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Research Article

OCCUPATIONAL EXPOSURE OF WORKERS TO MANGANESE AND ITS EFFECTSON BLOOD IRON INDICES VALUES IN A FERROALLOY INDUSTRY

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ABSTRACT
In this study, chronic occupational exposure to manganese and its effect on indices related to blood iron in workers of a ferroalloy factory have been investigated. Forty seven workers at a manganese (Mn) ferroalloy and 47 external controls were studied cross-sectionally. Respirable manganese and blood manganese were determined according to NIOSH method 7300 and all samples were analyzed by graphite furnace- atomic absorption spectroscopy (GF-AAS). Counting of blood cells was performed and amount of iron and ferritin, was determined. Statistical data processing was done by using software SPSS15. Mean exposure of case group to respirable manganese was 0.33±0.23 mg/m^3 which was higher than threshold limit value (TLV) of 0.2 mg/m^3. Indices having significant difference between case and control groups were orderly as blood manganese, TIBC and number of red globules ($p<0.05$). Iron, ferritin, mean hemoglobin within red globule, hematocrit, hemoglobin and average volume of red globules in both case and control groups did not have meaningful difference ($p>0.05$). The results showed that manganese of air was 1.65 times more than TLV, but did not cause anemia in workers group. However, values of TIBC and RBC in case group were more than control group with a significant difference. This can be predictive of iron deficiency occurrence. The minimum manganese of whole blood, 17 µg/l has not have undesired effects on blood iron indices of people at present study.

Keywords: *Blood, Ferroalloy Industry, Iron Deficiency, Manganese, Occupational Exposure*

INTRODUCTION
Name of manganese was taken from Greek word magic meaning magical because scientist has yet involved in studying different effects for lack of manganese and its poisoning on organism (Aslam *et al*., 2008; Aschner and Higdon, 2010). Manganese is one of the necessary elements required in the body. Required amount of manganese for body in a man with weight 70 mg/kg is 10-20. Physiological half life of manganese is 36-41 days but half life of manganese existing in the brain is more than this value (Schoeman, 2005). There are more than 250 substances containing manganese listed among poisonous chemical materials in need controlling most of which have application in metallurgy industry. Mineral stones including pirolozite, rudokerozite, rhodanate containing manganese (Shahtaheri and Afshari, 2007). Manganese is used in production of dry bottles, alloys with aluminum, fuel supplements with combination of D-N methyl syclopanta and 3 carbonyl manganese and in cover of welding electrodes (Shahtaheri and Afshari, 2007; Ellingsen *et al*., 2006). It also has application in textile whitewashing, leather tanning, production of some kind of ceramic and pesticide, of steel as reacting substance and of some colors (Schoeman, 2005). Linus Pauling Institute subject to medical and nutrition board in England

has offered the required amount of manganese based on milligram per day (AI- Adequate Intake) as well as age and sex of consumer in which required amount for men with above 19 years old is 2.3 mg/day (Aschner and Higdon, 2010). The body naturally controls absorbed amounts of manganese. If high amount of manganese is absorbed through meal, the body will then remove extra amount through faeces. If this amount is extremely high, the body may not be able to regulate and remove extra amount (Schoeman, 2005). Inhaling of manganese in high concentration has reverse effect on health especially metal fume fever and disturbances in central nervous system which is known as manganism (Nastiti *et al*., 2010). Poisoning by manganese leads to multiple nervous problems and this has been recognized as a risk for health of people who inhale manganese like welders and smelter workers. Poisoning symptoms with manganese usually appears slowly and during multi month or year period (Aschner and Higdon, 2010). In worst situation, it can cause permanent nervous damages with symptoms like parkinson and these symptoms include tremor, problem in walking and face spasm (Aschner and Higdon, 2010; Guilarte, 2011; Robert, 2008). In some studies, no symptoms, neurotic and behavioral effect were observed due to exposure to manganese with less than 0.2 mg/m^3. For example in the study done by Daschamp *et al*., (2001) on 138 enameling workers with average work experiences 20 years, psychological variations were not recorded for them with average inhaling amount of manganese 0.057 mg/m^3 (Brent and Annete, 2005). (TLV-TWA- Threshold Limit Value, Time Weighted Average) pronounced by (ACGIH-American Conference Govermental Institute Hygiene) and Environment and Workplace Health Center of Iran is 0.2 mg/m^3 (Nastiti *et al*., 2010; Health Center of Environmental and Work of Iran, 2011). Exposure to the amounts of higher than this value can cause different effects on human health (Ling *et al.*, 2005).

In a study, manganese concentration in blood of welders group was 25% higher than control group and the welders with further exposure had significant difference compared to control group (Ling *et al*., 2005). Early diagnosis in poisoning with manganese especially in low amount of professional exposure to preventing the disease will be sensitive and critical (Yueming *et al.*, 2006). Pre clinical symptoms have been seen in populations who have exposure to this element and in stages after damages incidence, stopping contact with manganese will prevent development of the symptoms (Aslam *et al.*, 2008). Biological exposure index (BEI-Biological Exposure Index) for manganese has been yet defined by no international and national standard organizations and scientists have been studying different effects of lack of manganese and its poisoning as to organisms (Aslam *et al.*, 2008; Aschner and Higdon, 2010). Manganese and iron have antagonist effect on the body, especially on central nervous system and have competition in arriving at the brain and passing through blood-brain barrier (Nastiti *et al.*, 2010). Manganese is transferred to target cells via different proteins especially transferrin after entering blood circulation. Combination of this element with transferrin can create disturbance in iron metabolism (Hassanzadeh, 2003; Hassanzadeh and Moshtaghi, 2002; Hassanzadeh and Sadahi, 2002). In domestic animals, iron deficiency is the result of controlling consequences of manganese on iron absorption (Badiei and Parchami, 2004).

Biggest transporter in intestinal absorption of iron and regulation indicator of body iron is the protein divalent metals transporting (DMT1=Divalent metal transporter-1). To investigate potential role of the transporter in absorption of respirable manganese, a study was carried out on rats which had meaningful results showing defect cause in iron and manganese metabolism (Khristy *et al.*, 2007).

In study of Smith, strong relationship was proved between blood manganese and iron deficiency (adjusted r^2= 34.3%). Also, there was significant difference between children with anemia and those having iron sufficiency (Smith and Ahmed, 2013).

In another study in 2012, iron reserves had decreased in few welders. Airborne manganese and iron had effect on blood manganese level and ferritin, respectively, and also strong relationship was observed between blood manganese and iron (Beate *et al.*, 2012).

According to the above mentioned studies and also due to the lack of sufficient information regarding biological exposure index (BEI) for manganese, this study was done to investigate chronic occupational exposure to manganese and its effect on indices related to blood iron in workers of a ferroalloy factory.

MATERIALS AND METHODS

This research was done at ferroalloy factory located in 75 kilometers far from Kerman city, Kerman province. Kerman is geographically in 57 degrees and 7 minutes of eastern length and 30 degrees and 18 minutes north of width and height in 1755 meters from sea level. From the North West, town of Kerman is limited to desert from the south to the town of Bam and Jiroft and from the west to the towns of the Ravar, Zarand, Rafsanjan and Bardsir.

According to pre tests, mean values and calculated standard deviation and also based on statistical methods, 47 workers of the factory were chosen by filling questionnaire and testimonial form and participated in this study. Forty seven more people participated in this study as control group from workers of the same factory without exposure experience to manganese whose demographic characteristics including age, wage status and work shift were similar to the case group. All participants of the study were men and they had complete knowledge and consent for entering into the research and present study has been appraised by moral committee of our university. Exclusion criteria included:

- Having herbal regime – involving in liver and kidney diseases- having anemia background- using medicines as ranitidine, tetracycline, aspirin, gentamicin, cimetidine, pancratine, indomethacine, chloramphenicol
- Having severe tooth problems, malignant marrow disease and thalassemia, exposure to ionization radiations.

*A) **Measuring General Amount of Dust, Non-respirable Dust and Manganese and Iron Amounts in Inhalation Dust***

Standard method NIOSH 500 (National Institute of Occupational Safety and Health (NIOSH), 1994) and NIOSH7300 (National Institute of Occupational Safety and Health (NIOSH), 1985) were used to measure the amount of total dust and respirable dust, respectively. Individual sampling pump MSAmodel ESCORT and cellulose ester filter with pore size 0.8 micrometer and cyclone 25 millimeter with sampling rate 2 liter/min and collected air volume 240- 480 liter were used for respirable dust sampling. Respirable dust samples of manganese were analyzed according to NIOSH7300 method using a Varian graphite furnace-atomic absorption spectroscopy (GF-AAS) model AA240 (National Institute of Occupational Safety and Health (NIOSH), 1985).

*B) **Measuring Blood Manganese and Items Related to Blood Iron of Workers among Case and Control Groups***

Blood sample was taken from workers after an hour passing from the beginning of work, so that fasting condition was considered. General blood sample (whole blood) was used to measure manganese concentration, because manganese concentration in whole blood is more than serum or plasma (Ling *et al.*, 2005). Whole blood samples were maintained in vials containing anticoagulant material EDTA at -20°C until analyzing samples to measure manganese and ferritin. Blood sample was collected in a vial lacking anti goring material to evaluate CBC experiment and transferred to the laboratory and CBC experiments were carried out on hematocrit immediately after separation of blood plasma using centrifuge 3000 rpm. To determine blood manganese amount, samples were analyzed based on NIOSH8005 method (National Institute of Occupational Safety and Health (NIOSH), 1994) using a Varian graphite furnace-atomic absorption spectroscopy (GF-AAS) model AA240 (National Institute of Occupational Safety and Health (NIOSH), 1985) and results were reported in microgram/ liter (ppb).

*C) **Method of Testing CBC, TIBC, FRRITIN***

Iron amount of serum, MCHC, MCH, HCT, HB, and MCV were determined by using counter cell system, TIBC with spectrophotometer and FRRITIN amount using Eliza test.

D) ***Statistical Analysis:*** Data processing was investigated using statistical software SPSS15. Also krauskal-wallis test and independent T test were applied to compare exposure rate to respirable manganese and other normal data. Normality of data was evaluated by Kolmogorov-Smirnov test. To determine which groups had significant difference, mann-whitney test was appliedfor non parametric data.

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RESULTS AND DISCUSSION

Findings

A) Demographic and Descriptive Data

Results showed that age range of mostworkerswas less than 35 years (21- 45 years). Average age and work experience for case group were 33.13±6.16 and 4.9±1.5 years while average age of control group was 40.26±6.1. According to the worker's duty, the way and also amount of exposure to dust, they were divided into three groups; workers in raw material store, maintenance operators, and shift operators with frequency 16, 12 and 19 respectively.

The smoking percentage in control and case groups were 15 and 9, respectively, and no significant difference observed in cigarette smoking (p=0.336).

B) Findings Related to Exposure to Manganese

Average exposure of case group to respirable dust and manganese, were 4.85±2.21 mg/m^3 and 0.33± 0.23 mg/m^3 respectively. It can be seen that both classes of exposure had significant differences compared to threshold limit values (TLVs) (p< 0.0001) (table 1). Results of individual samples for total and respirable dust in different workshops and studied occupations are shown in table 1.

Table 1: Average rate of exposure to dust, manganese and iron in case group workers and their comparison to threshold limit values (TLVs) (National Institute of Occupational Safety and Health (NIOSH), 1994; 1985)

Index	Legal Limit (mg/m^3)	Standard Deviation ± Average (mg/m^3)	Confidence Interval	P-value
Total dust	10	7.41±3.83	6.28 – 8.53	0.0001
Respirable dust	3	4.58 ± 2.21	3.93 – 5.22	0.0001
Manganese of respirable air	0.2	0.33 ±0.23	0.27 – 0.40	0.0001
Iron of respirable air	5	0.14 ± 0.07	0.12 – 0.16	0.0001

No result was recorded for Control group due to lack of exposure to manganese.

It can be seen from Table 1 that case group exposure to respirable dust containing manganese is higher than threshold limit values (TLVs) (p<0.0001). The rate exposure of workers for both total dust and iron (5 mg/m^3), was less than threshold limit values (p<0.0001).

C) Manganese Amount in Blood and Effective Items on Iron deficiency in Both Case and Control Groups

Significant differences were observed between effective indices on blood iron in case and control groups. Blood manganese 32.78 ± 14.75 and 17.06±5.69 µg/l (p<0.0001), TIBC 375.98 ± 53.41 and 404.40±52.84 µg/dl (p<0.0001) and RBC 5.79±0.54 and 5.56 ±0.51 million/µl (p<0.038). Some indices related to blood iron including iron, ferritin, HCT, HB, MCV and MCH in both case and control groups did not have significant difference (table 2).

Table 2: Average, Standard Deviation and P value of Effective Indices on Blood Iron

Index	**Units**	**Case (Standard Deviation ± Average)**	**Control (Standard Deviation ±Average)**	**P-value**
Blood Manganese	µg/l	32.78 ± 14.75	17.06 ±5.69	0.0001
TIBC	µg/dl	375.98 ±53.41	404.40 ± 52.84	0.011
R.B.C	million/µl	5.79 ± 0.54	5.56 ±0.51	0.038
MCV	Fl	85.52 ±6.51	87.83 ±5.05	0.058
Ferritin	mg/ml	169.49 ±90.02	207.17 ± 111.35	0.074
Fe	µg/dl	126.29 ± 50.17	111.96 ±35.20	0.112
MCHC	%	34.35 ±4.64	33.50 ±1.04	0.223
HGB	g/dl	16.55 ±1.32	16.27 ± 1.09	0.272
MCH	Pg	28.88 ±2.84	29.40 ±2.10	0.317
HCT	%	49.04 ±2.79	48.64 ±2.98	0.499

As it is shown in table 2, blood manganese amount in case group was double of control group and there was significant difference between blood manganese in these groups. Results showed significant difference between TIBC and RBC in case and control groups. Also, significant difference observed between MCV and ferritin in both groups.To compare indices related to blood iron including MCH, HGB, TIBC, RBC, MCHC, HCT and Fe, two- sample t-test was applied and results showed no meaningful difference between two groups of case and control in respect to all parameters (table 2).

D) Comparing Exposure Rate of Different Occupations at Present Study

- Average and standard deviation of exposure to manganese of respirable air in 3 professional groups of raw material store workers, maintenance operators, and shift operators were 0.25±0.39, 0.24 ±0.04, 0.35 ± 0.27mg/m^3.
- Results of krauskal-wallis test for nonparametric values of manganese in respirable air among 3 professional groups, showed meaningful difference for this index (p =0.043).
- Then accurate test of mann-whitney was done to determine the groups having meaningful differences for exposure rate to manganese among the above mentioned groups. Results showed this index for raw material store workers was more than maintenance and repairmen workers with significant difference (p=0.024) and exposure rate of maintenance workers and shift operators was meaningful in border (p=0.07). In addition, one-way ANOVA was used for comparing the amount of manganese in blood of workers of these professional groups (p=0.977). Consequently, no significant difference observed among existing professional groups in concentration of blood manganese.
- Weak correlation observed between blood manganese, amount of respirable manganese, RBCand ferritin as -0.132, - 0.182, and – 0.050, respectively.

Discussion

In some industries, occupational exposure rate to manganese and its related compounds is different, while biological exposure indices has not been defined for it and scientists have been yet studying its biological effects.

One of the biological effectsof manganese is the effectual changes on indices related to blood iron.

This study was done for investigation of professional exposure effects of manganese on these indices in ferroalloy industry. In this research, average exposure of case group to respirable manganese and variation range were 0.33±0.23mg/m^{3}and 0.13 – 1.25 mg/m^3, respectively which were 1.65 times more than threshold limit values (Allowable Occupational Exposure (AOE)) and had meaningful difference related to threshold limit value (0.2 mg/m^3) (10) (*p*<0.0001). This value was higher than exposure values of workers in the studies were done by Bowler *et al.*, (2011) and Ling *et al.*, (2005) and this is most probably due to high amount of manganese compounds existing in ferroalloy industry in comparison with welding operations. At present study, whole blood manganese of case group (32.78±14.75 µg/l) was double of control group (17.06±5.69 µl/l) with significant difference (*p*<0.0001). These values were lower than values found in the study of Ling Lu et al, but higher than values in the study of Bowler *et al.*, (2011). In above three studies, manganese amount of respirable air was higher than allowable professional limit; it means that, the amount of blood manganese in case group was higher than control group.Contrary to the present study, in some studies including Daschamp *et al.*, (2004), Ellingsen *et al.*, (2006) and Beate *et al.*, (2012), exposure to respirable manganese was less than allowable limit, 0.2mg/m^3. However, blood manganese of welders was 25% higher than control group with meaningful difference found in the study of Ellingsen *et al.*, (2006). In the study which carried out by Beate *et al.*, (2012), ferritin rate of few personnel decreased, while at the present study no lack of ferritin and MCVwas observed and difference between control and exposed groups was of marginal significance (*p*=0.07). Smith and Ahmed (2013) found strong relation between blood manganese and iron deficiency (Adjusted r^2=3.34%) while at the present study, this relation was so weak (Adjusted r^2= - 0.019%). Considering the above mentioned studies, shows that exposure to manganese, even in case of lower than threshold limit values, have had effects on the factors related to blood iron.

Hassani *et al.*, (2012) found that respirablemanganes was 150.0 ± 125.0 mg/m^3 in welders, while at the present study, the amount of respirablemanganes in case group was 23.0 ± 33.0 mg/m^3, that is 2.5 times of rate of exposure in welders. This is due to lower amount of manganese existing in welding electrodes, sheets or alloy steels (less than 20%) using in welding operation, while the ores used in the ferroalloy plant of this study and also end products of ferro manganese plant, contain about 45% and 90% manganese, respectively (Hassani *et al.*, 2012). Based on the study of Keyvani *et al.*, (2010), laboratorial criteria of anemia related to iron deficiency includes following cases:

Ferritin<10g/dl, MCV<80fl, HB<11g/dl, MCH<27pg/dl ,HCT <0.33, MCHC<30g/dl

In this study, there was no meaningful difference between case and control groups after performing statistical tests in related indices (table 2). At similar results obtained from the study of Yueming *et al.*, (2006), no significant difference was observed between any of experimental indices CBC related to anemia and iron deficiency. This is probably due to compensatory mechanisms in the body that allows no massive changes in blood parameters.

In study of Bowler *et al.*, (2011), average iron of blood serum did not show symptoms of iron deficiency, but in study of Ling *et al.*, (2005), blood iron in case group was significantly lower than control group. In study of Beate *et al.*, (2012) concentration of respirable manganese had strong relation with respirable iron (r= 0.92) (Beate *et al.*, 2012) while at present study, this relation was weak (r= 0.085). This could be considered as one cause of compensatory iron deficiency and also iron deficiency anemia due to exposure to manganese, as it has been mentioned in the studies of Ling *et al.*, (2005) and Beate *et al.*, (2012). The other factors that may influence the results of present study including social status and life style and their discrepancy (Ling *et al.*, 2005). Several factors such as workers diet, their habits and also considering air sampling, the manner of placing sampling device in relation with respiratory zone of workers, may have influence on results (Hassani *et al.*, 2012). On the other hand, regarding studied population which included just men in comparison to some studied in which women also participated, women's iron deficiency was omitted as a main interferer and men faced less than women with iron deficiency because of further iron reserves. Based on documents of United States Environment Protective Agency (US-EPA), during welding electric arc of metals, general fume containing manganese which penetrates into lungs via protective respiration devices is about 28.4% of weight of polluted air (Ling *et al.*, 2005).

According to workers' usage of protective respiration devices, entrance of respiratory pollutants into the lung has been significantly prevented at present study. Also, the blood manganese values are due to long time exposure, while sampled values in air related to same day of sampling which may influence the results (Hassani *et al.*, 2012).

Biological exposure index (BEI) for manganese has been yet defined by none of international and national standard organizations. Scientists have been investigating different effects of manganese deficiency and also its poisoning on organisms (Aslam *et al.*, 2008; Aschner and Higdon, 2010). Whenever the amount of manganese especially through inhalation is high, its biologic monitoring will be a problematic and confusing issue. Study of Smith and Ahmed (2013) suggested that children with anemia due to iron deficiency may be in danger of poisoning resulted from manganese with concentration of more than 20 microgram/liter (Smith and Ahmed, 2013). Study of Lander *et al.*, (1999) showed that blood manganese amounts of workers were 2.5- 5µg/l more than control group and two personnel with exposure rate of 29 and 25µg/l were clinically under sub-acute poisoning condition with manganese. Furthermore, after stopping their exposure, potential problems were disappeared generally and manganese values in their blood decreased by 9.4 and 14.1 µg/l respectively (Lander *et al.*, 1999). But at present study and some above mentioned studies, level difference of blood manganese in case and control groups had reached more than 17 µg/l but no significant differences observed between indices related to blood iron in these groups. Most probably the reason for this issue is the body compensatory mechanisms not to allow big changes in the blood parameters values as these symptoms may occur in special stages and conditions. However, finding more accurate results invokes further research in this area.

The results showed in a condition that manganese amount of respirable air was 1.65 times more than threshold limit values, cause of anemia and iron deficiency has been not studied, while the values of TIBC and RBC for both case and control groups had significant differences. Moreover, the difference between indices of MCV and ferritin was of marginal significance (p=0.07) and this can be predictive of iron deficiency. To have more accurate results, future studies in this area must be carried out for workers with further work experiences and alsotheother related factors should be considered precisely.

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REFERENCES

Aslam, Pejovic Milic A, Chettle DR and McNeill FE (2008). Quantification of manganese in human hand bones: a feasibility study. *Physics in Medicine and Biology* **53**(15) 4081-92.

Aschner M and Higdon J (2010). Micronutrient Research for Optimum Health. Linus Pauling Institute.

Badiei K and Parchami A (2004). Measurement of manganese concentrations in serum, liver, heart, muscle, spleen and hair in dromedary camels of Yazd province. *Pajouhesh and Sazandegi* **64** 81-4.

Beate Pesch, Tobias Weiss and Benjamin Kendzia *et al.*, (2012). Levels and predictors of airborne and internal exposure to manganese and iron among welders. *Journal of Exposure Science and Environmental Epidemiology* **291** 8-22

Bowler RM, Gocheva V and Harris M (2011). Prospective study on neurotoxic effects in manganese . exposed bridge construction welders. *NeuroToxicology* **32** 596–605.

Brent L Finley and Annette B Santamaria (2005). Current Evidence and Research Needs Regardingthe Risk of Manganese-Induced Neurological Effects in Welders. *NeuroToxicology* **26** 285–9.

Brent L Finley and Annette BS (2004). Current Evidence and Research Needs Regarding the Risk of Manganese-Induced Neurological Effects in Welders. *NeuroToxicology* **26** 285-9.

Ellingsen DG, Dubeikovskaya L and Dahl K *et al.*, (2006). Air exposure assessment and biological monitoring of manganese and other major welding fume components in weldersw. *Environmental Monitoring* **8** 1078–86.

Guilarte TR (2011). Manganese and Parkinson's Disease: A Critical Review and New Findings. *Ciência & Saúde Coletiva* **16**(11) 4549-66.

Health Center of Environmental and Work of Iran (2011). Occupational exposure limites of ministry of health and medical education of Iran. Institute for Environmental Research of tehran Universityof Medical Sciences.

Hassanzadeh Ghasabeh T (2003). Survey correlation iron and manganese in conjuncture to Apo-transferin. Hamedan University of Medical Siences **10**(2) 36-41.

Hassanzadeh Ghasabeh T and Moshtaghi SAA (2002). *Interralation betwin manganese and iron metabolism in rat (In vivo studies)* Urmia University of Medical Siences **13**(3) 205-12.

Hassanzadeh Ghasabeh T and Sadahi M (2002). Intraction abzorbtion iron with manganese. Yazd University of Medical Siences **10**(3) 42-5.

Hassani H, Golbabaei F and Ghahri A *et al.*, (2012). Occupational Exposure to Manganese-containing Welding Fumes and Pulmonary Function Indices among Natural Gas Transmission Pipeline Welders. *Journal of Occupational Health* **54** 316-22.

Khristy Thompson, Ramon M Molina, Thomas Donaghey, James E Schwob and Joseph D Brain aMW-R (2007). Olfactory uptake of manganese requires DMT1 and is enhanced by anemia. *The FASEB Journal* **21** 223-30.

Keyvani Z, Mirzaee M, Mahmoodzadeh M, Etemadifar SH, Avijgan M and Rafieean M (2010). The Relationship between Migraine Headache and Iron Deficiency Anemia in Patients Referred To Neurology Clinic of Shahrekord University of Medical Sciences. *Iran Journal of Nursing* **23**(64) 37-43.

Lander F, Keristiansen J and Lauritsen JM (1999). manganese exposure in foundry furnacemen and scrap recycling workers. *International Archives of Occupational and Invironmental Health* **72**(8) 546-50.

Ling Lu L-lZ, Jane Li G, Wenrui Guo, Wannian Liang and Wei Zheng (2005). Alteration of serum concentrations of manganese, iron, ferritin, and transferrin receptor following exposure to welding fumes among career welders. *NeuroToxicology* **26** 257-65.

Nastiti A, Oginawati K and Santoso M (2010). Manganese exposure onwelders in small -scale mild steel manual metal arc welding industry. *Applied Sciences in Environmental Sanitation* **5**(3) 227-38.

National Institute of Occupational Safety and Health (NIOSH) (1994). Particulates not otherwise regulated, total, Method 0500. NIOSH Manual of Analytical Methods (NMAM) (2).

National Institute of Occupational Safety and Health (NIOSH) (1985). Elementes by ICP, Method 7300. NIOSH Manual of Analytical Methods) NMAM (Fourth Edition).

National Institute of Occupational Safety and Health (NIOSH) (1994). Elements in blood or tissue, Method 8005. NIOSH Manual of Analytical Methods (NMAM), Fourth Edition (2).

Robert M Park (2008). occupational manganese exposure evidence for parkinsinian and neurobihaviral health effects and risk assesment. *American Industrial Hygiene Association.*

Smith EA NP BK and Ahmed N (2013). Increased whole blood manganese concentrations observed in children with iron deficiency anaemia. *Trace Elements in Medicine and Biology* **27**(2) 65-9.

Schoeman J (2005). Manganese exposure. Available: Nershcocom/case_studies/Manganese%20 Management pdf.

Shahtaheri SJ and Afshari D (2007). *Occupational Toxicology* (Iran: Baraye Farda Publisher) 292-7.

Yueming Jiang, Wei Zheng and Liling Long *et al.*, (2006). Brain magnetic resonance imaging and manganese concentrations in red blood cells of smelting workers: Search for biomarkers of manganese exposure. *NeuroToxicology* **28** 126-35.