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HEALTH EFFECTS OF MANGANESE EXPOSURES FOR WELDERS IN QINGDAO CITY, CHINA

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Abstract
Objectives: To document if manganese from welding causes health effects including neurological symptoms associated with manganese exposure. **Material and Methods:** An anonymous questionnaire survey for a total of 505 welders at 3 welding facilities in Qingdao City, China was administered and analyzed. **Results:** Numerous symptoms were reported by the welders including difficulty with eyes for 43% of them, sore throat for 30% of them, and tremors were reported by over 18% of them. Tremors were associated with longer periods of work as a welder and correlated with the relative cleanliness at the 3 different facilities. Tremors did not correlate with smoking. **Conclusions:** Manganese-exposed welders reported a variety of symptoms related to work and showed neurological disturbances that correlated with amount of exposure. Int J Occup Med Environ Health 2017;30(2):241–247

Key words:
Welding fumes, Neurologic symptoms, Hand tremor, Eye symptoms, Manganese exposure, Welding materials

INTRODUCTION

Since the work of Couper [1] it has been appreciated that exposure to manganese (MN) may cause neurologic damage. Although it is an element needed for proper bodily function, too much manganese may lead to significant neurologic disease, even death. No serious scientific questions have been raised regarding the effects of MN among manganese miners [2] and foundry workers [3,4] but there is some continuing controversy about the potential effects of MN from welding rods and its ability to cause disease among welders [5].

One of the difficulties in making this assessment has been the confusion about terminology. The neurologic problem arising from MN exposure has been called manganism, Parkinson's disease, manganese-induced Parkinson's disease, as well as other terms. As it is true for many organ system effects, it is not the name or description of the disease that is important but systematic findings that support toxic effect following exposure. As others have written about other workplace toxins, it is not important to make a note of the job category but the nature of the potential poison that is of importance.

If one looks at the scientific literature to date, there are differences of opinion as to the ability of manganese in welding rods being capable of causing neurologic damage. Santamaria [6] finds no problem while others [7–9] do find

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such a relationship. Others call for more research [10]. Our belief, especially given the findings reported here, is that there is indeed a significant effect on the neurologic system, as well as the development of other symptoms, following exposure to manganese through welding activities. Welding rods used in the welding of steel commonly contain manganese, the percentage rate varying by the rod type. The welders studied in Qingdao City, China all used manganese containing rods, and limited workplace measurements had been taken. There were 3 different worksites studied by means of various patterns of exposure and varied outcomes.

Some researchers have related iron levels with symptoms in patients with Parkinson's disease [11–13].

MATERIAL AND METHODS

This study was carried out by the Qingdao Municipal Center for Disease Control and Prevention in Qingdao City, China. This is a coastal city of almost 3 million on the Yellow Sea. Approval for the study was obtained from the Ethics Committee of the Qingdao Municipal Center for Disease Control and Prevention and an oral consent had been obtained from each worker before the questionnaire was given to each worker personally.

An anonymous questionnaire survey was administered to day shift workers at 3 facilities where rotating shifts were used. Each facility was studied on 1 working day with whichever workers were then on the day shift. The facilities used rotating shifts. The facilities did machinery manufacturing, automobile welding, shipyard welding and small parts welding. One was State-owned, one was foreign capital-funded, and one was a private enterprise.

All participants were male, and since it was done anonymously there was no ability to re-check or clarify answers but this was done to maximize return. All responses were self-reported and not verified medically.

Data analysis was done by means of Chi^2 using SPSS 13.0 (IBM, USA).

RESULTS

Out of the 523 questionnaires distributed, 505 were found to be complete and useable. All welders were males of an average age of 33.5±7.6 years old (19–54 years old). The education level was primarily middle and senior high school at 48.5% and 43.6%, respectively. Welders, on average, had worked for 9.2±6.4 years (0.5–30 years) and they had been at their specific workplace for 5.3±4.6 years (0.3–30 years). Welders will occasionally do other work but on average spent 62±20% (30–100%) of their time engaged in welding activities, working on average 5.9±0.7 days (2–7 days) per week. They spent 37.5±17.4% (5–100%) of their time welding on steel.

The welders' use of goggles included 97% of those wearing them, 66% – always, 28% – most of the time, and 4% – some of the time.

Manganese levels at the workplace ranged 0.01–45 mg/m^3, averaging 0.13±0.10 mg/m^3, with the Chinese occupational standard being 0.15 mg/m^3. The overall pass rate was 63.5% for meeting the standard. By location, the highest levels were found at the State-owned facility, the lower one – at the foreign funded facility, and the lowest one – at the private factory. These measured levels were consistent with observations made at each of the 3 facilities as to their worksite cleanliness.

Noise and ozone levels were also measured but not further discussed here.

The most regularly reported difficulty had to do with eye problems for 43% of the subjects, followed by sore throat (30%) and irregular cough (23%). The full range of symptoms reported may be found in the Table 1.

We compared these self-reported rates of symptoms from the 3 different worksites (Table 2). In general, as found here, State facilities tend to be the least hygienic, followed by foreign capital-funded enterprises and private facilities tend to be the cleanest.

The questionnaire collected smoking habit data and found that out of the 505 welders, 289 were smokers

Table 1. Self-reported occupational health symptoms of manganese-exposed welders

Symptom	Respondents (N = 505)	
	n	%
Difficulty with eyes	219	43
Sore throat	152	30
Regular cough	115	23
Nightime leg cramps	85	17
Decreased appetite	71	14
Muscle weakness	43	9
Tremor (shaking) of hands	36	7
Depression	33	7
Change in voice (speaking more softly)	24	5
Tingling in hand or feet	23	5
Slowed movements	18	4
Difficulty getting out of chair	10	2
Change of behavior	8	2
Balance problems	7	1
Unsteady gait	6	1
Difficulty walking	5	1

and 216 non-smokers. This is typical for Chinese males where generally some 50% of them are smokers. The only symptoms associated with a history of smoking included decreased appetite and nighttime leg cramps. Welding-related tremors were not related to smoking with no potentiation among smokers evident in this population, as it has been reported elsewhere [14,15].

Significant findings were noted when comparing the positive reporting of symptoms and the length of time spent on working as a welder. The neurologic symptoms also appeared to cluster in those reporting positive findings. Eleven out of the 16 symptoms recorded were associated with length of time spent as a welder. Most notable was the finding that 19% of workers with > 15 years of exposure complained about tremors, as compared with 4% among those with < 5 years, 3% at 5–10 years, and 5% at 10–15 years. Although there is no comparable data collected for this study, the background rate of essential tremor in China is reported to be 5–6%, and the rate of Parkinson's disease,

Table 2. Self-reported occupational health symptoms of manganese-exposed welders by worksite

Symptom	Respondents in worksite [n (%)]			Chi^2	p
	state-owned (N = 234)	foreign capital-funded (N = 99)	private (N = 172)		
Difficulty with eyes	108 (46)	52 (53)	59 (34)	9.875	0.007
Sore throat	91 (39)	41 (41)	20 (12)	42.509	0.000
Regular cough	76 (32)	28 (28)	11 (6)	40.476	0.000
Tingling in hands or feet	14 (6)	6 (6)	3 (2)	4.740	0.093
Tremor (shaking) of hands	26 (11)	8 (8)	2 (1)	14.988	0.001
Muscle weakness	27 (12)	14 (14)	2 (1)	18.705	0.000
Difficulty walking	3 (1)	2 (2)	0 (0)	2.995	0.224
Unsteady gait	4 (1)	2 (2)	0 (0)	3.194	0.203
Difficulty getting out of chair	9 (4)	1 (1)	0 (0)	8.152	0.017
Change in voice (speaking more softly)	20 (9)	3 (3)	1 (1)	14.703	0.001
Depression	24 (10)	5 (5)	4 (2)	10.653	0.005
Decreased appetite	46 (20)	17 (17)	8 (5)	19.464	0.000
Change in behavior	8 (3)	0 (0)	0 (0)	9.414	0.009

Table 2. Self-reported occupational health symptoms of manganese-exposed welders by worksite – cont.

Symptom	Respondents in worksite [n (%)]			Chi^2	p
	state-owned (N = 234)	foreign capital-funded (N = 99)	private (N = 172)		
Balance problems	4 (2)	2 (2)	1 (1)	1.285	0.526
Slow movements	10 (4)	5 (5)	3 (2)	2.636	0.268
Nighttime cramps	32 (14)	22 (22)	31 (18)	3.895	0.143

generally affecting a group older than these welders, is about 1%. The finding of 19% is therefore strikingly high as compared to the population rate of ≤ 7%.

Out of the 19% of them with tremor, 72.2% of them were at the State-owned facility, 22.2% – at the foreign capital-funded, and 5.5% – at the private facility with the percentage rate of participants in the overall study being 46.3%, 19.6%, 34%, respectively. As the facilities became cleaner the likelihood of developing a tremor decreased.

Given multiple symptoms of neurologic nature that were examined in relation to each other, there was a statistically significant relationship of tremor and tingling, tremor and reported muscle weakness, tremor and difficulty getting out of a chair, and tremor and a reported change in voice. All of these are neurologic symptoms that have been seen in welders, as well as patients with Parkinson's disease.

There was no statistical relationship of smoking and regular cough, with an independent relationship of coughing associated with welding, without regard to smoking history.

The Table 3 addresses the rate of symptoms by time worked.

Table 3. Self-reported occupational health symptoms of manganese-exposed welders by working time as a welder

Symptom	Respondents working as welders [n (%)]				Chi^2	p
	< 5 years (N = 201)	5–10 years (N = 138)	10–15 years (N = 81)	> 15 years (N = 85)		
Difficulty with eyes	73 (36)	56 (40)	35 (43)	55 (65)	20.263	0.000
Sore throat	34 (17)	27 (13)	43 (53)	48 (56)	72.323	0.000
Regular cough	22 (11)	17 (8)	28 (35)	48 (56)	85.855	0.000
Tingling in hands or feet	4 (2)	2 (1)	4 (5)	13 (15)	28.682	0.000
Tremor (shaking) of hands	9 (4)	7 (3)	4 (5)	16 (19)	21.162	0.000
Muscle weakness	6 (3)	7 (3)	6 (7)	24 (28)	52.552	0.000
Difficulty walking	2 (1)	1 (1)	0 (0)	2 (2)	2.520	0.472
Unsteady gait	2 (1)	2 (1)	0 (0)	2 (2)	2.100	0.552
Difficulty getting out of chair	4 (2)	5 (4)	1 (1)	1 (1)	3.869	0.276
Change in voice (speaking more softly)	6 (3)	9 (7)	5 (6)	4 (5)	2.703	0.440
Depression	11 (5)	8 (6)	2 (2)	12 (14)	10.689	0.014
Decreased appetite	15 (7)	12 (9)	12 (15)	32 (38)	49.730	0.000

Table 3. Self-reported occupational health symptoms of manganese-exposed welders by working time as a welder – cont.

Symptom	Respondents working as welders [n (%)]				Chi^2	p
	< 5 years (N = 201)	5–10 years (N = 138)	10–15 years (N = 81)	> 15 years (N = 85)		
Change in behavior	4 (2)	2 (2)	0 (0)	2 (2)	1.855	0.600
Balance problems	1 (1)	2 (2)	0 (0)	4 (5)	9.157	0.027
Slow movements	3 (1)	6 (4)	1 (1)	8 (9)	12.491	0.006
Nighttime leg cramps	20 (10)	26 (19)	12 (15)	27 (32)	20.973	0.000

DISCUSSION

Although a required trace element for humans, manganese is also a pollutant and toxicant if taken into the body in excess. In the case of welding activities, manganese is taken into the body primarily through the respiratory system. It has also been found to migrate into the brain through the nose. Manganese may accumulate in the brain, predominantly in the globus pallidus and midbrain. Short-term high exposures (> 1 mg/m^3) may cause classical manganism.

More difficult to assess are neurologic findings after long-term, lower levels of exposure. Some researchers have reported adverse health effects from smelting as well as welding activities. Others have stated they are unsure if welding activities may cause neurologic damage [10], while some have definitively stated it cannot occur [6]. Our findings fit with others already noted in the scientific literature attesting to the release of manganese from welding activities causing neurologic damage, as well as a variety of other symptoms. This would include the work of Bowler [7], Chandra et al. [16], Laohaudomchok et al. [8], and Racette et al. [9].

The finding in this study proves notable for the high rate of reported eye difficulties, even though most welders wear eye protection, albeit not very consistently.

Of note is the correlation of the facility with the highest level of contamination, being the site of the highest level of symptom reporting, with lower levels of reporting symptoms in the settings with lower levels of exposures, both measured and by observation.

A finding of special note is the finding of a high rate of reported tremor after 15 years of work as a welder. We are not aware of any similar report of this type of finding among welders, except for a report of a few subjects with noticeable tremor [17]. Others have reported, among smaller groups of workers, tremors being increased by smoking [12,13]. We have found no such a difference in this study.

In the literature on Parkinson's disease there are reports of potentiation with elevated iron levels [11–13]. We recognize that there may be potentiation of symptoms of Parkinson's disease with elevated iron levels. However, we have no quantification of iron exposure in our group of welders, and one would presume that all would have similar exposures from welding activities, although the levels might vary by plant.

Clearly there are issues with this report that need to be considered. All data was self-reported with no medical assessment. While there was no control group, other than tremor data for the general Chinese population, our data was assessed both by time of work, approximating dose, and by the 3 types of worksite with clear differences as to exposure levels. The measurements taken did not cover the whole period of work for all workers but were an assessment that matched observations of working conditions.

Given that there appears to be neurologic difficulties reported among welders in Qingdao City, China that

correlate with both working conditions and time of work as a welder there are some recommendations that would apply here and in other similar settings. It would be helpful to automate certain welding operations to isolate workers from welding fumes. Ventilation of fumes should be maximized and the percentage rate of manganese in rods minimized to the possible extent. Personal protective equipment needs to be provided and its use enforced to reduce the risk of disease or symptoms.

Although there will likely continue to be some controversy about the ability of manganese in welding rods to cause disease, this study documents the development of neurologic symptoms among welders that may be related to their exposure to manganese.

A continuing difficulty is linking symptoms with exposure to manganese and that there are no good methods to measure exposure in body tissues and fluids.

CONCLUSIONS

Based upon these results we feel that it is justified to conclude that exposure to manganese from welding fumes is a cause of neurologic, and other, symptoms. This paper adds further to the body of work making this conclusion and should assist moving those with no clear acceptance of this towards recognizing what the manganese in welding fumes are capable of. As noted in other settings, it is not the specific job but the exposure to a specific substance that should be considered.

REFERENCES

1. Couper J. On the effects of black oxide of manganese when inhaled into the lungs. Br Ann Med Pharmacol. 1837;1:41–2.
2. Rodier J. Manganese poisoning in Moroccan miners. Br J Ind Med. 1955;12:21–35, https://doi.org/10.1136/oem.12.1.21.
3. Wang J, Huang C, Hwang Y, Chiang J, Lin J. Chen JS. Manganese induced parkinsonism: An outbreak due to an unrepaired ventilation control system in a ferromanganese smelter. Br J Ind Med. 1989;46:856–9, https://doi.org/10.1136/oem.46.12.856.
4. Bouchard M, Mergler D, Baldwin M, Panisset M, Bowler R, Roels H. Neurobehavioral functioning after cessation of manganese exposure: A follow-up after 14 years. Am J Ind Med. 2007;50:831–40, https://doi.org/10.1002/ajim.20407.
5. Checkoway H. Documentary neurotoxicity from occupational manganese exposure. Occup Environ Med. 2012;67:362–3, https://doi.org/10.1136/oem.2009.047803.
6. Santamaria A, Cushing C, Antonini J, Finley B, Mowart F. State-of-the-science review: Does manganese exposure during welding pose a neurological risk? J Toxicol Environ Health B Crit. Rev. 2007;10:417–65, https://doi.org/10.1080/15287390600975004.
7. Bowler R, Gysen S, Diamond E, Nakagawa S, Drezgic M, Roels H. Manganese exposures: Neuropsychological and neurological symptoms and effects in welders. Neurotoxicology. 2006;27:315–26, https://doi.org/10.1016/j.neuro.2005.10.007.
8. Laohaudomchok W, Lin X, Herrick R, Fang S, Cavallari J, Shrairman R, et al. Neuropsychological effects of low-level manganese exposure in welders. Neurotoxicology. 2011;32:171–9, https://doi.org/10.1016/j.neuro.2010.12.014.
9. Racette B, Criswell S, Lundin J, Hobson A, Sexias N, Kotzbauer P, et al. Increased risk of Parkinsonism associated with welding exposure. Neurotoxicology. 2012;33:1356–61, https://doi.org/10.1016/j.neuro.2012.08.011.
10. Antonini J, Santamaria A, Jenkins N, Albini E, Lucchini R. Fate of manganese associated with the inhalation of welding fumes: Potential neurological effects. Neurotoxicology. 2006;27:304–10, https://doi.org/10.1016/j.neuro.2005.09.001.
11. Dexter DT, Carayon A, Janoy-Agid F, Agid Y, Wells FR, Daniel SE, et al. Alternations in the levels of iron, ferritin and other trace metals in Parkinson's disease and other neurodegenerative disease affecting the basal ganglia. Brain. 1991;114:1953–75, https://doi.org/10.1093/brain/114.4.1953.
12. Mann VM, Cooper JM, Daniel SE, Srai K, Jenner P, Marsden CD, et al. Complex I, iron, and ferritin in Parkinson's

disease substantia nigra. Ann Neurol. 1994;36:876–81, https://doi.org/10.1002/ana.410360612.

13. Hirsch EC, Brandel J-P, Galle P, Javory-Agid F, Agid F. Iron and aluminum increase in the substantia nigra of patients with Parkinson's disease: An X-ray microanalysis. J Neurochem. 2006;56: 446–51, https://doi.org/10.1111/j.1471-4159.1991.tb08170.x.
14. Sarić M, Markićović A, Hrustić D. Occupational exposure to manganese. Br J Ind Med. 1977;34:114–8, https://doi.org/10.1136/oem.34.2.114.
15. Bast-Pettersen R, Ellingsen DG, Hetland SM, Thomassen Y. Neuropsychological function in manganese alloy plant workers. Int Arch Occup Environ Health. 2004;77: 277–87, https://doi.org/10.1007/s00420-003-0491-0.
16. Chandra S, Shukla G, Srivastava R, Singh H, Gupta V. An exploratory study of manganese exposure to welders. Clin Toxicol. 1981;18:407–16, https://doi.org/10.3109/15563658108990264.
17. Ellingsen D, Konstantinov R, Bast-Petterson R, Merkurjeva L, Chashchin M, Thomassen Y, et al. A neurobehavioral study of current and former welders exposed to manganese. Neurotoxicology. 2008;29:48–59, https://doi.org/10.1016/j.neuro.2007.08.014.