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Occupational Exposure to Steady Magnetic Fields and Mental Health of Workers at the Copper Electrolysis Unit

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Abstract

Background: There are only a few studies about the health effects of steady magnetic fields on workers. This study was performed in order to evaluate some of the psychological effects of exposure to steady magnetic fields in the copper electrolysis unit.

Methods: This cross-sectional descriptive and analytical study was performed at the electrolysis unit of a Copper Complex in Kerman Province in 2013. The population under study was 90 workers exposed to steady magnetic fields who were selected as the exposed group and 90 workers without exposure chosen from the concentration unit as the control group. Both groups were similar in regard to working conditions. The intensity of steady magnetic field was measured in different parts of the saloon and in the head, waist and feet positions. Measuring psychological signs was assessed by the General Health Questionnaire GHQ-28. Data analysis was performed through SPSS19 and the Mann-Whitney U, one way ANOVA, Chi-square test and Regression analysis.

Results: In this study the mean intensity of the steady magnetic field in the exposed group was 2.5 mT. The mean rank of psychological testing results in the exposed group was 102.04 and in the control group was 78.96, representing a statistically significant difference (p=0.003). Also there were statistical differences between the two groups in self –reporting of anxiety, sleep disturbances (p=0.001) and depression (p=0.007) dimensions.

Conclusion: It appears exposure to static magnetic fields may cause psychological complications. Therefore, more research is recommended to improve the wellbeing of workers exposed to these fields.

Keywords: Magnetic Fields, Occupational Exposure, Mental Health, worker

1. Introduction

The process of industrialization has led to a considerable increase in the number of electrical equipment present in the workplace; and therefore, the spectrum of workers exposed to general and occupational electromagnetic fields has increased. These fields are important because of their probable harmful effects on human health (1). Magnetic fields are created by the movement of charged particles in a conductor carrying an electric current or by a magnet. There are two types of magnetic fields, one is alternative (dependent on frequency) and the other is steady which are produced by natural or artificial sources(2). Natural steady magnetic fields are about 50 micro Tesla (μT), and depending on the geographic position, this amount is between 25 to 65 micro Tesla (μT). The average human rarely experiences exposure to strong magnetic fields; however, in the future due to use of new public transportation services such as electric transportation systems, there may be greater potential for exposure to more intense and consistent magnetic fields (1-3).

All humans are continually exposed to the earth's magnetic field, which is not usually perceptible by people because it is weak and does not interfere with their lives. The earth's magnetic field is approximately 0.3 G (3×10^{-5} T) in the equator and 0.7 G (7×10^{-5} T) at the poles. Nowadays most magnets used in clinical practice have static magnetic field strengths above 0.5 T (4). Among the most important sources of steady magnetic fields are medical imaging devices such as MRI, electricity cables, direct currency generators, electrical welding devices, nuclear reactors, particle accelerators, isotope separating units, special spectrometers, electrolysis processors and etc. Currently, most commonplace exposure to steady magnetic fields happens when individuals use medical imaging devices such as MRI for clinical diagnosis (1-5). A recent study from the US done on a population of patients enrolled in large integrated healthcare systems showed that from 1996 till 2010 the use of MRI increased from 17 to 65 in 1000 patients and had a 10% annual growth (6).

The number of experimental and epidemiologic studies in regard to the effects of steady magnetic fields on humans is limited due to inability to achieve sufficient sample size (3). According to reports, there is a probability magnetic fields lead to infertility, affect human cells and increase the rate of various types of cancer in humans (3-8). Also long exposure (for months or years) to magnetic fields from direct currents in industries can lead to tiredness, dizziness, insomnia, headaches and stomach aches (9). Workers who are exposed frequently and for long durations to these fields appear to be more vulnerable. The use of steady magnetic fields in industry and healthcare has led to increased human exposure to these fields and therefore, has led to several scientific studies in regard to the effects of these fields on human health.

The result of these studies contributed to the preparation of guidelines by many international organizations. The World Health Organization and the International Commission on Non-Ionizing Radiation Protection have been pioneers in this regard (1-2). The levels of permissible occupational exposure to steady fields has been determined by the American Conference of Governmental Industrial Hygienists for the whole body as 60 milli Tesla and for the hands and feet as 600 milli Tesla for 8 hours work. The threshold has been determined as between 2 and 20 Tesla for the whole body and hands and feet. These levels have also been accepted as the maximum permissible levels in Iran (10). Also, the International Commission on Non-Ionizing Radiation Protection has suggested the maximum permissible level of 0.2 Telsa for 8 hours exposure to steady magnetic fields. However, these levels are only a guideline for calculating exposure to steady magnetic fields and therefore should not be considered as the certain end point for development of harmful effects (1).

Mental health conditions result in significant work disability. These workers tend to be more frequently absent from work and have more lost productive time when at work than all other workers because of their reduced performance on the job. Exposure to magnetic fields may increase the risk of sleep disturbances, anxiety and depression in workers, contributing to poor job performance. For example job performance is significantly compromised in individuals with depression compared to healthy workers (11).

Although there is still some doubt about the degree of hazards of electromagnetic fields, prudent avoidance is a necessity to protect the health of workers. This study was designed in order to evaluate the effect of steady magnetic fields on the psychological health of workers employed at the electrolysis unit of the Sarcheshmeh Copper Complex.

2. Methods

This cross-sectional descriptive and analytical study was performed at the electrolysis unit of the Sarcheshmeh Copper Complex in Kerman Province in 2013. In this unit 960 electrolysis cells are available. Fifty cells are used for producing the initial cathode and the rest are used for the production of commercial cathodes. Electricity enters the cathode and anode with the density of 210 A/m^2 and voltage of 0.25v, DC. Copper is produced with the purity of 99.99 %. The intensity of steady magnetic fields in the electrolysis unit of the Sarcheshmeh Copper Complex over the course of a worker's shift was measured. For this purpose a personal magnetic field monitor, model HI-3550 made by Holaday, USA was used.

Before starting the data collection, the device was calibrated and assessed the magnetic field by the IEEE C95.6 method in order to measure the environment magnetic field intensity (instantaneous peak value). Recording for the instant magnetic field peak was performed by estimating the total surface of the refinery saloon (223m×79m=17617) by networking and creating stations with 4×4.30 dimension in the saloon of the refinery. About 600 stations were measured.

The population under study consisted of the workers at the Electrolysis section of a copper plant. These 100 workers were exposed to steady electromagnetic fields except during lunch and prayer time which was estimated to be 7 hours of exposure a day. These workers had been exposed to the steady magnetic fields for at least 2 years. Workers age range was 24 to 55 years, the mean±SD of age was 34.2±7.5 and the median was 32 years. The machines were not shielded. Workers moved in the working area and stood as close as 3 feet away from the machines in operation. The workers did not use personal protective equipment (PPE) or shields except rubber shoes, as it was thought that this amount of exposure did not have a health impact. However, all workers had to attend 6 hours of educational classes about electromagnetic fields, the hazards of these fields and important cautionary and safety issues, at the beginning of their employment. Then later in their employment they attended 1 or 2 more advanced educational classes. But their learning was not assessed after completing the classes.

Control group subjects were enrolled from the concentration unit of the same complex. These workers had working conditions similar to workers in the electrolysis unit, but were not exposed to electromagnetic fields. The electromagnetic field intensity measured in this area was non-detectable. The worker health history and the results of entry and annual medical exams were screened before enrolling. Workers with a history of somatic or psychological problems, those using tranquilizers or painkillers, illicit or psychotropic drugs; and workers who did not give consent were excluded from the study. Eventually, after applying the inclusion and exclusion criteria, 90 people remained in each of the study and control groups.

The intensity of the magnetic field was measured at the head, abdomen and feet level in all of the workers.

Both the study and control groups completed the Hiller and Goldberg standard General Health Questionnaire (GHQ-28).

The GHQ-28 questionnaire is a self administered tool for evaluating psychological health and is one of the most well known questionnaires for screening non-psychotic mental disorders in the general population. The tool is capable of measuring different aspects of psychological health and can differentiate healthy people from people who appear healthy but suffer from psychological disorders (12).The GHQ-28 questionnaire has 4 categories with 7 questions each, and measures 4 groups of non-psychotic disorders including somatization, anxiety and sleep disorders, social dysfunction, and depression. In this study, the 4 scale questionnaire (never, sometimes, often and very often scored from 0 to 3) was used. The score in each category ranged from 0 to 21 and the total score of the questionnaire ranged from 0 to 84. The cut off point for each category was 6 and the total cut off point was 23. Scores above 6 and 23 reveal low health (13). Studies about the validity and reliability of this questionnaire documented these cutoff points and indicated the Cronbach's alpha was 0.84 - 0.93 in each dimension (13) and 0.68 - 0.94 for the whole questionnaire (14) in multiple research investigations.

The SPSS19 software was used for analyzing data through the Mann-Whitney U, one way-ANOVA, chi-square test and Logistic Regression analysis.

3. Results

The mean steady magnetic field in the refinery unit of the Sarcheshmeh Copper Complex measured 2.5±0.78 mT and was significantly different (P-value <0.001) from 60 mT which is the international permissible threshold. The steady magnetic field calculated in three different regions of the workers body revealed the foot received more exposure than the two other regions (Table 1). This was thought to be due to the location of the equipment that was positioned a few feet under the level that workers stood and walked on when performing job tasks over the course of their shift.

Table 1. Measurements of steady magnetic fields in 3 body regions.

Variable	Mean ± sd (mT)	Max (mT)	Min (mT)
Head	1.99 ± 0.5	3.45	0.15
Abdomen	2.02 ± 1.28	21.5	0.01
Foot	3.5 ± 1.15	6.65	0.17

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The age mean and standard deviation of the exposed and unexposed group was respectively 29.4 ± 4.5 and 38.8 ± 6.8 years. The demographic data of the workers has been shown in Table 2.

Table 2. The demographic characteristic of the workers evaluated in this study

Variable		Exposed Number (%)	Un exposed Number (%)	P-value
Marital status	Single	25 (27.8 %)	6 (6.7 %)	<0.001
	Married	65 (72.2 %)	84 (93.3 %)	
Education	Under diploma	9 (10 %)	18 (20 %)	0.655
	Diploma	69 (76.7 %)	49 (54.4 %)	
	Graduate certificate	9 (10 %)	11 (12.2 %)	
	Bachelor	3 (3.3 %)	12 (13.3 %)	
Job satisfaction	Very high	8 (8.9 %)	11 (12.2 %)	0.065
	High	10 (11.1 %)	20 (22.2 %)	
	Moderate	53 (58.9 %)	49 (54.4 %)	
	Low	5 (5.6 %)	9 (10 %)	
	Very low	11 (12.2 %)	1 (1.1 %)	
Town of Residence	Rafsenjan	54 (60 %)	40 (44.4 %)	0.070
	Shahrebabak	12 (13.3 %)	23 (25.6 %)	
	Sirjan	13 (14.4 %)	9 (10 %)	
	ShahrakeSarcheshme	12 (12.2 %)	18 (20 %)	
Shift work status	2 shifts	45 (50.0 %)	35 (40.0 %)	0.193
	4 shifts	45 (50.0 %)	52 (57.8 %)	
Smoking	Smoker	9 (10 %)	37 (41.1 %)	<0.001
	Non-smoker	81 (90 %)	53 (58.9 %)	
Working history	<5 years	61 (67.8 %)	6 (6.7 %)	<0.001
	5- 10 years	25 (27.8 %)	21 (23.3 %)	
	10-15 years	2 (2.2 %)	29 (32.2 %)	
	>15 years	2 (2.2 %)	34 (37.8 %)	
Age	<28 years	33 (36.3 %)	2 (2.2 %)	<0.001
	28-32 years	29 (32.2 %)	12 (13.2 %)	

32-39 years	21 (23.3 %)	34 (37.4 %)
>39 years	3 (3.3 %)	42 (46.7 %)

The age variable was not normally distributed and the Mann-Whitney U test showed a significant difference between the median of age between the two groups (P-value<0.001). Some other variables such as marital status, smoking, working history and status were also significantly different between the two groups. These variables were dealt with as confounders in the final regression analysis.

According to the results of the self-reported general health questionnaire, 48.9 % documented impaired social function, 28.9% reported signs of anxiety and sleep disturbances, 5.6 % noted symptoms of depression and 27.8 % complained of somatic signs. The questionnaire scores were not normally distributed and therefore were compared with the Mann-Whitney U test. The results documented the mean rank of the depression and the anxiety and sleep disturbances scores were significantly higher in the exposed than the unexposed group. The results of the workers general questionnaires have been shown in Table 3.

Table 3. The mean rank in exposure and non-exposure groups

Variable	Mean rank		P-value
	Exposure group	Non-Exposure group	
Somatization (n=180)	96.97	84.21	0.101
Anxiety and sleep disorders (n=180)	109.54	71.46	0.001
Social dysfunction (n=180)	88.31	92.69	0.569
Depression (n=180)	99.68	81.32	0.007
Total score (n=180)	102.04	78.96	0.003

In logistic regression, the effect of magnetic field exposure on the somatic health, anxiety and depression, social function and depression of the worker study group was evaluated through crude and adjusted models by the Enter method and the results are below in Table 4.

Table 4. Univariate and multivariate logistic regression analysis results for evaluating the effect of steady magnetic fields on workers

Variable	Crude OR (CI)	P-value	Adjusted OR (CI)	P-value
Somatization	1.78(0.87-3.62)	0.11	1.8 (0.62-5.16)	0.27

Anxiety and Sleep Disorders	3.65(1.60-8.35)	0.002	4.56 (1.4-14.78)	0.01
Social Dysfunction	0.88 (0.49-1.75)	0.65	0.69 (0.28-1.7)	0.42
Depression	2.59 (0.48-13.70)	0.26	0.55 (0.036-8.52)	0.67
Total	2.14 (0.93-4.90)	0.07	2.01 (0.59-6.78)	0.26

The results of univariate and multivariate regression documented anxiety and sleep disturbances were more severe in the exposed group and even after adjusting for confounders (age, working history, marital status, smoking), the result was significant.

4. Discussion

The results of this study examined the general health of workers in three subscales and found some of the measured parameters were of poorer quality in the exposed group in comparison to the unexposed group, but the difference was only statistically significant for self- reported anxiety and sleep disturbances.

A systematic review performed by Farnco et al about the health effects of occupational exposure to static magnetic fields stated symptoms such as dizziness, nausea, lack of concentration and amnesia were seen more significantly in workers exposed to steady electromagnetic fields (15). Chobineh et al noted exposure to steady magnetic fields in a Chloralkali plant resulted in increased worker reports of headache, nervousness, fatigue, loss of appetite, dizziness, irritability, visual disturbances, numbness, and sleeplessness. However, only fatigue and nervousness was significantly different between the two groups observed (16). The results of these two studies were in line with the current study.

Yousefi et al studied the effects of electromagnetic fields on workers employed at electric high voltage substations in Tehran with at least 10 years of continuous employment. Mental disorders were evaluated based on the revised symptom distress checklist (SCL90-R) questionnaire. The exposed group showed significantly more depression, paranoia, psychosis, somatization, internal sensitivity, obsession-compulsion, anxiety and hostility (17).

In a study done by Vocht et al on the health complaints and cognitive performance of employees of an MRI scanners manufacturing department who were exposed to steady magnetic fields, the results showed workers exposed to increased magnetic fields more often reported health issues such as dizziness, metal taste and lack of concentration in comparison to the control group (18). These results confirm the outcomes of our study.

In this study the effects of steady magnetic fields on psychological health has been examined and the data established the negative impact of these fields on health. Although the exposed and unexposed group had similar working conditions, those employees with continuous magnetic field contact and subsequent health effects mandate further evidence is required for determining the safe range of exposure for workers in these fields.

One of the limitations of this study was the lack of initiating clinical interviews for assessing worker psychological issues. Although the GHQ-28 questionnaire did have proper validity and reliability according to several studies, the use of clinical interviews would have provided greater understanding of the health and psychological matters and permitted more detailed evaluation of those workers prior to acceptance into the study group.

The importance of routinely assessing magnetic field workers' physical and psychological health and proper screening and treatment of other health issues for these workers cannot be underestimated. Improving the workers health and providing safe working conditions will result in better individual, social and economic outcomes. This research is one of the initial steps for evaluating the effects of steady magnetic fields on human physical and psychological health.

5. Conclusion

It appears exposure to steady magnetic fields even at assumed safe levels might lead to adverse psychological effects such as sleep disturbances, depression and anxiety. More research is recommended in order to improve the safety of workers exposed to these fields.

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References

1. International Commission on Non-ionizing Radiation Protection (ICNIRP). (2009). Guidelines on limits of exposure to static magnetic field. *Health physics, 96*, 504-514.

2. World Health Organization. Environmental health criteria 232. *Static fields Geneva: World Health Organization.* 2006.

3. Feychting, M. (2005). Health effects of static magnetic fields—a review of the epidemiological evidence. *Progress in Biophysics and Molecular Biology, 87*, 241-246.

4. Arezes, P. M., Baptista, J. S., Barroso, M. P., Carneiro, P., Cordeiro, P., Costa, N., (2014). *Occupational Safety and Hygiene II.* CRC Press, Taylor and Francis, The Netherlands. page 627.

5. Swerdlow, A. J. (2008). *Report of independent Advisory Group on Non-ionising Radiation. Static Magnetic Fields.* London: Health Proetection Agency.

6. Smith-Bindman, R., Miglioretti, D.L., Johnson, E., Lee, C., Spencer Feigelson, H., Flynn, M., Greenlee, R.T., et al. (2012). Use of Diagnostic Imaging Studies and Associated Radiation Exposure for Patients Enrolled in Large Integrated Healthcare Systems, 1996–2010. JAMA, 13; 307(22): . doi:10.1001/jama.2012.5960.

7. Pacini, S., Gulisano, M., Peruzzi, B., Sgambati, E., Gheri, G., Gheri, B. S. et al. (2003). Effects of 0.2 T static magnetic field on human skin fibroblasts. *Cancer Detect Prev., 27,* 327-332.

8. Tenuzzo, B., Chionna, A., Panzarini, E., Lanubile, R., Tarantino, P., Di Jeso, B. et al. (2006). Biological effects of 6 mT static magnetic fields: A comparative study in different cell types. *Bioelectromagnetics, 27*, 560-577.

9. Zhadin, M. N. (2001). Review of Russian literature on biological action of DC and low-frequency AC magnetic fields. *Bioelectromagnetics, 22*, 27-45.

10. American Conference of Governmental Industrial Hygienists (ACGIH). (2011). *Threshold limit values for chemical substances and physical agents and biological exposure indices.* Cincinnati.

11. Pomaki, G., Franche, R. L., Murray, E., Khushrushahi, N., & Lampinen, T. M. (2012). Workplace-Based Work Disability Prevention Interventions for Workers with Common Mental Health Conditions: A Review of the Literature. *J Occup Rehabil, 22*, 182-195.

12. Javanmard, G. H., & Mamaghani, J. (2013). Standardization of GHQ-28 Inventory on the Students of Azerbaijan Province of Iran. *Procedia - Social and Behavioral Sciences, 84,* 47-52.

13. Noorbala, A. A., Bagheri Yazdi, S. A., Yasamy, M. T., & Mohammad, K. (2004). Mental health survey of the adult population in Iran. *Br J Psychiatry*, *184*, 70-73.

14. Fakhar, A., Ranjbar, F., Dadashzadeh, H., Moghaddas, F. (2007). An epidemiological survey of mental disorders among adults in the north, west area of Tabriz, Iran. *Pak J Med Sci., 23*, 54-58.

15. Franco, G., Perduri, R., & Murolo, A. (2008). Health effects of occupational exposure to static magnetic fields used inmagnetic resonance imaging: a review. *Med Lav., 99*, 16-28.

16. Choobineh, A., Amirzadeh, F. (2005). Health effects of occupational exposure to static magnetic field in a chloralkali plant. *Indian Journal of Occupational and Environmental Medicine, 9*, 76.

17. Yousefi, H. A., & Nasiri, P. (2006). Psychological Effects of Occupational Exposure to Electromagnetic Fields. *Journal of Research in Health Science, 6,* 18-21.

18. de Vocht, F., van Drooge, H., Engels, H., & Kromhout, H. (2006). Exposure, health complaints and cognitive performance among employees of an MRI scanners manufacturing department. *J Magn Reson Imaging, 23*, 197-204.