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# Assessment of Exposure to Manganese in Arc Welding Fume

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**Abstract**
*This study evaluated the occupational exposure to manganese in arc welding fumes in a gas company. Fumes are formed during welding, and they contain gases and metal oxides in ultrafine particulate form. Manganese is a metal oxide formed during welding whose chronic exposure causes manganese. This study aimed to measure concentrations of manganese fume in the breathing zone (BZ) of welders and to assess neurobehavioral functions among them. The utilized descriptive statistics of mean and standard deviation to achieve its aim and objectives and Twenty (20) welders participated in this study. Full period sampling and analysis of manganese fumes in the BZ was performed according to NIOSH-7300 methods. The full period sampling was done for the entire duration of their work period (8 hours) for 4 days. Q16 questionnaire was used to evaluate neurobehavioral symptoms in welders. The study revealed that Fifty percent (50%) of respondents do have problems with concentration, 90% have to make notes about what they must remember, 100% often have to go back and check things they have done, such as turning off the stove, locking the door etc. The study findings showed that eighty percent (80%) do have a headache at least once a week and 40% are less interested in sex than normal. The average concentration of manganese in the welders' BZ was 0.03 ± 0.01 mg/m$^3$. This value is higher than the TLV-TWA recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for manganese (0.02 mg/m$^3$). It is recommended that measures be put in place to reduce workers' exposure to manganese in arc welding fume.*

***Keywords:*** *Manganese, Arc welding, Welding fume, Assessment, Exposure*

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## 1. Introduction

Welding metals together for industrial purposes became commonplace in modern society beginning in the 1800s, which was primarily due to the discovery of acetylene gas to produce open working flames (Cary, 2015). Oxygen, unlike acetylene, is currently the ideal gas used during welding because it does not burn intrinsically, but rather supports and accelerates combustion that facilitates the heating of metal. Presently, welding is considered a hazardous activity that poses a health and safety risk to over 500,000 workers nationwide in a variety of industries, ranging from ship manufacturing to general construction to auto-mechanic repair (OSHA, 2013). Since the formation of the Occupational Safety and Health Administration in 1971, safety practices and regulations described in 29 CFR 1910.252 have been federally enforced to protect welders from the various risks associated with the practice. In 1983, the first revision of the American National Standards Institute (ANSI) Z49.1:2012, which is the Safety in Welding, Cutting, and Allied Processes standard, was created. This standard "is for the protection of workers from injury and illness and the protection of property from damage by fire and explosions arising from welding, cutting, and allied processes" (ANSI, 2012). The standard specifically explains safe welding practices in the occupational workplace, including protection of personnel and those in the general area, ventilation requirements and recommendations, fire prevention requirements and recommendations as well as the detailed safety information for specific processes, such as oxygen gas welding or arc welding.

Manganese is a key metal, an essential ingredient in the welding of steel because it increases hardness and strength, prevents seethe lying from cracking during manufacture, improves metallurgical properties, and acts as a deoxidizing

agent to remove iron oxide from the weld pool to form a stable weld (Harris, 2002). Manganese is contained in arc welding fumes and workers get exposed to it via inhalation. Though manganese is an essential element found in the brain region, necessary for the proper functioning of the brain, excessive manganese inhalation can cause a neurodegenerative disorder characterized by both central nervous system (CNS) abnormalities and neurological disturbances.

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended a time-weighted average (TLV-TWA) of 0.02 mg/m$^3$ for manganese dust (ACGIH, 2013). Manganese associated neurological symptoms have been reported in several cases of welders who have been exposed to high levels of manganese contained in welding fume due to work in poorly ventilated areas and bad work practice. There is an increasing concern among occupational health officials about the potential neurological effects associated with the exposure to manganese in welding fumes. Long-term, high-level exposure to Mn is associated with impaired neurobehavioral function. Therefore, this study investigated workers' exposure to manganese in welding fumes and the prevalence of neurobehavioral symptoms.

## 2. Materials and methods

### 2.1 Research design

The research employed descriptive survey, field measurement and site inspection. Copies of questionnaire were distributed to welders. Field measurements were via personal sampling using active pumps for a duration of four days and also site inspection of the welding workshop was done during the sampling period.

### 2.2 Study population

A Gas Company was chosen for the case study for its intensive, day-to-day indoor welding practice. After a preliminary review of the company, shielded metal arc welding (SMAW) was chosen as having major welding fume emissions. The total number of welders in the gas company was 36. The welders worked 8 hours per day and had been employed for 2 – 20 years.

### 2.3 Sample size

The sample size for the study was 20 welders and was calculated using Taro Yamane's formula.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

where n is the minimum sample size required for the study, N is the population under study and e is the margin of error set as 15% of significance.

### 2.4 Data collection techniques

Copies of self-administered questionnaire were used to obtain personal and work history information of welders as well as the prevalence of neurobehavioral symptoms amongst the welders. Full period air sampling for determination of respirable manganese in arc welding fume was conducted at the welding workshop according to NIOSH 7300 (NIOSH, 2003) using 5 personal sampler pumps (224 PCMTX8; SKC, USA), calibrated with a digital calibrator (Defender-510, Canada), as well as filter holders and mixed cellulose esters filters (MCE) with 37 mm diameters, 0.8 µm pore sizes and 2 L/min airflow rates (NIOSH, 2003[70]). Rented forensic analytical SKC sampling pump fitted with sampling heads containing mixed cellulose ester-MCE-filters were used to carry out the personal sampling for the welding fume. An average pump rate of 2 ml/min was used for the sampling. Personal samples were obtained by attaching the sampling pumps to the personnel's belt with the sampling filter heads placed within the welders breathing zone as their normal, daily work activities were being performed. The full period sampling was done for the entire duration of their work period (8 hours) for 4 days. In addition, for every 5 samples, a control sample was also prepared. During air sampling, each welder made use of personal respiratory protective equipment and each welding booth had local exhaust ventilation (LEV).

### 2.5 Determination of manganese concentrations

To determine manganese concentrations of welding fumes, the samples collected on filters (MCE) after extraction, based on NIOSH 7300, were analysed using plasma atomic emission spectroscopy (ICP-AES) by a forensic laboratory SGS Galson in the United States of America. The sample and shift concentration time-weighted average of manganese were then calculated for comparison to ACGIH OEL.

### 2.6 Validity/reliability of questionnaire

Subjective face validity checks were conducted by reviewing the measure and making the determination of content validity based on the face of the measure, to ensure that questionnaire items were easily understood by respondents. Cronbach's alpha was used to check for the reliability of the internal consistency of the instrument. It was carried

out on SPSS with a score of 0.81 reliability, exceeding the validity level of 0.75, thereby confirming the consistency and precision of the questionnaire instrument for use.

### 2.7 Data analysis

The collected data were analysed using Statistical Package for Social Sciences (SPSS) version 22. The mean and standard deviation were used to interpret descriptive statistics.

## 3. Results and discussion

### 3.1 Demographics of respondents

The demographics of the 20 studied welders are presented in Figures 1 – 3, The average age range of the welders is 36 – 45 years, with 6 - 10 years of work experience. They all work for eight hours daily. The implication is that preponderance of the subjects had been exposed to welding fumes long enough to manifest neurobehavioral symptoms indicative of manganese toxicity. According to Bouchard et al. (2007), periods of occupational exposure of 6 months to 2 years may lead to the development of manganism and the motor and neuropsychiatric symptoms may remain even 14 years after the end of exposure to manganese. Prolonged occupational exposure to concentrations of manganese increases the risk of neurobehavioral disorders, with more subtle effects on learning, memory, and behaviour, such as tremor and weakness (Sriram et al., 2010). According to Al-Lozi et al. (2017), chronic exposure to manganese is a health concern in occupations such as welding due to its proven stimulatory effects on basal ganglia, a region of the brain which plays an important role in movement regulation.

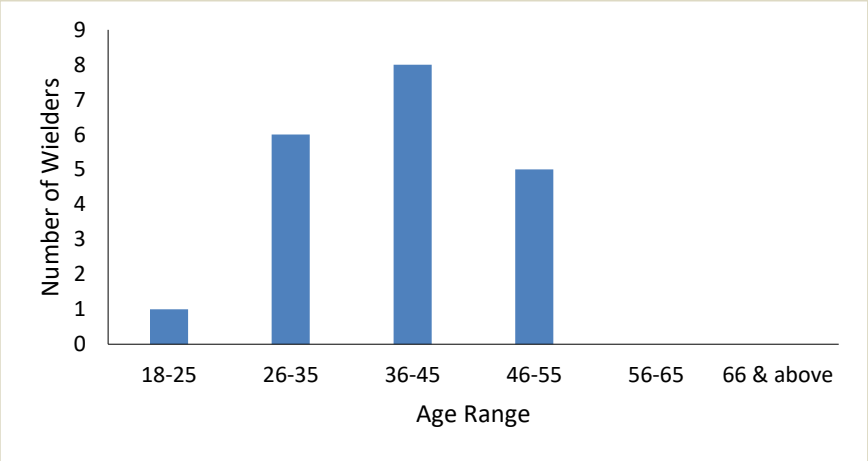


**Fig. 1:** Age range of welders


**Fig. 2:** Work experience of welders


**Fig. 3:** Number of hours worked daily

### 3.2 Neurobehavioral symptoms

Table 1 shows the frequency of neurobehavioral symptoms amongst the studied welders. From the table, 50% have problems with concentration, 90% have to make notes about what they must remember, 100% often have to go back and check things they have done, such as turning off the stove, locking the door, etc. 80% do have a headache at least once a week and 40% are less interested in sex than normal. Similar results have been obtained in other studies. A study conducted by Hassani et al. (2013) in a steel company in Iran showed that the frequency of neurobehavioral symptoms of the welders exposed to manganese was significantly higher than that of the administrative staff.

**Table 1:** Frequency of neurobehavioral symptoms

| S/N | Question | Frequency | |
|---|---|---|---|
| | | Yes | No |
| 1 | Are you abnormally tired? | 1 (5%) | 19 (95%) |
| 2 | Do you have palpitations even when you don't exert yourself? | 1 (5%) | 19 (95%) |
| 3 | Do you often have a painful tingling in some part of your body? | 9 (45%) | 11 (55%) |
| 4 | Do you often feel irritated without any part particular reason? | 3 (15) | 17 (85%) |
| 5 | Do you feel depressed without any particular reason? | 1 (5%) | 19 (95%) |
| 6 | Do you have problems with concentration? | 10 (50%) | 10 (50%) |
| 7 | Do you have a short memory? | 2 (10%) | 19 (90%) |
| 8 | Do you perspire without any particular reason? | 1 (5%) | 19 (95%) |
| 9 | Do you have any problem with buttoning and unbuttoning? | 0 (0%) | 20 (100%) |
| 10 | Do you generally find it hard to get the meaning from reading newspapers and books? | 3 (15%) | 17 (85%) |
| 11 | Have your relatives told you that you have a short memory? | 2 (10%) | 18 (90%) |
| 12 | Do you sometimes feel oppression on your chest? | 4 (20%) | 16 (80%) |
| 13 | Do you often have to make notes about what you must remember? | 18 (90%) | 2 (10%) |

| | | | |
|---|---|---|---|
| 14 | Do you often have to go back and check things you have done, such as turning off the stove, locking the door, etc.? | 20 (100%) | 0 (0%) |
| 15 | Do have a headache at least once a week? | 16 (80%) | 4 (20%) |
| 16 | Are you less interested in sex than what you can think is normal? | 9 (45%) | 11 (55%) |

### 3.3 TWA concentration of manganese in welding fumes

Table 2 shows manganese concentrations in arc welding fume in the breathing zone of the welders, with values ranging from 0.0126 to 0.0532 mg/m$^3$. The average concentration of manganese was 0.03 ± 0.01 mg/m$^3$, which is 1.5 times higher than the TLV-TWA recommended by the ACGIH for manganese (0.02 mg/m$^3$). This implies that the welders are exposed to manganese above the exposure limit and requires that measures be put in place to reduce workers' exposure to manganese in arc welding to prevent adverse health effects. Meeker et al. (2007) reported that the level of manganese exposure varies dependent upon the type of welding activity performed, ranging from 0.01 to 2.0 mg/m$^3$. The observed mean concentration of manganese in the welders' breathing zone falls within this range.

The studied welders use manual or metal arc welding (SMAW) welding technique. According to Nastiti et al. (2010), manual welding technique increases the risk of exposure to manganese. Because of the hazards of manual welding and to increase productivity, and improve product quality, various forms of mechanization and automation have been developed such as machine welding, automatic welding, and robotic welding (Groover et al., 2002). Unfortunately, majority of industries in African countries relies on manual welding (Adu and Danquah, 2016).

**Table 2:** TWA concentrations of manganese fume in the breathing zone

| Sample No | Duration (mins) | Manganese (mg/m$^3$) |
|---|---|---|
| 01 | 480 | 0.0435 |
| 02 | 480 | 0.0353 |
| 03 | 480 | 0.0532 |
| 04 | 480 | 0.0180 |
| 05 | 480 | 0.0126 |
| 06 | 480 | 0.0381 |
| 07 | 480 | 0.0413 |
| 08 | 480 | 0.0241 |
| 09 | 480 | 0.0310 |
| 10 | 480 | 0.0438 |
| 11 | 480 | 0.0382 |
| 12 | 480 | 0.0370 |
| 13 | 480 | 0.0394 |
| 14 | 480 | 0.0381 |
| 15 | 480 | 0.0439 |
| 16 | 480 | 0.0246 |
| 17 | 480 | 0.0137 |
| 18 | 480 | 0.0382 |
| 19 | 480 | 0.0245 |
| 20 | 480 | 0.0386 |
| | Average Concentration | 0.0339 |
| | Standard Deviation | 0.0108 |

## 4. Conclusion

Shielded metal arc welding (SMAW) was the welding technique adopted by the selected welders in the chosen gas company. Results showed that welders performing SMAW are exposed to manganese concentrations above an 8-hour OEL established by ACGIH (TLV-TWA) (0.02 mg/m$^3$). The studied welders exhibited neurobehavioral disorders indicative of chronic exposure to high levels of manganese fumes.

## References


Adu, E. and Danquah, A. (2016) Welding practices in selected metal welding industries in Ghana International Journal of Scientific & Engineering Research, 7(6), 462-471.

ACGIH (2013) Documentation of TLV for Manganese, Elemental and Inorganic Compounds. Cincinnati, OH: ACGIH.

Al-Lozi, A., Nielsen, S.S., Hershey, T., Birke, A., Checkoway, H. and Criswell, S.R. (2017) Cognitive control dysfunction in workers exposed to manganese-containing welding fume. American Journal of Industrial Medicine, 60, 181–188.

ANSI (American National Standards Institute) (2012) An American National Standard Approved by the American National Standards Institute March 9, 2012 Safety in Welding, Cutting, and Allied Processes.

Bouchard, M., Mergler, D., Baldwin, M., Panisset, M., Bowler, R. and Roels, H.A. (2007) Neurobehavioral functioning after cessation of manganese exposure: A follow-up after 14 years. American Journal of Industrial Medicine, 50, 831–40.

Cary, H. (2015) Modern Welding Technology, 4th edition. Web March 1st, 2015. Retrieved from http://www.millerwelds.com/resources/articles/welding-history/

Groover, M.P. (2002) Fundamentals of Modern Manufacturing, Materials Processes and Systems, Second Edition, John Wiley and Sons, Inc. USA.

Harris, M. (2002) Welding health and safety: A field guide for OEHS professionals. American Industrial Hygiene Association Press, Fairfax, Virginia, USA.

Hassani, H., Golbabaei, F., Shirkhanloo H. and Foroushani, R. (2013) A survey of neurobehavioral symptoms of welders exposed to manganese. Journal of Health and Safety at Work, 3(1): 39–46.

Meeker, J.D., Susi, P. and Flynn, M.R. (2007) Manganese and welding fume exposure and control in construction. Journal of Occupational and Environmental Hygiene, 4, 943–51.

Nastiti, A., Oginawati, K. and Santoso, M. (2010). Manganese exposure on welders in small-scale mild steel manual metal arc welding industry. Journal of Applied Sciences in Environmental Sanitation, 5(3), 23-45.

NIOSH (National Institute of Occupational Safety and Health) (2003) NIOSH Manual of Analytical Methods (4th ed.). NIOSH Manual of Analytical Methods.

OSHA (Occupational Safety and Health Administration) (2013) Safety and Health Topics: Welding, Cutting, and Brazing. Retrieved 25th January, 2022, from https://www.osha.gov/welding-cutting-brazing/hazards-solutions.

Sriram, K., Lin, G., Jefferson, A., Roberts, J., Chapman, R., Chen, B., Soukup, J., Ghio, A. and Antonini, J. (2010). Dopaminergic neurotoxicity following pulmonary exposure to manganese-containing welding fumes. Archives Toxicology, 84(7), 521–540.