International Journal of Engineering & Technology, 8 (1.4) (2019) 527-532

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Heavy metal concentrations in the blood and the risk of allergic diseases for South Korean children and adolescents

Hye-Seon Choi[1], Hye-Young Ahn[2]*, Jin-Ju Woo[3]

[1]*Assistant Professor, Dept. of Nursing, Woosuk University*
[2]*Professor, Dept. of Nursing, Eulji University*
[3]*Assistant Professor, Dept. of Nursing, Gyeongbuk College of Health*
**Corresponding author E-mail: ahanaya@eulji.ac.kr*

Abstract

The purpose of this study was to investigate the effects of heavy metal concentration in the blood on allergic diseases in Korean children and adolescents using the Korean National Health and Nutrition Examination Survey (KNHANES) data. For the study, a secondary analysis of the data collected via the sixth KNHNES in the first year (2013) was conducted. The study subjects were 1,065 children. All the data were analyzed through a two-sided test at a significance level α=.05 using SPSS 24. As a result, the geometric mean concentrations of lead, mercury and cadmium in the blood were 1.25±0.03 ㎍/dL, 1.95±0.08 ㎍/L and 0.35±0.03 ㎍/L. As for allergic diseases, 6.2% of the children were diagnosed by doctors with asthma, 17.7% with atopic dermatitis, and 24.7% with allergic rhinitis. When mercury concentration in the blood increased by 0.1 ㎍/L, the possibility of allergic rhinitis prevalence was significantly increased by 1.31 times (p=.040). The above results indicate that heavy metal concentration in the blood of children affects allergic diseases. Therefore, in the future, an analytic epidemiological study should be conducted to investigate allergic diseases and related factors considering the characteristics of each heavy metal.

Keywords: *Atopic Dermatitis, Allergic Rhinitis, Asthma, Health Surveys, Heavy Metal*

1. Introduction

Air pollution warnings are frequently issued. In this regard, the number of items within big data related to fine dust increased by 2.65 times in two years, from 254,913 in 2015 to 676,312 in 2017 [1]. Fine dust, which is too tiny to be visible, stays in the air, flows into the lungs through the respiratory organs, travels through the blood vessels, and ultimately, exerts adverse effects on our health [2]. Fine dust contains diverse environmental pollutants, one of which is heavy metals [3]. In accordance with the severe increase in environmental pollution, there has been an increase in the risk of exposure to heavy metals, which is in addition to the commonly conceived fine dust pollution. According to a study by the US National Institute of Environmental Health Sciences (NIEHS), lead, a prime example of a toxic heavy metal that can cause harm to the human body, was found primarily in dust and soil, but was also detected in the air via vehicular emissions [4]. As such, heavy metals are contaminants to which we can be easily exposed during daily life.

The principal channels for heavy metals to flow into our bodies include inhalation, skin contact, and oral intake through food [5, 6]. When heavy metals are ingested, they bioaccumulate in the body without degradation and cause various negative health effects [7]. In the life cycle, particularly, it is more hazardous in childhood and in adolescence. During these periods, immaturity based on growth and development allows more exposure to heavy metals. Children are less able to filter out hazardous substances because they are more likely to inhale air for their weight than adults and are characterized by mouth breathing. They have a higher gastrointestinal absorption rate than adults and can be exposed to hazardous substances until adulthood; consequently, they show high rates of cumulative exposure [7]. It is therefore necessary to focus on children and adolescents in dealing with the issue of heavy metals.

The negative health effects of excessive exposure to heavy metals on children include developmental delays [8], asthma [9], learning disorders [10], emotional behavioral disorders, and sleep problems [7, 11]. Further, the ever-increasing cases of allergic diseases and heavy metal poisoning should be noted [11, 12]. In particular, allergic diseases among children and adolescents in Korea have been increasing annually and should be of concern [13]. While various allergic diseases do occur simultaneously, cases indicate that atopic dermatitis appears first, followed by asthma and allergic rhinitis in young children [14]. Therefore, to understand the characteristics of allergic diseases, children should be examined from childhood to adolescence.

Many South Korean researchers have determined the association between the heavy metal concentration in blood and food intake [15-17] and children's goods [18], among others. In other countries, there has been substantial research on the association between the heavy metal concentration in blood and allergic diseases [11, 12, 19]. In contrast, limited research has been conducted on the association between the heavy metal concentration in blood and allergic diseases for South Korean children [20]. The purpose of this study was to investigate the effects of the heavy metal concentration in blood on allergic diseases in Korean children and adolescents using the Korean National Health and Nutrition Examination Survey (KNHANES) data.

Copyright © 2019 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2. Methods

2.1. Study design

This is descriptive research that involves a secondary analysis of the data from the sixth KNHNES in the first year (2013) to determine the effects of heavy metal concentration in the blood on allergic diseases in children.

2.2. Subject and data collection

This study used the data from the sixth KNHNES in the first year (2013), and it was conducted with the approval of the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB No.: 2013-07CON-03-4C) [21]. The final analysis included 1,065 children participating in every test for heavy metal (lead, mercury, and cadmium) among the items in KNHNES.

2.3. Instrument

2.3.1. General characteristics

The data concerning gender, age, income, quartile (household), 16 cities, and housing type among the items in KNHNES were used to analyze the general characteristics [21]. Age groups in the raw data were divided into categories of 7-12 years (elementary school children), 13-15 years (middle school students), and 16-18 years (high school students). For economic status, the quartiles (household) for income in the raw data were classified into high, middle, and low levels. For residential districts, the 16 cities in the raw data were divided into five areas: the Metropolitan area (Seoul, Incheon, and Gyeonggi Province), the Chungcheong area (Daejeon and North and South Chungcheong Provinces), the Daegu, Gyeongbuk, and Gangwon area (Daeju, North Gyeongsang Province, and Gangwon Province), the Busan, Ulsan, and Gyeongnam area (Busan, Ulsan, and South Gyeongsang Province), and the Honam and Jeju area (Gwangju, North and South Jeolla Provinces, and Jeju). For housing type, the 'apartment division' in the raw data was used.

2.3.2. Allergic disease

Of the items in the survey on health, those regarding doctors' diagnosis status and time for asthma, atopic dermatitis, and allergic rhinitis were analyzed for allergic diseases [21].

2.3.3. Heavy metal concentration in the blood

The concentration of lead and cadmium in the blood was measured using PerkinElmerAAnalyst600 (PerkinElmer/Finland) to perform graphite furnace atomic absorption spectroscopy (GFAAS). The concentration of mercury in the blood was measured using PerkinElmer ICP-MS (PerkinElmer/USA) to perform inductively coupled plasma-mass spectroscopy (ICP/MS) [21]. The recommended concentration of heavy metal in the blood was based on the CDC criteria [22] for lead and cadmium and on the HBMI criteria [23] for mercury.

2.4. Data analysis

All the data were analyzed using an SPSS 24 program with a two-sided test at the α=.05 significance level. The data drawn by complex stratified sampling were statistically analyzed by applying weight, stratified variables, and cluster variables. Since applying integrated weight, stratified variables, and cluster variables can produce estimated frequency and values generalized for the whole nation, this study generated examined and estimated values. As for the statistical methods, complex sampling frequency and percentage were used to analyze the general characteristics and allergic diseases, and complex sampling descriptive statistics (mean and standard deviation) were used to analyze the heavy metal concentration in the blood. Complex sampling t-test and ANOVA were used to analyze the differences in the general characteristics and the heavy metal concentration in the blood, and complex sampling logistic regression analysis was used to analyze the effects of the heavy metal concentration in the blood on allergic diseases.

3. Results

3.1. Subjects' general characteristics

Among the respondents, 52.2% were male and 47.8% female; 52.9% were aged 7-12 years (elementary school children), 30.4% 13-15 years (middle school students), and 16.7% 16-18 years (high school students). With respect to economic status, 61.5% were at the middle level, 27.3% at the high level, and 11.3% at the low level. Among the respondents, 48.9% resided in the metropolitan area; 58.4% lived in apartments, and 41.6% in general houses (Table 1).

Table 1: General characteristics of subjects

		(N=1,065)	
Characteristics	Categories	Weighted %	n
Gender	Male	52.2%	563
	Female	47.8%	502
Age (year)	7-12 (elementary school students)	52.9%	641
	13-15 (middle school students)	30.4%	291
	16-18 (high school students)	16.7%	133
Economic status*	Low	11.3%	116

	Middle	61.5%	632
	High	27.3%	309
Residential area	Capital area	48.9%	553
	Chungcheong area	11.2%	109
	Daegu · Gyeongbuk · Gangwon area	12.2%	145
	Busan · Ulsan · Gyeongnam area	15.4%	114
	Honam · Jeju area	12.2%	144
Housing type	House	41.6%	403
	Condominium	58.4%	662
* Excludes no reply			

3.2. Allergic disease

As for allergic diseases, 6.2% of the children were diagnosed by doctors with asthma, 17.7% with atopic dermatitis, and 24.7% with allergic rhinitis. Asthma and atopic dermatitis were diagnosed at the age of three years, and allergic rhinitis at the age of six years on average (Table 2).

Table 2: Diagnosis of allergic disease*

Variables	Categories	Weighted %	n
Asthma	No	93.7%	982
	Yes	6.2%	63
	None	0.1%	1
	Age (yr) at diagnosis	Mean±SD	3.03±0.27
Atopic dermatitis	No	82.2%	864
	Yes	17.7%	181
	None	0.1%	1
	Age (yr) at diagnosis	Mean±SD	3.50±0.29
Allergic rhinitis	No	75.2%	780
	Yes	24.7%	265
	None	0.1%	1
	Age (yr) at diagnosis	Mean±SD	6.82±0.20

* Exclude no reply

3.3. Heavy metal concentration in the blood

The geometric average of concentration in the blood was 1.25±0.03 ㎍/dL for lead, 1.95±0.08 ㎍/L for mercury, and 0.35±0.03 ㎍/L for cadmium. As for the rate of heavy metal poisoning in the blood, poisoning (> 5 μg/L) was 2.2% in the concentration of mercury in the blood alone (Table 3).

This finding was similar to that of the environmental exposure and health status survey for children and adolescents IV (KorEHS-C IV): The geometric average of lead concentration in the blood was 1.20 ㎍/dL [24]. In contrast, the National Health and Nutrition Examination Survey (NHANES) in the United States and Canada (Canadian Health Measures Survey; CHMS) presented a lower geometric average of lead concentration in the blood: 0.84 ㎍/dL for children aged 6-11, 0.68 ㎍/dL for adolescents aged 12-19 [22], 0.90 ㎍/dL for children aged 6-11 and 0.80 ㎍/dL for adolescents aged 12-19 [25], respectively. The geometric average of mercury concentration in the blood was similar to KorEHS-C IV 1.84 ㎍/L [24] and was higher than the NHANES finding: 0.42 ㎍/L for children aged 6-11 and 0.54 ㎍/L for adolescents aged 12-19 [22]. The geometric average of cadmium concentration in the blood was similar to KorEHS-C IV 0.38 ㎍/L [24] and NHANES 0.33 ㎍/L for adolescents aged 12-19 [22].

Table 3: Blood heavy metal concentration

Variables	GM	SD	Poisoning rate Weighted %
Lead (㎍/dL)	1.25	0.03	0.0%
Mercury (㎍/L)	1.95	0.08	2.2%
Cadmium (㎍/L)	0.35	0.03	0.0%

Note. GM: Geometric mean, SD: Standard deviation
Lead: Blood heavy metal poisoning (> 10μg/dL)
Mercury: Blood heavy metal poisoning (> 5μg/L)
Cadmium: Blood heavy metal poisoning (> 5μg/L)

3.4. Differences in heavy metal concentration in the blood by general characteristics

The heavy metal concentration in the blood differed significantly by gender, age, and economic status among the general characteristics of the respondents. Males showed significantly higher concentrations of lead ($p<.001$) and mercury ($p=.002$) in the blood than females. The high school students aged 16-18 showed a significantly higher concentration of cadmium in the blood than middle school students aged 13-15 and elementary school children aged 7-12 ($p<.001$). As for economic status, the respondents at the 'middle' level showed a significantly higher concentration of lead in the blood than those at the 'high' level ($p=.007$), and the respondents at the 'high' level showed a significantly higher concentration of mercury in the blood than those at the 'middle' and 'low' levels ($p<.001$). In contrast, no statistically significant difference was found in the heavy metal concentration in the blood by residential area and housing type (Table 4).

These results were similar to the findings of the literature review that males showed higher concentrations of mercury and lead in the blood than females [26] and that the younger, the higher the concentration of cadmium in the blood [16, 26]. It was also similar to the finding that the greater the household income, the higher the concentration of mercury in the blood [15].

3.5. Effects of heavy metal concentration in the blood on allergic disease

A 0.1 ㎍/L increase in the concentration of mercury in the blood led to a significant increase of 1.31 times in the risk of allergic rhinitis ($p=.040$) (Table 5).

4. Conclusion

This study was conducted to analyze the effects of heavy metal concentration in the blood of children on their allergic diseases by performing a secondary analysis of the KNHANES data. As a result, the blood lead concentration in this study was 1.25±0.03 ㎍/dL, which was higher than that of foreign countries (NHANES 0.84 ㎍/dL, CHMS 0.80 ㎍/dL) [22, 25]. Furthermore, the blood mercury concentration was 1.95±0.08 ㎍/L, which was higher than that of the United States (NHANES 0.54 ㎍/L) [22]. However, the concentration of cadmium in the blood was 0.35±0.03 ㎍/L in this study and was similar to that of NHANES (0.33 ㎍/L) [22]. Interestingly, in this study, a child’s blood mercury levels affected allergic rhinitis. That is, when mercury concentration in the blood increased by 0.1 ㎍/L, the possibility of allergic rhinitis prevalence was significantly increased by 1.31 times ($p=.040$).

The concentration of both lead and mercury in the blood of children in South Korea was still higher than in neighboring advanced countries. It is concerning that poisoning (> 5 μg/L) was 2.2% in the concentration of mercury in the blood of children. In addition, the concentration of mercury in the blood increased the risk of allergic rhinitis among allergic diseases. The literature review found that one of the principal causes of increases in the concentration of mercury in the blood was fish intake [15, 27, 28]. The representative fish with a high content of mercury include shark, swordfish, king mackerel, and canned tuna [28].

Table 4: Blood heavy metal concentration according to Characteristics

Characteristics	Categories	Lead (μg/dL)			Mercury (μg/L)			Cadmium (μg/L)		
		GM	SD	*p*	GM	SD	*p*	GM	SD	*p*
Gender	Male	1.35	0.03	<.001	2.18	0.11	.002	0.39	0.04	.074
	Female	1.16	0.04		1.81	0.07		0.31	0.02	
Age (year)	7-12 [a] (elementary school students)	1.32	0.05	.179	1.95	0.11	.559	0.19	0.01	<.001
	13-15 [b] (middle school students)	1.26	0.05		1.94	0.10		0.33	0.03	
	16-18 [c] (high school students)	1.22	0.04		2.07	0.12		0.44	0.05	c>b>a
Economic status	Low [a]	1.19	0.07	.007	1.82	0.13	<.001	0.37	0.06	.257
	Middle [b]	1.31	0.04		1.88	0.08		0.36	0.04	
	High [c]	1.16	0.04	b>c	2.31	0.18	c>a,b	0.30	0.02	
Residence area	Capital area	1.26	0.04	.198	1.94	0.10	.882	0.33	0.02	.334
	Chungcheong area	1.16	0.07		1.89	0.19		0.33	0.04	
	Daegu·Gyeongbuk·Gangwon area	1.17	0.07		2.08	0.28		0.27	0.03	
	Busan·Ulsan·Gyeongnam area	1.32	0.05		2.09	0.21		0.49	0.11	
	Honam·Jeju area	1.33	0.08		2.13	0.21		0.32	0.06	
Housing type	House	1.31	0.05	.118	1.99	0.10	.941	0.38	0.03	.171
	Condominium	1.22	0.03		2.00	0.11		0.32	0.04	

Note. GM: Geometric Mean, SD: Standard deviation

Table 5: Influence of blood heavy metal concentration on allergic disease

	β	OR	95% CI			*p*
Asthma						
Lead (μg/dL)	0.36	1.43	0.53	~	3.85	.472
Mercury (μg/L)	-0.32	0.73	0.48	~	1.09	.124
Cadmium (μg/L)	-0.15	0.86	0.33	~	2.23	.751
Atopic dermatitis						
Lead (μg/dL)	0.39	1.33	0.69	~	2.58	.388
Mercury (μg/L)	0.67	1.06	0.82	~	1.35	.667
Cadmium (μg/L)	0.93	0.96	0.38	~	2.44	.925
Allergic rhinitis						
Lead (μg/dL)	0.10	1.10	0.56	~	2.18	.783
Mercury (μg/L)	0.27	1.31	1.01	~	1.70	.040
Cadmium (μg/L)	-0.41	0.67	0.30	~	1.48	.315

Fat may accumulate lead in the body. In contrast, vitamin C, calcium, and iron may reduce lead in the body [7]. It is therefore necessary to help children consume small amounts of food with a high content of fat and fish with a high content of mercury, and to provide them with a balanced diet full of vitamin C, calcium, and iron with the objective of lowering the concentration of mercury in the blood.

The government needs to make regulatory efforts to minimize the use of lead in vehicle fuels—particularly, gasoline—with the objective of lowering the concentration of lead in the blood. The Korea Food and Drug Administration needs to take the lead in the reinforcement of lead content monitoring in canned food and drinks. It is also important to avoid using paints containing lead and to change the plumbing fixtures of aged buildings in schools where children and adolescents spend substantial time. Parents need to keep their houses clean, preventing dust from flowing in, and to avoid using toys and school supplies made of paints containing lead. In addition, parents exposed to lead either during their work or while enjoying their hobbies need to take care by changing their clothes and by having a bath before returning home [7].

In addition to these efforts to lower the concentration of heavy metals in the blood, it is necessary to manage allergic diseases. Recent research found that those residing in areas with more green spaces were less vulnerable to allergic diseases, such as asthma and atopic dermatitis [29]. Therefore, one of the ways of managing allergic diseases can be to increase greens in urban centers at the level of local governments. Hong et al. [30] indicated that using household items (toothpastes, soaps, hand sanitizers, dishwashing detergents, fungicides, laundry detergents, deodorants, aerosol cleaners, wet wipes, and household pesticides) with the term 'antimicrobial' or 'antibacterial' could help to reduce asthma and allergic rhinitis. It would therefore be desirable to use antibacterial goods at home when a fine dust warning is issued or when severe environmental pollution occurs.

The above results indicate that heavy metal concentration in the blood of children affects allergic diseases. Unfortunately, this study did not reflect various factors related to heavy metal exposure and allergic diseases such as dietary or internal/external environmental factors (e.g. parents and environment) as the KNHANES data were used. Therefore, in the future, an analytic epidemiological study should be conducted to investigate allergic diseases and related factors considering the characteristics of each heavy metal. Of the items in KNHNES targeting the whole nation, there has been no measurement of the heavy metal concentration in the blood for children aged ≥10 years since 2013. To make matters worse, even the Korea Youth Risk Behavior Web-Based Survey, which can represent South Korean elementary, middle, and high school students, fails to measure heavy metal concentrations in the blood. As the changes in the atmospheric environment and environmental pollution are currently becoming serious, it is urgent to monitor and manage heavy metal concentrations in the blood of people at the national level [31].

References

[1] YonhapNews (2018), *A serious fine dust*, available online: http://www.yonhapnews.co.kr/bulletin/2018/01/21/0200000000AKR20180121025400033.HTML?input=1195m, last visit:1.5.2018.

[2] Ailshire JA & Clarke P (2015), Fine particulate matter air pollution and cognitive function among U.S. older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 70(2), 322-328.

[3] Ministry of Environment (2016), *What is it about fine dust*, available online: http://www.me.go.kr/ebook/svs/gt/view/159, last visit:1.5.2018.

[4] NIH (National Institute of Environmental Health Sciences) (2018), *Lead*, available online: https://www.niehs.nih.gov/health/topics/agents/lead/, last visit:1.5.2018.

[5] KCDC (Korea Centers for Disease Control and Prevention) (2016), *Heavy metals in daily life: lead*, available online: http://health.cdc.go.kr/health/HealthInfoArea/HealthInfo/View.do?idx=14210, last visit:1.5.2018.

[6] Falck AJ, Mooney S, Kapoor SS, White KM, Bearer C & Metwally D (2015), Developmental exposure to environmental toxicants. *Pediatric Clinics of North America* 62(5), 1173-1197.

[7] Edelman C, Mandle CL & Kudzma EC (2014), *Health Promotion Throughout the Life Span*, 8th edn. Amsterdam: Elsevier, pp.415-503.

[8] Hsueh YM, Lee CY, Chien SN, Chen WJ, Shiue HS, Huang SR, Lin MI, Mu SC &. Hsieh RL (2017), Association of blood heavy metals with developmental delays and health status in children. *Scientific Reports* 7(43608), 1-9.

[9] NIH (National Institute of Environmental Health Sciences) (2018), *Asthma*, available online: https://www.niehs.nih.gov/health/topics/conditions/asthma/, last visit:2.5.2018.

[10] Wang S & Zhang J (2006), Blood lead levels in children. China. *Environmental Research* 101(3), 412-418.

[11] Sears CG & Zierold KM (2017), Health of children living near coal ash. *Global Pediatric Health* 4, 1-8.

[12] Miyake Y, Tanaka K, Yasutake A, Sasaki S & Hirota Y (2011), Lack of association of mercury with risk of wheeze and eczema in Japanese children: the Osaka maternal and child health study. *Environmental Research* 111(8), 1180-1184.

[13] Lee YH, Choi JH, Park MR, Kim JH, Kim WK, Park YM, Lee SY, Han MY, Chae YM, Ham MI, Lee KJ, Kwon HJ & Ahn KM (2015), Analysis of regional prevalence of allergic diseases in Korean school children. *Allergy Asthma & Respiratory Disease* 3(1), 62-69.

[14] Nutten S (2015), Atopic dermatitis: global epidemiology and risk factors. *Annals of Nutrition and Metabolism* 66(1), 8-16.

[15] Shin JY, Kim JM & Kim YR (2012), The association of heavy metals in blood, fish consumption frequency, and risk of cardiovascular diseases among Korean adults: the Korean National Health and Nutrition Examination Survey (2008-2010). *The Korean Journal of Nutrition* 45(4), 347-361.

[16] Kim JY, Shin MS, Kim SH, Seo JH, Ma HS & Yang YJ (2017), Association of iron status and food intake with blood heavy metal concentrations in Korean adolescent girls and women: based on the 2010~2011 Korea National Health and Nutrition Examination Survey. *Journal of Nutrition and Health* 50(4), 350-360.

[17] Chung SE & Cheong HK, The correlation of blood metal concentration and daily nutrition intake amount in Korea (2011), *Proceedings of the 2011 Annual Conference of Korean Society of Environmental Toxicology*, 10(1), 228-229.

[18] Choi IS & Choi SC (2014), Contents and migration of heavy metals and phthalates in children`s products and phthalates in children`s products. *Journal of Korean Society of Environmental Engineers* 36(2), 127-138.

[19] Vrijheid M, Casas M, Gascon M, Valvi D & Nieuwenhuijsen M (2016), Environmental pollutants and child health - a review of recent concerns. *International Journal of Hygiene and Environmental Health* 219(4), 331-342.

[20] Kim JH, Jeong KS, Ha EH, Park H, Ha MN, Hong YC, Lee SJ, Lee KY, Jeong JS & Kim YH (2013), Association between prenatal exposure to cadmium and atopic dermatitis in infancy. *Journal of Korean Medical Science* 28(4), 516-521.

[21] KCDC (Korea Centers for Disease Control and Prevention) (2013), *The Sixth Korea national health and nutrition examination survey* (KNHANES VI).

[22] CDC (Centers for Disease Control and Prevention) (2018), *National report on human exposure to environmental chemicals*, available online: https://www.cdc.gov/exposurereport/, last visit:2.5.2018.

[23] Schulz C, Wilhelm M, Heudorf U & Kolossa-Gehring M (2011), Update of the reference and HBM values derived by the German human biomonitoring commission. *International Journal of Hygiene and Environmental Health* 215(1), 26-35.

[24] Ministry of the Interior and Safety (2014), *Environmental exposure and health survey in children and adolescents*, available online: http://www.prism.go.kr/homepage/entire/retrieveEntireDetail.do?pageIndex=1&research_id=1480000-201400091&leftMenuLevel=160&cond_research_name=%EA%B1%B4%EA%B0%95%EC%8B%A4%ED%83%9C&cond_research_start_date=&cond_research_end_date=&pageUnit=10&cond_order=3, last visit:1.5.2018.

[25] CHMS (Canadian Health Measures Survey) (2010), *Table 10: final human health state of the science report on lead*, available online: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/environmental-contaminants/table-10-blood-lead-levels-blls-canada-united-states-canadian-adults-children.html, last visit:1.5.2018.

[26] Ku IY, Kim HS, Lee JP, Song KS & Kim YK (2015), Pb, Hg and Cd concentration of blood and exposure related factors. *Journal of Korea Academia-Industrial Cooperation Society* 16(3), 2089-2099.

[27] Kim YA, Kim YN, Cho KD, Kim MY, Kim EJ, Baek OH & Lee BH (2011), Blood heavy metal concentrations of Korean adults by seafood consumption frequency: using the fourth Korea national health and nutrition examination survey (KNHANES IV), 2008. *The Korean Journal of Nutrition* 44(6), 518-526.

[28] Lando AM & Zhang Y (2011), Awareness and knowledge of methylmercury in fish in the United States. *Environmental Research* 111(3), 442-450.

[29] Lee JY, Lee MJ, Leem JH, Lamichhane DK, Hong YC, Kim YH, Ha MN & Ha EH (2016), Green spaces and allergic outcomes in children, *Proceeding of the 2016 Annual Conference of Korean Society of Environmental Toxicology*, 6(1), 96.

[30] Hong SY, Kwon HJ, Choi WJ, Lim WR, Kim JH & Kim KS (2014), Association between exposure to antimicrobial household products and allergic symptoms. *Environmental Health and Toxicology* 29, 120-125.

[31] Choi HS, Ahn HY & Woo JJ (2018), Effects of blood heavy metal concentration in school children on allergic disease. *International Journal of Bio-Science and Bio-Technology* 10(2), 7-12.