Total Environ., Vol. 619-620, 2018, pp. 621-629.

[21] Kaygorodov R.V., Tiunova M.I., and Druzshinina A.A., Polluting substances in a dust of travelers of parts and in the wood vegetation of roadside strips of a city zone, Bulletin of Perm. University, 2009, Vol 10, Issue 36, pp. 141-146. (Rus).

[22] Bityukova V.R. and Kasimov N.S., Atmospheric pollution of Russia's cities: Assessment of emissions and immissions based on statistical data GEOFIZIKA, Vol. 29, Issue 1, 2012, pp. 53-67.

[23] Russian State Statistics Service of Chelyabinsk region, The report, the population of the Chelyabinsk region in General, and cities with a permanent population of 100 thousand or more by sex and age on 1 January 2017, 2017. (Rus).

[24] Russian State Statistics Service of Chelyabinsk region, Report Transport and communications in Chelyabinsk region, 2017. (Rus).

[25] GN 2.1.7.2041-06, National Standard Russian Federation. Maximum Permissible Concent-ration of Chemicals in the Soil. 2006. (Rus)

[26] Zybalov V.S. and Yudina E.P. Influence of Heavy Metals on Agricultural Soils of Chelyabinsk Region. Bulletin of the South Ural State University. Ser. Chemistry. Vol. 8, no. 3, pp. 13–18 (Rus)

[27] Huang M., Wang W., Chan C.Y., Cheung K.C., Man Y.B., Wang X. and Wong M.H., Contamination and risk assessment (based on bioaccessibility via ingestion and inhalation) of metal(loid)s in outdoor and indoor particles from urban centers of Guangzhou, China. Sci. Total Environ., Vol. 479-480, 2014, pp. 117-124.

[28] Shabbaj I.I., Alghamdi M.A., Shamy M., Hassan S.K., Alsharif M.M. and Khoder M.I. Risk assessment and implication of human exposure to road dust heavy metals in Jeddah, Saudi Arabia. Int. J. Environ. Res. Public Health, Vol. 15, Issue 1, 2018.

[29] Apeagyei E., Bank M.S. and Spengler J.D., Distribution of heavy metals in road dust along an urban-rural gradient in Massachusetts. Atmos. Environ. Vol. 45, Issue 13, 2011, pp. 2310-2323.

[30] Madany I.M., Akhter M.S. and Jowder O.A.A., The correlations between heavy metals in residential indoor dust and outdoor street dust in Bahrain. Environ. Int. Vol. 20, Issue 4, 1994, pp. 483-492.

[31] Rasmussen P. E., Levesque C., Chénier M., Gardner H.D., Jones-Otazo H. and Petrovic S., Canadian House Dust Study: Population-based concentrations, loads and loading rates of arsenic, cadmium, chromium, copper, nickel, lead, and zinc inside urban homes, Sci. Total Environ., Vol. 443, 2013, pp. 520–529.

[32] Khan M.N., Nurs C.Z.B., Islam M.M., Islam M.R. and Rahman M.M., Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: a nationwide population-based study, Environmental Health, Vol. 16, Issue 1, 2017, p.1.

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.