The Relationship between Exposure to Lead-Containing Welding Fumes and the Levels of Reproductive Hormones

Somayeh Farhang Dehghan*, Younes Mehrifar† and Arash Ardalant

Background: Inhalation of lead oxide fumes may cause lead poisoning. Lead has been proven to have harmful effects on different organs. This study aimed to investigate the relationship between the concentration of lead fumes and the levels of reproductive hormones among exposed welders.

Methods: A total number of 165 individuals of a construction industry of water pipelines, including 85 welders as the exposure group and 80 administrative staff as the non-exposure group were selected for study. The National Institute for Occupational Safety and Health (NIOSH) 7300 method was used for the purpose of sampling and analysis of lead fumes. Likewise, the NIOSH 8003 method was employed to determine the blood lead level. The level of luteinizing hormone (LH), follicle-stimulating hormone (FSH), and testosterone were measured by Chemiluminescence immunoassay (CLIA) test. Data analyses were done by SPSS ver.21 using descriptive statistics, Student’s t-test and Spearman’s correlation test.

Results: The average concentration of lead fumes in the breathing zone and blood were 0.57 ± 0.12 mg/m³ and 460.28 ± 93.65 μg/L, correspondingly, which both were significantly higher than threshold limit values (TLV) and biological exposure index (BEI) recommended by American Conference of Governmental Industrial Hygienists (ACGIH) (P < 0.05). The mean levels of LH and FSH were higher in the exposed group than those in the control group (P < 0.05), however, the mean levels of testosterone were lower in the exposed group compared to non-exposed ones (P < 0.05). A strong correlation was found between the concentration of lead fumes and the blood lead levels (r = 0.82; P = 0.003). Blood lead levels were inversely related to the testosterone levels and directly related to LH (r = 0.72; P = 0.004) and FSH (r = 0.78; P = 0.001) levels.

Conclusions: Occupational exposure to metal fumes containing lead among welders may alter the level of sexual hormones and potentially harm the reproductive system.
Male reproductive hormones play a significant role in growth and development of sperm. The concentration of steroid hormones such as Luteinizing Hormone (LH), Follicle Stimulating Hormones (FSH), and Testosterone are considered as a sensitive indicator of reproductive system performance. LH regulates spermatogenesis by stimulating interstitial cells as well as producing testosterone; while FSH along with testosterone works on spermatogonial tubes and stimulates production of spermatzoa [32]. Lead reduces both the testosterone levels and the number of LH receptors on Leydig cells while it destructs the Sertoli cells. As such, it causes a negative feedback on the pituitary-gonadal axis and increases both LH and FSH levels in order to modulate the resulted damages to testis [29, 33, 34]. This study aimed to determine the concentration of lead fumes in the breathing zone and blood lead and LH, FSH, and testosterone levels. Our purpose was to assess the relationship between exposure to lead-containing welding fumes and the levels of reproductive hormones.

Methods
Study Design
This cross-sectional study was carried out based on the data derived from a water transfer company in Iran. After a preliminary review of the industry, SMAW was selected as the main source of releasing welding fume. SMAW welders were all eligible to enter the study. A number of 85 welders and 80 male individuals were selected as the exposure and control groups, respectively. Inclusion criteria consisted of being male, age between 20–50 years, married, non-drinker, non-smoker, no use of medications that likely affect the sexual derive, as well as no history of infertility, any major illnesses that affect sexual function, and no history of drug use. Participants were all required to sign a consent form. Those who failed to complete the questionnaire were withdrawn from the study. The individuals were allowed to leave the study at any time. Patients were assured their demographic information will be kept confidential.

Air Sampling and Analysis
All air sampling and analysis of welding fumes were done according to the Method Number 7300 of the National Institute for Occupational and Safety (NIOSH) using Mixed Cellulose Ester (MCE) filter (25 mm, 0.8 μm, SKC Inc., USA), personal sampling pump (224-PCMTX8, SKC Inc.) [35]. Samples were prepared and analyzed by inductively coupled plasma (ICP) (Varian, Liberty-RL model, Italy) with detection limit of 0.01 μg l⁻¹.

Blood Sampling and Analysis
Plastic tubes containing heparin were used to collect 8 cc of blood after 8 to 10 hours of fasting in order to measure the lead levels. Those were sent to a lab immediately. The blood lead levels were determined by an atomic absorption spectroscopy (Chemtech, UK) according to the method NIOSH 8003 [36]. The levels of LH, FSH, and testosterone were determined by chemiluminescence immunoassay (CLIA) which uses the MAGLUMI full-automatic chemiluminescence immunoassay analyzer designated by Snibe diagnostics (Shenzhen, China). The same technician conducted all measurements to avoid any predispositions.

Statistical Analysis
SPSS software version 21 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Data were analyzed using descriptive statistics, Student’s t-test and Spearman’s correlation test. P values of less than 0.05 were regarded as statistically significant. The Shapiro–Wilk test was used to test the normality of the data.

Results
A total of 165 individuals, including 85 welders as an exposure group, and 80 administrative staff as non-exposed group participated in this study. According to Table 1, age ranged from 25 to 51 years with a mean and standard deviation of 38.17 and 12.44 years, respectively. The welders exposed to fumes for a length of 4.2 to 14 years with mean of 8.77 ± 3.61 years. According to Table 1, the concentration of lead fumes among welders averaged 0.57 ± 0.12 mg/m³. This was significantly higher than the threshold limit values-time weighted average (TLV-TWA) by the American Conference of Governmental Industrial Hygienists (ACGIH) (0.05 mg/m³) [18]. Likewise, the blood lead level averaged 460.28 ± 93.65 μg/L which was significantly higher than the biological exposure index (BEI) recommended level by ACGIH (200 μg/L).

Table 2 compares the levels of the sexual hormone between two groups. The average level of testosterone in the exposure group (2.02 ± 0.62 ng/ml) was significantly lower than that of the control group (7.26 ± 1.84

| Table 1: Background characteristics and exposure data in exposed and non-exposed groups. |
|---------------------------------------------------------------|
| Exposed (n = 85) | Non-exposed (n = 80) | P-value* |
| Mean ± SD | Range | Mean ± SD | Range |
|---------------------------------------------------------------|
| Age (year) | 38.17 ± 11.04 | 25–50 | 32.82 ± 9.66 | 22–43 | 0.026 |
| History of Welding (year) | 8.77 ± 3.61 | 4.2–14 | ND** | ND | 0.017 |
| Lead fume (mg/m³) | 0.57 ± 0.12 | 0.20–0.73 | ND | ND | 0.013 |
| Blood Lead (μg/L) | 460.28 ± 93.65 | 150.46–589.24 | 10.41 ± 3.76 | 3.31–12.09 | 0.010 |

* P < 0.05 was considered as statistically significant.
** ND: Not Detected.
Dehghan et al: Levels of Sexual Hormones and Lead Exposure

Spearman correlation

shows the results of Spearman correlation

This finding is consistent with the results of Wang et al. (62x50)

According to the results, there is a paradoxical correlation

fact, the average blood testosterone levels among welders 

Dorosti et al. was also able to show blood lead levels of welders 

Likewise, lead concentrations in welders' breathing zone 

Likewise, a strong correlation between the concentration of airborne lead and its level in the blood of welders 

A paradoxical correlation was found between the blood lead and testosterone levels 

However, blood lead levels was directly related to both LH (r = 0.724, p = 0.001) and FSH (r = –0.625, p = 0.002); however, blood lead levels was significantly higher compared to the values of control group (12.01 ± 5.36 mIU/ml) (P = 0.013).

Table 3 shows the results of Spearman correlation test between the concentration of lead fume, blood level levels, as well as blood levels of LH, FSH, and testosterone. There was a strong correlation between the concentration of airborne lead and its level in the blood of welders (r = 0.823, p = 0.003). A paradoxical correlation was found between the blood lead and testosterone levels (r = −0.625, p = 0.002); however, blood lead levels was directly related to both LH (r = 0.724, p = 0.001) and FSH (r = 0.789, p = 0.001) levels.

Discussion

Our finding indicates the welders have relatively high blood levels of lead which may adversely affect the reproductive system function [37]. The results of the study shows the average concentration of lead fumes among welders is significantly higher than recommended levels by ACGIH. According to the findings, mean blood level of lead in welders was 460.28 ± 93.65 μg/l. This is significantly higher than the recommended level by ACGIH. Likewise, lead concentration in welders' breathing zone and blood was as high as 11.4 and 10 times the recommended levels, respectively. The congruence between air and blood lead levels might be due to lack of using respiratory protective equipment by most of the welders (87.75%).

The results of this study show a statistically significant relationship between the concentration of lead fumes in respiratory zone and the level of blood lead among welders. This is consistent with the findings of the study done by Dehghan et al. [38] Previous studies have also brought similar results with ours in respect to blood lead levels of welders [38, 39]. Dorosti et al. was also able to show blood lead levels of welders were significantly higher than that of the control group [40].

Previous studies demonstrate exposure to lead has adversely affected the human reproductive system. Our study also shows the levels of sex hormones are significantly different between welders and control subjects. In fact, the average blood testosterone levels among welders are significantly lower than that of the control group. According to the results, there is a paradoxical correlation between the blood lead and testosterone levels among welders. This finding is consistent with the results of Wang et al. in which the concentrations of testosterone among workers exposed to lead in battery plant was significantly lower than that of the control group [41]. They also showed a reverse association between blood lead and testosterone levels among workers exposed to lead [41].

There are also significant differences in the levels of pituitary-ovaries axis hormones such as LH and FSH between welders who were exposed to lead fumes compared to the control group. According to the results, the concentration of LH and FSH hormones in lead-exposed welders was significantly higher than those of non-exposed group. As such, a direct significant correlation can be described between blood lead and both LH and FSH levels. Taher et al. (2017) reported significantly higher levels of LH and FSH among workers who were exposed to lead particles than that of the non-exposed group [42]. Likewise, Vivoli and colleagues reported a reverse correlation between blood lead level and both LH and FSH levels in men with blood lead levels of 9 μg/dl or higher [43].

There are many other studies which support relatively high levels of both LH and FSH among lead-exposed workers. In a study on lead melting workers, the amount of LH in the exposed group was significantly higher than non-exposed group [44]. Likewise, Kumar et al. reported lower levels of both LH and FSH among welders who were exposed to lead fumes with a concentration higher than recommended values by TLV-TWA. They also found welders who worked longer than 10 years in welding industries had higher levels of blood FSH than those who worked less than 10 years as a welder [45]. Similarly, Pant et al. was able to show a significant inverse correlation between blood lead levels (5.29–7.25 μg/dl) and both mobility and concentration of sperms among lead-exposed men [46].

Chowdhury et al. reported an increased risk of sperm depletion and reproductive system dysfunction in men who were constantly exposed to lead [37].

Histological studies of semen also support the findings. In fact, sperm analysis of exposed individuals demonstrated morphological damages to sperm as well as reduction in the levels of fructose and benzene dehydrogenase in semen [47]. Welders who were exposed to lead carried

### Table 2: Reproductive hormones levels in exposed and non-exposed groups.

|                      | Exposed (n = 85) | Non-exposed (n = 80) | P value* |
|----------------------|------------------|---------------------|----------|
|                      | Mean ± SD        | Range               | Mean ± SD | Range |          |
| FSH (mIU/ml)         | 9.34 ± 2.56      | 3.17–21.57          | 5.50 ± 2.19 | 1.61–11.42 | 0.024   |
| LH (mIU/ml)          | 21.05 ± 6.39     | 5.23–31.66          | 12.01 ± 5.36 | 3.33–24.76 | 0.013   |
| Testosterone (ng/ml) | 2.02 ± 0.62      | 1.9–5.81            | 7.26 ± 1.84 | 3.73–10.35 | 0.019   |

### Table 3: Correlation between blood lead level with lead fumes and reproductive hormones.

|                          | r     | P value |
|--------------------------|-------|---------|
| Lead fumes (mg/m³)       | 0.823 | 0.001   |
| FSH (mIU/ml)             | 0.789 | 0.001   |
| LH (mIU/ml)              | 0.724 | 0.004   |
| Testosterone (ng/ml)     | −0.625| 0.002   |
a relatively low sperm count and motility compared to the control group [39]. There are, however, studies that did not come up with these results. Seleven and colleagues reported no changes in sperm quality among workers who were exposed to lead [48]. Likewise, it has been reported there was no relationship between blood lead levels and variations in hormonal parameters [49]. The observed inconsistency might be due to the differences in lead levels in the breathing zone and blood of exposed individuals, exposure length of time, or the effect of confounding factors such as toxic gases, heat, and ultraviolet radiations during welding process, or even a combination of all.

This study includes some limitations as follows:

- The impossibility of collecting semen samples because of some cultural issues.
- Having small sample size due to lack of sufficient facilities and human resources for measurement of environmental and biological parameters.
- Not considering other environmental parameters like noise, vibration, electromagnetic field, other metal fume and toxic gases effecting on reproductive parameters of welders.

Yet, further studies are recommended to be performed on this issue in order to eliminate the aforementioned limitations.

Conclusion

According to the results of the study, welders are exposed to relatively high levels of lead fumes at work. An increased blood lead level may reduce the blood testosterone and increase both LH and FSH levels among welders which may cause reproductive disorders. Therefore, occupational health professionals are required to apply the preventive measures such as installing local exhaust ventilation systems, limiting exposure time, biological monitoring and periodic screening health examination, and finally, providing appropriate respiratory protection devices for welders.

Acknowledgements

The authors of this article appreciate welders who participated in this study.

Competing Interests

The authors have no competing interests to declare.

Author Contribution

SF managed and planned the project. YM and SF analyzed the data and made the preliminary information in a state of measurable and SF, YM, and AA were a major contributor in writing the manuscript. YM collected the data in the field. All authors read and approved the final manuscript.

References

1. Mehrifar Y, Zeverdegani SK, Faraji M and Rismanchian M. Risk assessment of welders exposure to the released contaminated gases in different types of welding processes in a steel

Industry. Health Scope; 2018. DOI: https://doi.org/10.5812/jhealthscope.58267
2. Sajedifar J, Kokabi AH, Dehghan SF, et al. Evaluation of operational parameters role on the emission of fumes. Industrial health. 2018; 56: 198–206. DOI: https://doi.org/10.2486/indhealth.2017-0155
3. Meo SA and Al-Khliawi T. Health hazards of welding fumes. Saudi Medical Journal. 2003; 24: 1176–1182.
4. Popović P, Prokić-Cvetković R, Burzić M, Lukić U and Belić B. Fume and gas emission during arc welding: Hazards and recommendation. Renewable and Sustainable Energy Reviews. 2014; 37: 509–516. DOI: https://doi.org/10.1016/j.rser.2014.05.076
5. Karimi Ze'veverdegani S, Mehrifar Y, Faraji M and Rismanchian M. Occupational exposure to welding fumes during three welding processes and risk assessment by SQRCA method. Journal of Occupational Health and Epidemiology. 2017; 6: 144–149. DOI: https://doi.org/10.29252/johe.6.3.144
6. Rahmani A, Golbabaei F, Dehghan SF, Mazlomi A and Akbarzadeh A. Assessment of the effect of welding fumes on welders’ cognitive failure and health-related quality of life. International Journal of Occupational Safety and Ergonomics. 2016; 22: 426–432. DOI: https://doi.org/10.1080/10803548.2016.1164499
7. Lyttle K. Optimizing consumable selection increases productivity, decreases fumes. Gases & Welding Distribution. 2004; 45–47.
8. Cezar-Vaz MR, Bonow CA and Vaz JC. Risk communication concerning welding fumes for the primary preventive care of welding apprentices in southern Brazil. International Journal of Environmental Research and Public Health. 2015; 12: 986–1002. DOI: https://doi.org/10.3390/ijerph120100986
9. Sajedifar J, Kokabi AH, Azam K, et al. The comparative assessment of welders’ exposure to welding fumes based on mass and number concentration. Health and Safety at Work. 2016; 6: 17–26.
10. Hubbs AF, Sargent LM, Porter DW, et al. Nanotechnology: Toxicologic pathology. Toxicologic Pathology. 2013; 41: 395–409. DOI: https://doi.org/10.1177/0192633712467403
11. El-Zein M, Malo J, Infante-Rivard C and Gautrin D. Prevalence and association of welding related systemic and respiratory symptoms in welders. Occupational and Environmental Medicine. 2003; 60: 655–661. DOI: https://doi.org/10.1136/ oem.60.9.655
12. Mehrifar Y, Zamanian Z and Pirami H. Respiratory exposure to toxic gases and metal fumes produced by welding processes and pulmonary function tests. Int J Occup Environ Med. 2019; 1: 40–49. DOI: https://doi.org/10.15171/ijoem.2019.1540
13. Lilienberg L, Zock J, Kromhout H, et al. A population-based study on welding exposures at work and respiratory symptoms. Annals of Occupational Hygiene. 2008; 52: 107–115.
14. Mehrifar Y, Pirami H and Farhang Dehghan S. The relationship between exposure to manganese in

"
welding fumes and incidence of migraine headache symptoms. *Tehran University Medical Journal*. TUMS Publications. 2018; 76: 135–141.

15. Yu J, Song KS, Chang HK, et al. Lung fibrosis in Sprague-Dawley rats, induced by exposure to manual metal arc-stainless steel welding fumes. *Toxicological Sciences*. 2001; 63: 99–106. DOI: https://doi.org/10.1093/toxsci/63.1.99

16. Persoons R, Arnoux D, Monssu T, et al. Determinants of occupational exposure to metals by gas metal arc welding and risk management measures: A biomonitoring study. *Toxicology Letters*. 2014; 231: 135–141. DOI: https://doi.org/10.1016/j.toxlet.2014.09.008

17. Adonaylo V and Oteiza P. Lead intoxication: Antioxidant defenses and oxidative damage in rat brain. *Toxicology*. 1999; 135: 77–85. DOI: https://doi.org/10.1016/S0300-483X(99)00051-7

18. ACGIH. TLVs and BEIs, Documentation of the Threshold Limit Values and Biological Exposure Indices. *American Conference Governmental of Industrial Hygienists*, Cincinnati, OH. 2017; 36–101.

19. Acharya U, Acharya S and Mishra M. Lead acetate induced cytotoxicity in male germinal cells of Swiss mice. *Industrial Health*. 2003; 41: 291–294. DOI: https://doi.org/10.1080/002069403100008126

20. Antonini JM, Zeidler-Erdely PC, Young S-H, Roberts JR and Erdely A. Systemic immune cell response in rats after pulmonary exposure to manganese-containing particles collected from welding aerosols. *Journal of Immunotoxicology*. 2012; 9: 184–192. DOI: https://doi.org/10.3109/1547691X.2011.650733

21. García-Lestón J, Méndez J, Pácharo E and Laffon B. Genotoxic effects of lead: An updated review. *Environment International*. 2010; 36: 623–636. DOI: https://doi.org/10.1016/j.envint.2010.04.011

22. Poreba R, Gać P, Poreba M and Andrzejak R. The relationship between occupational exposure to lead and manifestation of cardiovascular complications in persons with arterial hypertension. *Toxicology and Applied Pharmacology*. 2010; 249: 41–46. DOI: https://doi.org/10.1016/j.taap.2010.08.012

23. Ekong EB, Jaar B and Weaver V. Lead-related nephrotoxicity: A review of the epidemiologic evidence. *Kidney International*. 2006; 70: 2074–2084. DOI: https://doi.org/10.1038/sj.ki.5001809

24. Telíšman S, Čolak B, Pizent A, Jurasović J and Cvitković P. Reproductive toxicity of low-level lead exposure in men. *Environmental Research*. 2007; 105: 256–266. DOI: https://doi.org/10.1016/j.envres.2007.05.011

25. Vigest M, Smith DR and Hsu P-C. How does lead induce male infertility? *Iranian Journal of Reproductive Medicine*. 2011; 9: 1.

26. Allouche L, Hamadouche M and Touabti A. Chronic effects of low lead levels on sperm quality, gonadotropins, and testosterone in albino rats. *Experimental and Toxicologic Pathology*. 2009; 61: 503–510. DOI: https://doi.org/10.1016/j. etp.2008.12.003

27. Gulson BL, Mizon KJ, Korsch MJ, Palmer JM and Donnelly JB. Mobilization of lead from human bone tissue during pregnancy and lactation—A summary of long-term research. *Science of the Total Environment*. 2003; 303: 79–104. DOI: https://doi.org/10.1016/S0048-9697(02)00355-8

28. Henkel R. The impact of oxidants on sperm function. *Andrologia*. 2005; 37: 205–206. DOI: https://doi.org/10.1111/j.1439-0272.2005.00699.x

29. Tapisso JT, Marques CC, da Luz Mathias M and da Graça Ramalhinho M. Induction of micronuclei and sister chromatid exchange in bone-marrow cells and abnormalities in sperm of Algerian mice (Mus spretus) exposed to cadmium, lead, and zinc. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*. 2009; 678: 59–64. DOI: https://doi.org/10.1016/j.mrgentox.2009.07.001

30. Batra N, Nehru B and Bansal M. Influence of lead and zinc on rat male reproduction at ‘biochemical and histopathological levels’. *Journal of Applied Toxicology: An International Journal*. 2001; 21: 507–512. DOI: https://doi.org/10.1002/jat.796

31. Uzun FG, Kalender S, Durak D, Demir F and Kalender Y. Malathion-induced testicular toxicity in male rats and the protective effect of vitamins C and E. *Food and Chemical Toxicology*. 2009; 47: 1903–1908. DOI: https://doi.org/10.1016/j. ftc.2009.05.001

32. Sinclair S. Male infertility: Nutritional and environmental considerations. *Alternative Medicine Review: A Journal of Clinical Therapeutic*. 2000; 5: 28–38.

33. Anjum MR, Sainath S, Suneetha Y and Reddy PS. Lead acetate induced reproductive and paternal mediated developmental toxicity in rats. *Ecotoxicology and Environmental Safety*. 2011; 74: 793–799. DOI: https://doi.org/10.1016/j.ecoenv.2010.10.044

34. Smoooda K. Effect of lead exposure on gonadotropin in rats. *J Toxicology Physiological*. 2015; 44: 313–322.

35. NIOSH. Elements (ICP): Method 7300, Issue 3. *NIOSH Manual of Analytical Methods: National Institute of Occupational Safety and Health; 2003.*

36. NIOSH. LEAD in blood and urine: Method 8003, Issue 2. *NIOSH Manual of Analytical Methods: National Institute of Occupational Safety and Health; 1994.*

37. Chowdhury AR. Recent advances in heavy metals induced effect on male reproductive function: A retrospective. *Al Ameen J Med Sci*. 2009; 2: 37–42.

38. Dehghan-Nasiri M, Golbabaii F, Koohpaii A, Rahimi-Forooshani A and Shahtaheri S. Biological and environmental monitoring of lead and exposure in the automobile industry. *Iran Occupational Health*. 2012; 8.

39. Golpayegani A and Khanjani N. Occupational and environmental exposure to lead in Iran: A systematic
review. Journal of Health and Development. 2012; 1: 74–89.
40. Dorosti A and Shahrai J. Study of blood lead levels, hemoglobin, & plasma ascorbic acid in A Car Company Welders. Salāmat-i kār-i Īrān. 2006; 3: 43–49.
41. Wang P, Zhu B-L, Zhang H-D, et al. Notice of retraction investigation the concentrations of serum hormone among the male workers in the battery plant. 5th International Conference on Bioinformatics and Biomedical Engineering. IEEE. 2011; 1–4. DOI: https://doi.org/10.1109/icbbe.2011.5781446
42. Taher MA, Hammadi SA and Ali AA. The changes in sex hormones in female working in batter Abbey manufacturing plant. Iraqi Journal of Pharmaceutical Sciences. (P-ISSN: 1683–3597, E-ISSN: 2521–3512) 2017; 15: 23–28.
43. Vivoli G, Fantuzzi G, Bergomi M, et al. Relationship between low lead exposure and somatic growth in adolescents. Journal of Exposure Analysis and Environmental Epidemiology. 1993; 3: 201–209.
44. Rodamilans M, Osaba MJM, To-Figueras J, et al. Lead toxicity on endocrine testicular function in an occupationally exposed population. Human Toxicology. 1988; 7: 125–128. DOI: https://doi.org/10.1177/096032718800700203
45. Kumar S, Zaidi S, Gautam A, Dave L and Saiyed H. Semen quality and reproductive hormones among welders—A preliminary study. Environmental Health and Preventive Medicine. 2003; 8: 64–67. DOI: https://doi.org/10.1007/BF02897929
46. Pant N, Kumar G, Upadhya A, et al. Reproductive toxicity of lead, cadmium, and phthalate exposure in men. Environmental Science and Pollution Research. 2014; 21: 11066–11074. DOI: https://doi.org/10.1007/s11356-014-2986-5
47. Chowdhury A, Chinoy N, Gautam A, et al. Effect of lead on human semen. Advances in Contraceptive Delivery Systems: CDS. 1986; 2: 208–210.
48. Selevan SG, Borkovec L, Slott VL, et al. Semen quality and reproductive health of young Czech men exposed to seasonal air pollution. Environmental Health Perspectives. 2000; 108: 887. DOI: https://doi.org/10.1289/ehp.00108887
49. Aminian O, Chavoshi F, Bahaedini LS, Soltani S and Najarkolaei FR. Relationship between blood lead level and male reproductive hormones in male lead exposed workers of a battery factory: A cross-sectional study. Iranian Journal of Reproductive Medicine. 2013; 11: 673.