Archives of Hygiene Sciences
Qom University of Medical Sciences

https://jhygiene.muq.ac.ir/
10.34172/AHS.12.2.1.414
Vol. 12, No. 2, 2023, 70-74

Original Article

Does Occupational Lead Exposure Affect the Relationship Between Neurobehavioral Characteristics and Productivity?

Mina Salehi[1], Asma Zare[2*], Mahdi Malakoutikhah[3], Salman Farahbakhsh[3]

[1]Department of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Department of Occupational Health Engineering, Sirjan School of Medical Sciences, Sirjan, Iran
[3]Department of Occupational Health Engineering, School of Health, Kashan University of Medical Sciences, Kashan, Iran

Abstract

Background & Aims: Lead (Pb) may cause cognitive impairments in both recent acute and chronic exposures. In this study, the effect of Pb exposure on the relationship between neurobehavioral characteristics and productivity was evaluated among battery manufacturing workers.

Materials and Methods: In general, 179 production workers and 179 office workers participated in this cross-sectional study. Venous blood sampling was used to measure the level of Pb in the blood. Psychomotor performance and intellectual functioning were measured using the digit symbol substitution test and the Wechsler adult intelligence scale-revised, respectively. Finally, productivity was assessed using a health and work performance questionnaire.

Results: Exposed workers had a significantly higher level of Pb, while a lower level of intellectual functioning and psychomotor performance than non-exposed workers. The results of linear regression indicated that the increase in the blood level of Pb was accompanied by a significant decrease in the positive effects of intellectual functioning on productivity. However, exposure to Pb had no effect on the relationship between psychomotor performance and productivity.

Conclusion: Occupational exposure to Pb affected the relationship between psycho-diagnostic performance and productivity and could induce neurobehavioral dysfunction in the exposed workers. For the early detection of cognitive impairment, the neurobehavioral assessment is recommended to be implemented in work assessments.

Keywords: Occupational exposure, Lead, Intelligence, Cognition, Battery factory

Received: September 12, 2022, **Accepted**: December 21, 2022, **ePublished**: May 31, 2023

1. Introduction

Due to the increasing use of lead (Pb) in industry, human exposure and absorption of this unnecessary element have increased. The effect of Pb on humans has always been a health concern. Although the amount of Pb in the industry has decreased significantly in recent years, occupational exposure to Pb is still extremely high. Occupational exposure to Pb can have a variety of toxic effects on the human body, including abnormal kidney function, blood diseases, reproductive disorders, and neurocognitive impairment [1].

Pb can cause cognitive impairments whether in recent acute or chronic exposures [2]. Previous studies have shown that exposure to Pb reduces the activity of neurotransmitters, ultimately affecting cognitive function [3-5]. Pb can also disrupt in simple reaction time, memory impairment, impaired motor behaviors, poor speech performance, impaired performance, and impaired learning [6,7]. In adults, occupational exposure to Pb causes cognitive deficits in memory, manual dexterity, learning ability, and related psychomotor speed [2].

Most workers exposed to Pb exhibit poor performance on psychological and neuromotor tests [8]. This effect on cognitive function has been observed at both high and low levels of exposure [1,9]. However, the recommended values for Pb exposure are not accurate and consistent. The blood level of Pb (PbB) for adults is 5 µg/dL according to the United States National Institute for Occupational Safety and Health [10]. According to the World Health Organization (WHO), PbB for adults needs to be less than 10 µg/dL [11]. Based on the US Occupational Safety and Health Administration, when the PbB level is more than 60 µg/dL, you should not be exposed to Pb [12]. In addition, the American Conference of Governmental Industrial Hygienists (ACGIH) recommended 30 µg/dL as the biological exposure index for Pb [13].

The levels of Pb with detrimental effects also varied in the studies. For example, in some studies, cognitive impairment was observed in workers with PbB between 20 and 40 µg/dL [14,15], while a meta-analysis showed neurobehavioral dysfunction in exposed workers with PbB between 50 and 60 µg/dL [15,16]. However, the researchers noted that the reviewed studies did not provide definitive information regarding the effects of Pb on cognitive function.

Up to now, there have been no safety thresholds. However, PbB levels lower than 5 µg/dL do not appear to increase the risk of short- and long-term exposure and

*Corresponding Author: Asma Zare, Email: zareasma605@gmail.com

do not require further management [15]. Of course, in industries that deal with Pb, exposure to Pb is extremely higher than 5 μg/dL, and even low levels of Pb may adversely affect cognitive function. Long-term exposure to Pb may also be associated with a faster cognitive decline and accelerated cognitive aging [17] and adversely affect the spatial domain of cognition [18], which may be a subclinical symptom of central nervous system damage [14].

Previous studies demonstrated that functional disability and impairments in daily activities are the result of cognitive impairments. Further, work-related performance deteriorates in people with more severe cognitive impairments [19-22]. However, there is little information about the impact of Pb exposure on different dimensions of productivity loss and neurobehavioral characteristics in Pb-related industries, particularly in battery manufacturing factories. Hence, this study aimed to assess the effect of Pb exposure on the relationship between neurobehavioral characteristics and productivity.

2. Materials and Methods

This cross-sectional study was performed on 179 male workers in a battery factory in Isfahan, Iran in 2021. Workers who had at least five years of work experience and worked in the production line were included in the study. On the other hand, the workers under treatment with cerebra-active drugs and other substances interfering with neurobehavioral performances were excluded from the study. Furthermore, after taking the history, workers with a history of psychometric diseases, cognitive disorders, and underlying diseases leading to behavioral disorders were excluded from the study. Demographic information, smoking status, residential area (presence of nearby industries or factories), and employment history (during the past three periods) were collected through interviews. The control group included 179 men who were similar in age to the case group. These workers were not exposed to Pb in their current or past jobs. The control group included workers working in the administrative department of the company located in Isfahan and was randomly selected, and an informed consent form was provided to all participants.

Neurobehavioral tests were performed by a clinical psychologist after workers' shifts in a standardized environment using identical procedures. The environmental assessment data of workplace Pb levels were extracted from the documentation available in the factory. The amount of environmental Pb was more than the threshold limit of 0.05 mg/m^3 (ACGIH recommendation) [13]. To evaluate the PbB level, venous blood samples were taken from the participants. Heparinized Pb-free drain tubes were used to collect blood samples. Blood samples were kept at + 4 ˚C for two weeks until performing all analyses. The PbB concentration was determined using a transversely-heated graphite furnace and Zeeman background correction.

2.1. General intelligence measurement using the Wechsler Adult Intelligence Scale-Revised (WAIS-R)

The WAIS, first presented in 1955, is an intelligence assessment test in adults. The WAIS-R [23] is, as its name implies, a revised form of the WAIS. The structure of the WAIS-R is the same as the original structure of the WAIS. This test measures intelligence components using 11 subtests. The subtests are divided into two categories, including verbal intelligence and functional intelligence. The first group includes the subtests of vocabulary, information, arithmetic, reading comprehension, digit range, and similarities. Moreover, the second group contains the subtests of image arrangement, image completion, object assembly, block design, and numerical symbols. The results of all subtests are employed to obtain a full-scale intelligence quotient.

2.2. Cognitive function measurement using the Digit Symbol Substitution Test (DSST)

The DSST is a psychomotor performance assessment test consisting of a key grid of matching numbers and symbols and a test section with numbers and blank boxes. In this test, the participant must fill in empty boxes with the symbol corresponding to that number. For this test, 90 seconds of time is considered, and the score is calculated by counting the number of matching numbers and correct symbols [24]. The test-retest reliability of this test is high [25].

2.3. Productivity measurement

The WHO Health and Work Performance Questionnaire (WHO-HPQ) was applied to assess productivity quality and job performance [26]. The Iranian version of the HPQ was used in the present study [27]. The questionnaire included A (health), B (work), and C (demographic) parts. There were 57 questions in Section A to assess mental and physical health and medical history in the past year. Part B included 23 questions on working hours, occupational accidents, sick leave, and productivity in the last seven days and last four weeks. In Section C, demographic information was collected with 8 questions. This questionnaire had a test-retest correlation equal to 0.76 [27].

2.4. Statistical analysis

SPSS 22 software was used for data analysis. Independent t-test was utilized to compare the differences between groups ($P < 0.05$). To check the normality of the data, the Kolmogorov-Smirnov test was employed before performing inferential statistical analysis. The results revealed that the level of significance for all research variables was greater than 0.05. Therefore, the assumption of normal distribution was observed and thus it was possible to use the Pearson correlation coefficient and regression analysis. A linear regression model was applied to evaluate the relationship between variables.

3. Results

The sociodemographic characteristics and biomarkers of case and control groups are presented in Table 1. Based on the results, there was no significant difference between the case and control groups in terms of age, work experience, and education level. Therefore, these variables did not have an interventionist effect on the results. The mean level of PbB was significantly higher in the case group than in the control group. The PbB levels were found to be higher than 30 mg/dL (the threshold limit value) in 46 exposed workers (25%). The level of Pb was 21-92 µg/dL and 6-18 µg/dL in the exposed workers and the control group, respectively.

The results of psycho-diagnostic variables are provided in Table 2. General intelligence (WAIS-R output) and cognitive function (DSST output) were significantly lower in the case group compared to the control group. Based on the results, productivity (WHO-HPQ output) was significantly better in the control group.

A linear regression model was used to assess the relationship between the PbB and psycho-diagnostic variables, and performance (productivity). According to the results (Table 3), the correlation coefficient between general intelligence and productivity was 0.855 and 0.530 for no exposure and exposure to unauthorized amounts of Pb, respectively. In addition, the correlation between cognitive function and productivity was 0.732 and 0.581 for no exposure and exposure to unauthorized amounts of Pb, respectively.

Based on data in Table 4, for general intelligence and exposure to unauthorized amounts of Pb, the regression coefficient was 0.161, which was statistically significant ($P=0.001$). Hence, exposure to Pb as a moderating variable weakened the effect of general intelligence on productivity. For cognitive function and exposure to unauthorized amounts of Pb, the regression coefficient was -0.551, which was not statistically significant ($P=0.259$). Therefore, exposure to unauthorized amounts of Pb could not reduce the correlation between cognitive function and productivity.

4. Discussion

According to the findings, occupational Pb exposure at currently safe levels may lead to the impairment of some cognitive abilities and as a result, indirectly affects productivity. There was a significant difference between the case and control groups in the tests mainly involving general intelligence and cognitive function. The results showed that exposure to Pb weakened the effect of general intelligence on productivity. However, Pb did not affect the relationship between cognitive function and productivity.

Based on the literature review, no study has been conducted on the effect of Pb as a mediating variable on the relationship between psycho-cognitive functions and worker productivity. However, concerning studies on the effect of Pb on psycho-cognitive functions, as well as the effect of psycho-cognitive characteristics on productivity, it is possible to interpret the results of the present study to some extent.

Numerous studies have evaluated the Pb exposure's effect on psychological cognitive functions. For

Table 1. Sociodemographic characteristics and biomarkers of Pb exposure in the participants

Variables		Battery workers	Office workers	P*
Sample size (N)		179	179	NS**
Age (years, mean ± SD)		35.7 ± 7.62	34.9 ± 5.32	NS
Education level (years, mean ± SD)		12.32 ± 1.3	11.03 ± 0.5	NS
Work experience (years, mean ± SD)		13.25 ± 6.96	12.68 ± 4.3	NS
Smoking (%)	Yes	28	31	NS
	No	72	69	NS
PbB (µg/dL, mean ± SD)		49.58 ± 18.3	14.47 ± 1.8	0.001

Note. SD: Standard deviation; PbB: Lead in blood; *T-test; **Not significant at the level of 0.05.

Table 2. Comparison of exposed and non-exposed workers regarding the psycho-diagnostic variables (Mean ± SD)

Variables	Battery workers	Office workers	P*
General intelligence	97.54 ± 0.73	98.15 ± 0.76	0.023**
Cognitive function	37.03 ± 0.586	40.07 ± 0.119	0.043**
Productivity	0.9034 ± 0.169	1.0652 ± 0.220	0.021**

Note. SD: Standard deviation; *Independent t-test; **$P<0.05$.

Table 3. The correlation between PbB and psycho-diagnostic variables, and productivity

Groups	Variables	Productivity
Battery workers	General intelligence	0.530*
	Cognitive function	0.581*
Office workers	General intelligence	0.855*
	Cognitive function	0.732*

Note. *Pearson's correlation.

Table 4. The results of regression among the biomarker of lead exposure, psycho-diagnostic variables, and productivity variables

Variable affecting productivity	Regression coefficient	t	P*
Exposure to lead	1.147	2.709	0.043
General intelligence without exposure to lead	0.698	5.206	0.029
General intelligence with exposure to lead	0.161	3.27	0.001
Cognitive function without exposure to lead	1.312	3.114	0.036
Cognitive function with exposure to lead	-0.551	-1.153	0.059

Note. *Statistically significant when $P<0.05$.

instance, Lasley reported that neurological function was significantly impaired among workers with Pb levels between 40 and 80 μg/dL, which led to impaired cognitive function, impaired visual-spatial information processing, and lack of proper attention control [28]. Wilson et al also stated that the cumulative levels of PbB were significantly associated with tension, hostility, and anxiety [29]. Similarly, Salehzadeh et al found that anxiety, social dysfunction, and depression were related to PbB levels [30]. In addition, in the closest study to the present study, Aminian et al concluded that neurobehavioral dysfunction may occur among battery manufacturing workers due to occupational exposure to Pb [31]. All the mentioned aspects in these studies may be related to individual productivity [32].

How Pb affects the cognitive performance of adults is still unknown. However, several mechanisms have been proposed, the most important of which include the effect of Pb on oxidative stress, mitochondrial damage, and neurotransmitters [17,33]. Pb could also indirectly affect cognitive function by increasing blood pressure [34]. Fenga et al indicated that Pb can also cause some cognitive-behavioral problems such as depression, tension, anger, and confusion in permitted amounts [1]. These results are consistent with the latest scientific findings, suggesting that there may be a link between elevated PbB levels and measured cognitive abnormalities, and that there is no safe blood level for Pb deleterious effects on neurological function. In line with previous studies such as those conducted by Fenga et al, Aminian et al, and Nestorova et al [1,14,31], the association between increased blood levels of Pb and measurable neurocognitive abnormalities was confirmed in this study.

Based on the prevalence of cognitive dysfunction in workers exposed to Pb, and its impact on workers' lives from a human and economic perspective, the relationship between cognitive dysfunction and work-related outcomes, including productivity, requires investigation. Clark et al stated that despite the limited evidence, the relationship between cognitive dysfunction and productivity is probably a direct negative impact [20]. Indirect evidence for the effects of Pb on productivity appears to be found in the mentioned studies.

According to the regression results in the current investigation, in addition to its direct effects on cognitive function and productivity, Pb could reduce the direct effect of general intelligence on productivity. However, exposure to Pb had no effect on the correlation between cognitive function and productivity. This was the first time that a relationship was found between a performance index (productivity) and Pb exposure. In this study, different dimensions of neurobehavioral characteristics were analyzed, which helped determine the part of cognitive function that was exactly affected by Pb exposure. In addition, another strength of this study was having a relatively large number of samples. The large sample size of this study makes it possible to generalize the results to the population of workers exposed to Pb in battery factories. In general, it should be noted that no amount can be expressed as a safe level for Pb from the point of view of the effect on the nervous system, and the only way to measure these effects is to perform neuropsychological tests.

On the other hand, one of the limitations of this study was the inclusion of the workers of only one battery factory. The causal relationships of the results were also limited due to the study design. Therefore, a prospective study is recommended to control the confounding effects. Further, the performed tests were limited to some psychological features. The use of various tests can improve the certainty of the results.

5. Conclusion

The study findings revealed that the PbB level and productivity have a significant negative correlation. Accordingly, occupational exposure to Pb affected the relationship between psycho-diagnostic performance and productivity and could induce neurobehavioral dysfunction in the exposed workers. For the quick diagnosis of cognitive problems, it is recommended that neurobehavioral assessments should be implemented in work assessments.

Acknowledgments

The authors would like to acknowledge the support and assistance provided by all participants. They would also like to thank Ms. A. Keivanshekouh at the Research Improvement Center of Shiraz University of Medical Sciences for improving the use of English in the manuscript.

Competing Interests

The authors declare that they have no competing interests.

Ethical Approval

The protocol of the present study was approved by the Ethics Committee of the Sirjan School of Medical Sciences (IR. SIRUMS.1400.39).

Funding

This work was supported by the Sirjan School of Medical Sciences (No. 400000039).

References

1. Fenga C, Gangemi S, Alibrandi A, Costa C, Micali E. Relationship between lead exposure and mild cognitive impairment. J Prev Med Hyg. 2016;57(4):E205-E10.
2. Sharma S, Wakode S, Sharma A, Nair N, Dhobi M, Wani MA, et al. Effect of environmental toxicants on neuronal functions. Environ Sci Pollut Res Int. 2020;27(36):44906-21. doi: 10.1007/s11356-020-10950-6.
3. Muñoz MP, Rubilar P, Valdés M, Muñoz-Quezada MT, Gómez A, Saavedra M, et al. Attention deficit hyperactivity disorder and its association with heavy metals in children from northern Chile. Int J Hyg Environ Health. 2020;226:113483. doi: 10.1016/j.ijheh.2020.113483.
4. Boskabady M, Marefati N, Farkhondeh T, Shakeri F, Farshbaf

A, Boskabady MH. The effect of environmental lead exposure on human health and the contribution of inflammatory mechanisms, a review. Environ Int. 2018;120:404-20. doi: 10.1016/j.envint.2018.08.013.
5. Rocha A, Trujillo KA. Neurotoxicity of low-level lead exposure: history, mechanisms of action, and behavioral effects in humans and preclinical models. Neurotoxicology. 2019;73:58-80. doi: 10.1016/j.neuro.2019.02.021.
6. Ramírez Ortega D, González Esquivel DF, Blanco Ayala T, Pineda B, Gómez Manzo S, Marcial Quino J, et al. Cognitive impairment induced by lead exposure during lifespan: mechanisms of lead neurotoxicity. Toxics. 2021;9(2):23. doi: 10.3390/toxics9020023.
7. Maheshwari S, Chaturvedi M, Anthony A, Kushwaha S, Singh J, Singh S. Chronic lead exposure: a cause for brain degeneration and calcifications: a case report. SN Compr Clin Med. 2021;3(1):346-9. doi: 10.1007/s42399-020-00699-x.
8. Zhang Y, Hou D, O'Connor D, Shen Z, Shi P, Ok YS, et al. Lead contamination in Chinese surface soils: source identification, spatial-temporal distribution and associated health risks. Crit Rev Environ Sci Technol. 2019;49(15):1386-423. doi: 10.1080/10643389.2019.1571354.
9. Bakulski KM, Seo YA, Hickman RC, Brandt D, Vadari HS, Hu H, et al. Heavy metals exposure and Alzheimer's disease and related dementias. J Alzheimers Dis. 2020;76(4):1215-42. doi: 10.3233/jad-200282.
10. CDC. NIOSH Adult Blood Lead Epidemiology Surveillance (ABLES). 2015. Available from: https://wwwn.cdc.gov/niosh-whc/chart/ABLES.
11. WHO WHO. T, editor. BEIs: Threshold Limit Values for Chemical Substances and Physical Agents. Cincinnati 2015. Available from: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/2823642.
12. (OSHA) TOSaHA. Threshold limit values & Biological Exposure Indices 2003. Available from: https://www.osha.gov/annotated-pels/note.
13. ACGIH. TLVs and BEIs. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2015. https://www.acgih.org/science/tlv-bei-guidelines.
14. Nestorova V, Ivanov B, Mircheva I, Dimitrov I, Kaprelyan A, Drenska K. Occupational lead exposure and cognition in adults. J IMAB. 2018;24(2):2069-73. doi: 10.5272/jimab.2018242.2069.
15. Ettinger AS, Egan KB, Homa DM, Brown MJ. Blood lead levels in U.S. women of childbearing age, 1976-2016. Environ Health Perspect. 2020;128(1):17012. doi: 10.1289/ehp5925.
16. Goodman M, LaVerda N, Clarke C, Foster ED, Iannuzzi J, Mandel J. Neurobehavioural testing in workers occupationally exposed to lead: systematic review and meta-analysis of publications. Occup Environ Med. 2002;59(4):217-23. doi: 10.1136/oem.59.4.217.
17. Satarug S, Gobe GC, Vesey DA, Phelps KR. Cadmium and lead exposure, nephrotoxicity, and mortality. Toxics. 2020;8(4):86. doi: 10.3390/toxics8040086.
18. Mir RH, Sawhney G, Pottoo FH, Mohi-Ud-Din R, Madishetti S, Jachak SM, et al. Role of environmental pollutants in Alzheimer's disease: a review. Environ Sci Pollut Res Int. 2020;27(36):44724-42. doi: 10.1007/s11356-020-09964-x.
19. Chokka P, Bougie J, Rampakakis E, Proulx J. Assessment in Work Productivity and the Relationship with Cognitive Symptoms (AtWoRC): primary analysis from a Canadian open-label study of vortioxetine in patients with major depressive disorder (MDD). CNS Spectr. 2019;24(3):338-47. doi: 10.1017/s1092852918000913.
20. Clark M, DiBenedetti D, Perez V. Cognitive dysfunction and work productivity in major depressive disorder. Expert Rev Pharmacoecon Outcomes Res. 2016;16(4):455-63. doi: 10.1080/14737167.2016.1195688.
21. Kim JM, Chalem Y, di Nicola S, Hong JP, Won SH, Milea D. A cross-sectional study of functional disabilities and perceived cognitive dysfunction in patients with major depressive disorder in South Korea: the PERFORM-K study. Psychiatry Res. 2016;239:353-61. doi: 10.1016/j.psychres.2016.01.022.
22. Toyoshima K, Inoue T, Shimura A, Masuya J, Ichiki M, Fujimura Y, et al. Associations between the depressive symptoms, subjective cognitive function, and presenteeism of Japanese adult workers: a cross-sectional survey study. Biopsychosoc Med. 2020;14:10. doi: 10.1186/s13030-020-00183-x.
23. Barona A, Reynolds CR, Chastain R. A demographically based index of premorbid intelligence for the WAIS—R. J Consult Clin Psychol. 1984;52(5):885-7. doi: 10.1037/0022-006x.52.5.885.
24. Rosano C, Newman AB, Katz R, Hirsch CH, Kuller LH. Association between lower digit symbol substitution test score and slower gait and greater risk of mortality and of developing incident disability in well-functioning older adults. J Am Geriatr Soc. 2008;56(9):1618-25. doi: 10.1111/j.1532-5415.2008.01856.x.
25. Babaei N, Saliminia A, Azimaraghi O, Aghajani Y, Khazaei N, Movafegh A. Preoperative oral valiflore reduces anxiety in laparoscopic cholecystectomy: a double blind, placebo controlled study. J Cell Mol Anesth. 2017;2(3):103-11. doi: 10.22037/jcma.v2i3.16121.
26. Kessler RC, Barber C, Beck A, Berglund P, Cleary PD, McKenas D, et al. The World Health Organization Health and Work Performance Questionnaire (HPQ). J Occup Environ Med. 2003;45(2):156-74. doi: 10.1097/01.jom.0000052967.43131.51.
27. Pournik O, Ghalichi L, Tehrani Yazdi AR, Tabatabaee SM, Ghaffari M, Vingard E. Reliability and validity of Persian version of World Health Organization health and work performance questionnaire in Iranian health care workers. Int J Occup Environ Med. 2012;3(1):33-8.
28. Lasley SM. Developmental neurotoxicology of lead: neurobehavioral and neurological impacts. In: Slikker W, Paule MG, Wang C, eds. Handbook of Developmental Neurotoxicology. 2nd ed. Academic Press; 2018. p. 413-25. doi: 10.1016/b978-0-12-809405-1.00037-7.
29. Wilson RS, Barnes LL, Mendes de Leon CF, Aggarwal NT, Schneider JS, Bach J, et al. Depressive symptoms, cognitive decline, and risk of AD in older persons. Neurology. 2002;59(3):364-70. doi: 10.1212/wnl.59.3.364.
30. Salehzadeh H, Ebrahemzadih M, Nourani MR, Kourghi M, Taheri RA. The impact of lead contamination on psychiatric disorders and quality of life. J Biochem Technol. 2019;10(2):18-27.
31. Aminian O, Saneian AA, Izadi N. The relationship between serum lead level and neurobehavioral performance. Health Scope. 2019;8(4):e68441. doi: 10.5812/jhealthscope.68441.
32. Burton WN, Conti DJ, Chen CY, Schultz AB, Edington DW. The role of health risk factors and disease on worker productivity. J Occup Environ Med. 1999;41(10):863-77. doi: 10.1097/00043764-199910000-00007.
33. Masri S, LeBrón A, Logue M, Valencia E, Ruiz A, Reyes A, et al. Social and spatial distribution of soil lead concentrations in the city of Santa Ana, California: implications for health inequities. Sci Total Environ. 2020;743:140764. doi: 10.1016/j.scitotenv.2020.140764.
34. Rehman K, Fatima F, Waheed I, Akash MSH. Prevalence of exposure of heavy metals and their impact on health consequences. J Cell Biochem. 2018;119(1):157-84. doi: 10.1002/jcb.26234.