National Academy of Sciences of RA
Electronic Journal of
NATURAL SCIENCES

ՀՀ Գիտությունների ազգային ակադեմիա
Էլեկտրոնային ամսագիր
ԲՆԱԿԱՆ ԳԻՏՈՒԹՅՈՒՆՆԵՐ

Национальная Академия наук РА
Электронный журнал
ЕСТЕСТВЕННЫЕ НАУКИ

1(28), 2017

Ecology *Էկոլոգիա* *Экология*

ASSESSMENT OF HEAVY METAL POLLUTION LEVEL AND CHILDREN'S HEALTH RISK IN A KINDERGARTEN AREA (YEREVAN)

N. Maghakyan, L. Sahakyan, O. Belyaeva, M. Kafyan, G. Tepanosyan

Center for Ecological-Noosphere Studies of NAS RA, Environmental Geochemistry Department, 68 Abovian, 0025 Yerevan, Armenia; email: nairuhi.maghakyan@cens.am, lilit.sahakyan@cens.am, olga.belyaeva@cens.am, mkhitar.kafyan@cens.am, gevorg.tepanosyan@cens.am; Phone: (+374 10) 572924; Fax: (+374 10) 572938

ABSTRACT

The contents of Hg, Cd, Mo, Pb, Ni, Cr, Co, Ag, Zn and Cu in soil and dust from kindergarten area of city of Yerevan, Armenia, were measured by Atomic absorption spectroscopy. Summary pollution index (SPI) and Summary concentration index (SCI) were calculated to evaluate the heavy metal contamination levels. Non-cancerogenic health risk was assessed bassed on the US EPA Health Risk Model. The results show that contents of Cd, Mo, Pb, Ni, Zn, Cu were higher than local geochemical background in all samples. The content of Pb was higher than Maximum Acceptable Concentration in all dust samples, Zn- in soil and outdoor dust, and Cu in indoor dust. According to SPI the level of pollution was medium in soil, low in leaf dust and high in other dust samples. SCI pollution levels were acceptable in all samples. Risk assessment shows that there is no health risk for children.

Key words: *heavy metal, dust, pollution, health risk*

INTRODUCTION

Heavy metals enter the environment through vehicular exhausts, fossil fuel combustion, industrial wastes, and other activities [[8]]. Presently it is urban areas which are characterized by high levels of heavy metal pollution determined by rapid industrialization and urbanization. In urban areas main accumulators of heavy metals are soils and dust [[8]], the latter serving as indicators of environmental quality. All this makes the issue of heavy metal pollution increasingly attractive to researchers. Such studies are mainly aimed at studying pollution of street dust [[4], [11]], outdoor dust [[6], [18]], indoor dust [[10], [14], [22]], house dust [[5], [27]] and soils [[8]] with heavy metals. Some of researches cover not only heavy metal pollution levels, but also assessment of heavy metal-induced health effects [[1], [3], [12], [24], [26]] as from soils and dust these elements can freely enter a human organism via inhalation, skin and ingestion [[17], [23]] and consequently cause grave health effects.

Children, as one of sensitive groups in the population, differently response to the impact of environmental pollution with heavy metals depending on their physiological, biological and social conditions. They have imperfect immune system, higher demand in oxygen and food [[2], [7]], besides they are under the impact of secondary pollution from soil via near-surface air layer. Children play in points of exposure such as playgrounds and therefore directly, due to their hand-to-mouth behavior, contact with soils, outdoor, indoor dust and different dusty articles polluted with heavy metals, thus being at a risk of direct penetration of pollutants into their organisms [[7]]. In children heavy metals commonly cause allergic reactions, kidney damage, dysfunction of digestive system, disorders in neurodevelopment (such as autism), poor coordination, and mental retardation [[25]]. For this reason, in recent years much research was done devoted to assessment of not only heavy metal pollution levels in soil and dust of playgrounds of kindergartens and nursery schools, but also potential health risk to children [[21], [2][3]].

Researches implemented in different years in Yerevan [[19], [20]] have indicated that the detected contents of heavy metals in Yerevan area are alien both to geochemical and natural landscapes of the city. This fact has emphasized a necessity to also study kindergarten sites all over the city. The study covered playgrounds soils alone and as a result allowed to reveal the background- and MAC (Maximum Acceptable Concentration)-exceeding contents of heavy metals in the studied soils of the majority of kindergartens. Presence of such levels of pollution in the soils of Yerevan kindergartens justifies a necessity of conducting more detailed studies.

So, the goal of this research was to assess heavy metal pollution levels in the soils of playgrounds and dust (indoor, outdoor, leaf) in one of Yerevan kindergartens from geochemical standpoint and in compliance with national legal requirements.

MATERIAL AND METHODS

1. Study site

Yerevan (latitude 40°10'40"N, longitude 44°30'45"E), Armenia's capital, covers an area of 223 km^2 and has a population of over one million. The climate is typically dry continental; the amount of annual precipitation is 250–400 *mm*.

Mean air temperature varies from 22 to 26 C in summer and -4 to -6^{o}C in winter. Dry steppe and semi-desert natural landscapes are common.
The study kindergarten is located in Shengavit residential community of Yerevan at a distance of some 20 *m* from a busy street with heavy traffic. Most of the kindergarten area is asphalted, vegetation is scarce. According to earlier research, V, Cr, Mo, Hg, Cu, Zn detected in soils were excessive against background concentrations and MAC for Zn [[13]].

2. Sampling and analytical methods

Sampling of kindergarten soils, indoor, outdoor and leaf dust (*Fig. 1*) was done in October 2015.

2.1 Collection and pretreatment of leaf samples

From the kindergarten area leaves of common lilac (*Syringa vulgaris*) were sampled. For a composite sample leaves were sampled at a height of 1.5–2.0 *m* above the ground from at least three trees of the same species per sampling site and then placed into paper bags for transportation. After the sampled leaves had been dried at a room temperature, they were washed with de-ionized water (MilliQ). The generated liquid underwent filtration using a weighed ash free filter (retention limit 2–3 *mkm*).

2.2. Soil sampling and pretreatment

One soil (S) sample (some 500-600 *g*) was taken by a stainless steel spade at 0-5 *cm* deep. The composite sample consisted of 6 individual subsamples including soil from the playground, 'original' soil on the site and that indended for gardening. With a purpose of transportation and storage, soil was placed into plastic bags and labeled with numbers. In lab soil was dried at a room temperature, homogenized and sifted using a 2 mm sieve.

2.3. Collection and pretreatment of outdoor and indoor dust samples

One indoor dust (D(I)) sample was taken from interior windowsills, stairs and floor corners with help of a brush and a filter paper and through accepted methods [[2]]. One outdoor dust (D(O)) sample consisted of 5 subsamples; sampling was done with help of a brush from exterior windowsills, stairs, corner sections of the walls and the door. The sample was then homogenized, separated through a 2 *mm* sieve, crushed with an agate pestle and sifted with a 0.8 *mm* sieve.

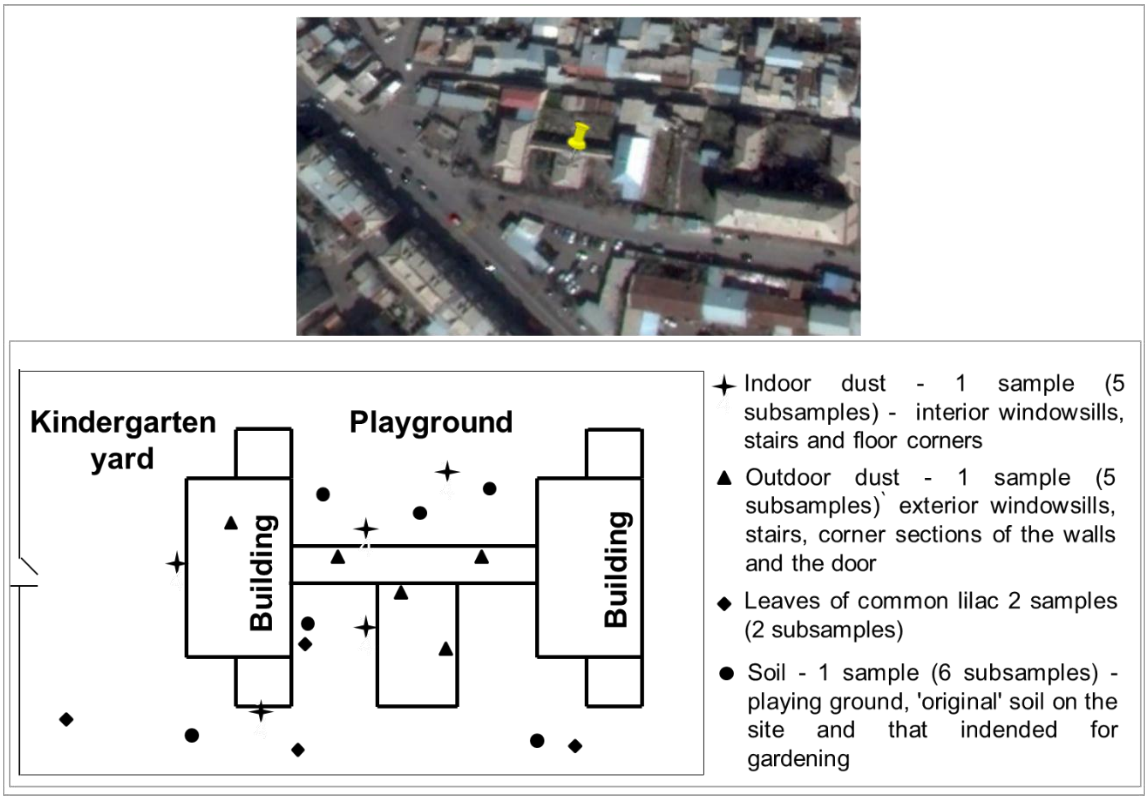

Fig. 1. Location and scheme of studied kindergarten and sampling sites

2.2. Analysis of samples

The analysis of samples was done at the the Central Analytical Laboratory CENS accredited by ISO-IEC 17025. Contents of ten elements Hg, Cd, Mo, Pb, Ni, Cr, Co, Ag, Zn and Cu were determined by AAnalyst 800 AAS PE, USA.

2.3. Determination of dust load

Dust load was calculated by accepted formulae [[15]]. The following classification is given for the dust load: <250 mg/km^2 day-low, 250-450 mg/km^2 day- medium, 450-800 mg/km^2 day - high, >800 mg/km^2 day- very high [[15]].

2.4 Assessment of heavy metal pollution

To provide a complex assessment of heavy metal pollution of dust and soils, the Summary Pollution Index (SPI /Zc/) was calculated [[9], [15]]. The summary pollution level was classified as low (16<Zc), moderately hazardous (16<Zc<32), high/hazardous (32<Zc<128), or very high/extremely hazardous (Zc>128). Then the contents of elements were collated with national MAC for soils and Summary Concentration Index (SCI) calculated. The SCI levels were classified according to RA Government Resolution [[16]]. In Armenia MAC values are set for Cr, Ni, Cu, Zn, Mo, Hg, Pb, Cd.

2.5. Assessment of noncarcinogenic risk

A probable health risk from soil and dust heavy metals was assessed in compliance with a US EPA model [[17], [23]]. Calculation of noncarcinogenic chronic risk was done in respect of Hg, Cd, Mo, Pb, Ni, Cr, Co, Ag, Zn, Cu from ingestion and covered the hazard quotient (HQ) and the hazard index (HI). HQ or HI>1 shows a probability of health risk.

3. RESULTS AND DISCUSSION

Results obtained from the kindergarten lilac leaf dust study have indicated that leaf dust load is 57.23 *kg/sq.m* daily and thus according to A.I.Perelman's [[15]] scale belongs to low level of dust loading. It has also been established that the leaf dust (D(L)) contains the whole set of study elements Cd, Mo, Pb, Ni, Cr, Co, Ag, Zn, Cu, except Hg which was found only in soil. Relatively high contents of elements are detected in indoor and outdoor dust (*Tab. 1, 2*). The highest contents of Cd, Ni, Ag, Cu were detected in D(I), Mo- in D(L), Zn –in D(O), Cr and Co – in S.

Cd, Mo, Pb, Ni, Zn, Cu contents exceeded the background values for soils in all substrates. Only Co showed no excess against the background, while Hg in soils exceeded the background by 1.76 times. Cr was excessive only in outdoor dust and soils and exceeded the background by 1.25 and 1.1, times, respectively.

In indoor dust maximal excess of Ni, Cd, Ag, Cu against the background were detected – by 3.78, 16.15, 3.72 times, respectively, whereas Pb and Zn showed maximal excess in outdoor dust – by 51.12 and 3.79 times, respectively (*Fig. 2*).

High contents of Cd and Pb in indoor and outdoor dust can also be explained by the fact that dry fragments of a white paint used for interior and exterior painting of kindergarten windows are found in the collected dust sample. According to literature, the paint may contain the mentioned elements and thus become an additional source of pollution when combined with other sources [[8]]. Maximal excess of background of Mo – by 28.38 times -is detected in leaf dust that can be explained by the fact that this element is a priority pollutant to Yerevan air basin.

Table 1. Concentrations of study elements in soil, indoor, outdoor and leaf dust

Medium	**Concentrations of chemical elements (mg/kg)**									
	Hg	**Cd**	**Mo**	**Pb**	**Ni**	**Cr**	**Co**	**Ag**	**Zn**	**Cu**
Background	**0.017**	**0.31**	**1.75**	**4.8**	**30.4**	**71.09**	**15.65**	**0.25**	**78.38**	**40.03**
MAC	**2.1**	**2**	**132**	**65**	**80**	**90**	**-***	**-***	**220**	**132**
Soil	0.03	0.61	19.07	61.55	59.96	89.06	11.20	0.06	221.73	45.45
D (I)	-	1.18	29.37	156.05	64.51	39.05	6.85	4.04	170.00	149.03
D (O)	-	0.73	10.20	240.59	44.19	78.25	7.81	0.01	296.82	109.04
D (L)	-	0.35	49.67	83.87	41.54	44.36	4.42	0.93	148.58	113.64

Note: in «-» values were not detected, «in «-* no data, in red: excessive values vs background, underlined: excessive values vs MAC are given

Table 2. Decreasing series of studied mediums according to concentration of elements

Element	***Decreasing series***	**Element**	***Decreasing series***
Cd	D (I) > D(O) > S > D(L)	**Co**	S > D(O)> D (I)> D (I)
Mo	D(L) > D (I) > S > D(O)	**Ag**	D (I)> D (I) > S > D(O)
Pb	D(O)> D (I) > D (I)>Հ	**Zn**	D(O) >Հ> D (I)> D (I)
Ni	D (I)> S >D(O) > D (I)	**Cu**	D (I)> D (I) > D(O)> S
Cr	S > D(O)> D (I)> D (I)	**Hg**	S

The constructed geochemical series show that priority pollutants to all the samples are Pb and Mo. All geochemical series constructed for all substrates are qualitatively close to each other and are characterized by high intensity.

The maximal value of summarized intensity is detected in indoor dust making 77.23 (*Tab. 3*). According to summarized intensity samples are arranged in the following order: indoor dust > outdoor dust >leaf dust >soil.

Collation between geochemical status of in-kindergarten area substrates and geochemical specificities of adjacent soil sampling locations (N52012, N52008) (*Tab. 3*) shows that they are similar in quality and quantity. In geochemical series constructed for adjacent soils Pb is also a priority pollutant, its value being close to that of a kindergarten soil sample. Besides, geochemical series for both the kindergarten area and adjacent soils are characterized by similar excess of Zn, Cu, Ni (*Tab. 3*).

Table 3. Geochemical series of heavy metals in soil and dust

Medium	Geochemical series	Summary intensity
S	$Pb_{(12.82)}$-$Mo_{(10.9)}$-$Zn_{(2.83)}$-$Ni_{(1.97)}$-$Cd_{(1.97)}$-$Hg_{(1.76)}$-$Cr_{(1.25)}$-$Cu_{(1.14)}$	34.64
D (I)	$Pb_{(32.51)}$-$Mo_{(16.79)}$-$Ag_{(16.15)}$-$Cd_{(3.78)}$-$Cu_{(3.72)}$-$Zn_{(2.17)}$-$Ni_{(2.12)}$-$Cr_{(1.1)}$	77.23
D (O)	$Pb_{(50.12)}$-$Mo_{(5.83)}$-$Zn_{(3.79)}$-$Ag_{(3.7)}$-$Cu_{(2.72)}$-$Cd_{(2.34)}$-$Ni_{(1.45)}$	67.36
D (L)	$Mo_{(28.38)}$-$Pb_{(17.47)}$-$Cu_{(2.84)}$-$Zn_{(1.9)}$-$Ni_{(1.37)}$-$Cd_{(1.13)}$	56.78
52012	$Pb_{(24)}$>$Zn_{(4.5)}$-$Cr_{(3)}$-$Cu_{(2)}$-$V_{(1.9)}$-$Ni_{(1.74)}$-$Sr_{(1)}$-$Mn_{(1)}$	41.68
52008	$Pb_{(12.08)}$>$Zn_{(2.43)}$-$Ni_{(2.34)}$-$V_{(2.03)}$-$Cr_{(1.65)}$-$Cu_{(1.55)}$-$Mo_{(1.24)}$-$Sr_{(1.14)}$	25.4

Note: in brackets excesses vs. geochemical background are given

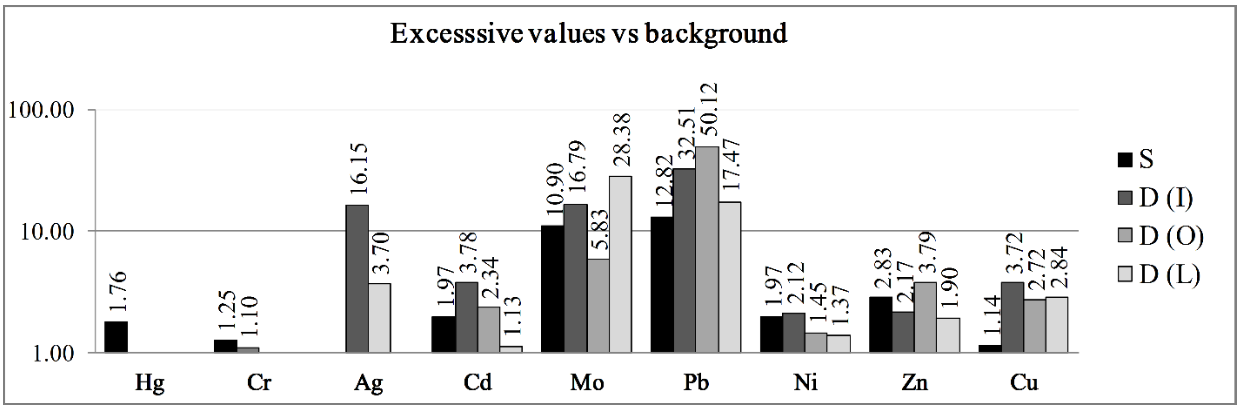

Fig. 2. Excessive concentration of elements vs. background

According to SPI, pollution level of soil is assessed as moderate making 28.55, of leaf dust -as low making 51.69, of other mediums - as high equal to 72.22 in indoor dust, 61.89 in outdoor dust (*Fig. 3*). It should be stressed that the study kindergarten is located not only rather close to a heavily loaded street, but also within the high pollution field of Yerevan soils (*Fig. 4*), and therefore both the adjacent soils and street dust particularly in terms of heavy traffic can be an additional heavy metal pollution source to the kindergarten. The scarcity of green barriers throughout the kindergarten area also contributes to this fact.

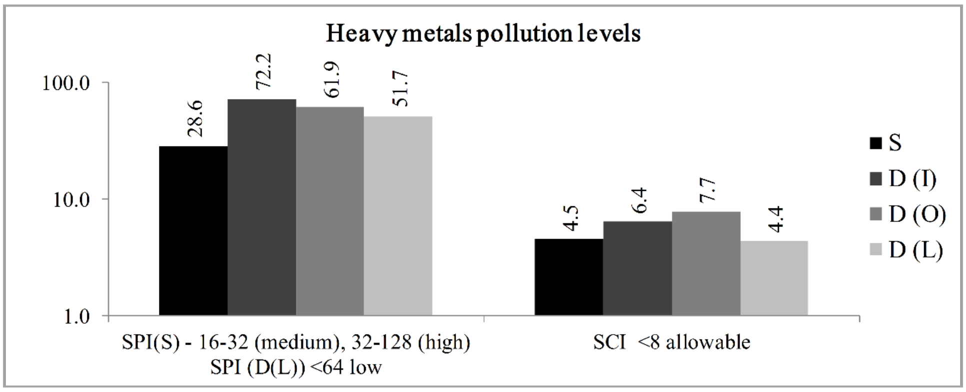

Fig. 3. Pollution levels according to SPI and SCI.

A sanitary and hygienic analysis has indicated that MAC is exceeded only by Pb, Zn, Cu (*Fig. 5*). Pb exceeds MAC in indoor, outdoor and leaf dust by 3.7, 2.4, 1.29 times, respectively; Zn – in soil (1.01) and indoor dust (1.35); Cu – in indoor dust (1.13). The sanitary and hygienic series constructed for indoor and outdoor dust are characterized by presence of 2 elements and are dominated by Pb; a sanitary and hygienic series for leaf dust and soil is represented respectively by Pb alone and Zn (*Tab. 4*).

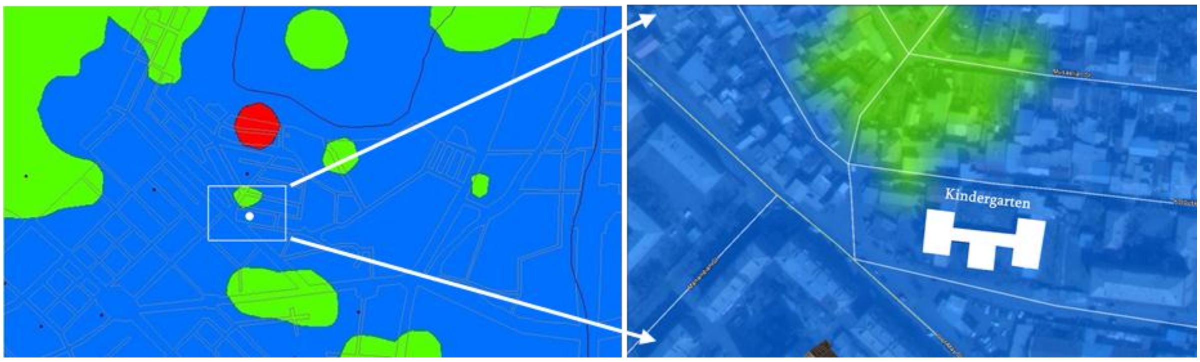

Fig. 4. Position of the kindergarten on the map of summary heavy metal pollution of Yerevan soils according to SPI

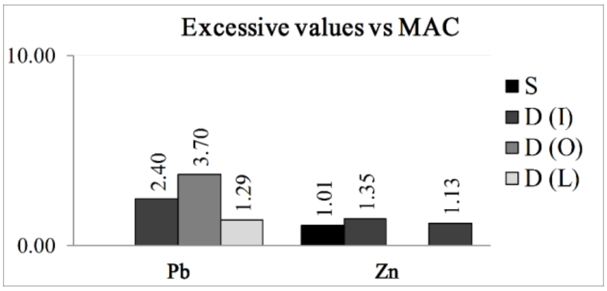

Fig. 5. Excessive values vs MAC.

Table 4. *Sanitary and hygienic series of heavy metals in soil and dust*

Medium	Sanitary and hygienic series	Summary intensity
S	$Zn_{(1.01)}$	4.50
D (I)	$Pb_{(2.4)}$-$Cu_{(1.1)}$	6.36
D (O)	$Pb_{(3.7)}$-$Zn_{(1.4)}$	7.74
D (L)	$Pb_{(1.3)}$	4.39
52012	$Cr_{(2.4)}$-$Pb_{(1.8)}$-$Zn_{(1.6)}$	8.61
52008	$Cr_{(1.3)}$	5.90

Note: in brackets excesses vs. MAC are given

A relatively high value of summary intensity is detected in outdoor dust 7.74. According to summary intensity the samples are arranged as follows: Outdoor Dust>Indoor Dust>Soil>Leaf Dust (*Tab. 4*). According to SCI**,** all the substrates have allowable level of pollution (*Fig. 3*), allowable contents of Hg, Cd, Pb, Cu, Mo, Ni, Cr and low level of Zn pollution.

A comparative analysis of sanitary and hygienic assessment of soils adjacent to the kindergarten has indicated that despite the fact that a sanitary and hygienic series for adjacent soil samples are dominated by Cr, one of the series is characterized by presence of Pb, Zn a like sanitary and hygienic series for the kindergarten substrates.

Results of assessment of heavy metal-induced noncarcinogenic risk to children in the kindergarten area have indicated that HQ values for all the samples and all the elements are at the allowable level (HQ<1), i.e. no risk is identified in respect of separate elements (*Tab. 5*). Total risk has not been identified in the study mediums either, as proved by HI<1.

Table 5. *Non carcinogenic risk values of heavy metals*

	HQ										**HI**
	Hg	Cd	Mo	Pb	Ni	Cr	Co	Ag	Zn	Cu	
RFD	1.60E-04	1.00E-03	5.00E-03	3.50E-03	2.00E-02	3.00E-03	3.00E-04	5.00E-03	3.00E-01	4.00E-02	
S	2.77E-07	5.67E-06	1.76E-04	5.69E-04	5.54E-04	8.23E-04	1.03E-04	5.08E-07	2.05E-03	4.20E-04	4.70E-03
D(I)	_	1.09E-05	2.71E-04	1.44E-03	5.96E-04	3.61E-04	6.33E-05	3.73E-05	1.57E-03	1.38E-03	5.73E-03
D(O)	_	6.76E-06	9.43E-05	2.22E-03	4.08E-04	7.23E-04	7.22E-05	7.39E-08	2.74E-03	1.01E-03	7.28E-03
D(L)	_	3.25E-06	4.59E-04	7.75E-04	3.84E-04	4.10E-04	4.08E-05	8.55E-06	1.37E-03	1.05E-03	4.50E-03

4. CONCLUSION

The contents of heavy metals in dust and soils of a Yerevan model kindergarten were studied and pollution levels and health risks assessed.

The obtained research results have indicated that the contents of Cd, Mo, Pb, Ni, Zn, Cu, except Co, exceed the background. The maximal exceeding was detected in respect of a larger amount of elements including Ni, Cd, Ag, Cu in indoor dust. Priority pollutants to all the samples are Pb, Mo. According to SPI, soil shows a moderate, leaf dust low and other dust samples - high level of pollution. Excess against MAC was detected only for Pb, Zn, Cu. Indoor dust contains a large amount of elements which exceed MAC values. According to SCI all the studied mediums show allowable level of pollution. The US EPA model-based risks assessment data have indicated that such contents of element in kindergarten soils and dust pose no health risk to kindergarten attendees.

Based on geochemical peculiarities of city of Yerevan and the kindergarten site one may conclude that similar detailed researches are required for the rest of preschool establishments of the city, for which a set of measures should be developed.

REFERENCES

[1] Cao S, Duan X, Zhao X, et al (2014) Health risks from the exposure of children to As, Se, Pb and other heavy metals near the largest coking plant in China. Sci Total Environ 472:1001–1009. doi: 10.1016/j.scitotenv.2013.11.124

[2] Chen H, Lu X, Chang Y, Xue W (2013) Heavy metal contamination in dust from kindergartens and elementary schools in Xi'an, China. Environ Earth Sci 71:2701–2709. doi: 10.1007/s12665-013-2648-9

[3] Chen H, Lu X, Li LY (2014) Spatial distribution and risk assessment of metals in dust based on samples from nursery and primary schools of Xi'an, China. Atmos Environ 88:172–182. doi: 10.1016/j.atmosenv.2014.01.054

[4] 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. doi: 10.1016/j.geoderma.2009.04.016

[5] Fergusson JE, Kim ND (1991) Trace elements in street and house dusts: sources and speciation. Sci Total Environ 100 Spec N:125–150. doi: 10.1016/0048-9697(91)90376-P

[6] Huang M, Wang W, Chan CY, et al (2014) 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 479–480:117–124. doi: 10.1016/j.scitotenv.2014.01.115

[7] Ian Alexander MLHWM (2011) Children, Soils, and Health: How Do Polluted Soils Influence Children's Health? In: Johnson CC, Demetriades A, Locutura J, Ottesen RT (eds) Mapping the Chemical Environment of Urban Areas. John Wiley & Sons, Ltd, pp 134–150

[8] Johnson CC (2011) Mapping the chemical environment of urban areas. Wiley-Blackwell

[9] Johnson CC, Demetriades A, Locutura J, Ottesen RT (eds) (2011) Mapping the Chemical Environment of Urban Areas. John Wiley & Sons, Ltd, Chichester, UK

[10] Kang Y, Cheung KC, Wong MH (2011) Mutagenicity, genotoxicity and carcinogenic risk assessment of indoor dust from three major cities around the Pearl River Delta. Environ Int 37:637–643. doi: 10.1016/j.envint.2011.01.001

[11] Li X, Poon C, Liu PS (2001) Heavy metal contamination of urban soils and street dusts in Hong Kong. Appl Geochemistry 16:1361–1368. doi: 10.1016/S0883-2927(01)00045-2

[12] Lu X, Wu X, Wang Y, et al (2014) Risk assessment of toxic metals in street dust from a medium-sized industrial city of China. Ecotoxicol Environ Saf 106:154–163. doi: 10.1016/j.ecoenv.2014.04.022

[13] Maghakyan N, Kafyan M, Tepanosyan G, et al (2013) Ecological-Geochemical and Sanitary-Hygienic Assessment of Soil in the Areas of Kindergartens of Yerevan. In: Environmnetal Problems and Risk Groups Identification among Population. Gitutyun, pp 118–126

[14] Olujimi O, Steiner O, Goessler W (2015) Pollution indexing and health risk assessments of trace elements in indoor dusts from classrooms, living rooms and offices in Ogun State, Nigeria. J African Earth Sci 101:396–404. doi: 10.1016/j.jafrearsci.2014.10.007

[15] Perelman AI, Kasimov NS (2000) Landscape geochemistry. Astrea, Moscow

[16] RA Government (2005) Resolution № 92 of 25 January 2005 "About approval of the order of assessment of the economic activities - induced impact on soil resources.

[17] RAIS (2016) The Risk Assessment Information System. http://rais.ornl.gov/.

[18] Rout TK, Masto RE, Ram LC, et al (2013) Assessment of human health risks from heavy metals in outdoor dust samples in a coal mining area. Environ Geochem Health 35:347–356. doi: 10.1007/s10653-012-9499-2

[19] Saghatelyan A (2004) The peculiarities of heavy metal distribution on Armenia's territory. CENS NAS RA, Yerevan, 157 pp. (in Russian)

[20] Saghatelyan A, Sahakyan L, Belyaeva O, Maghakyan N (2014) Studying Atmospheric Dust and Heavy Metals on Urban Sites through Synchronous Use of Different Methods. J Atmos Pollut 2:12–16. doi: 10.12691/jap-2-1-3

[21] Sun G, Li Z, Bi X, et al (2013) Distribution, sources and health risk assessment of mercury in kindergarten dust. Atmos Environ 73:169–176. doi: 10.1016/j.atmosenv.2013.03.017

[22] Tong STY (1998) Indoor and outdoor household dust contamination in Cincinnati, Ohio, USA. Environ Geochem Health 20:123–133. doi: 10.1023/A:1006561832381

[23] US EPA (1989) Risk Assessment Guidance for Superfund. Volume I Human Health Evaluation Manual (Part A). United States Environmental Protection Agency, Washington

[24] Wang L, Lu X, Ren C, et al (2014) Contamination assessment and health risk of heavy metals in dust from Changqing industrial park of Baoji, NW China. Environ Earth Sci 71:2095–2104. doi: 10.1007/s12665-013-2613-7

[25] WHO (2011) Summary of principles for Evaluating Health Risks in Children Associated with Exposure to Chemicals.

[26] Wu S, Peng S, Zhang X, et al (2015) Levels and health risk assessments of heavy metals in urban soils in. J Geochemical Explor 148:71–78. doi: 10.1016/j.gexplo.2014.08.009

[27] Yoshinaga J, Yamasaki K, Yonemura A, et al (2014) Lead and other elements in house dust of Japanese residences - Source of lead and health risks due to metal exposure. Environ Pollut 189:223–228. doi: 10.1016/j.envpol.2014.03.003