2008-5435/12/41-6-9
INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE

IJOH 4: 6-9, 2012

ORIGINAL ARTICLE

Risk Assessment of Exposure to Gases Released by Welding Processes in Iranian Natural Gas Transmission Pipelines Industry

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Received June 5, 2011; Accepted November 14, 2011

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

Exposure to welding gases can cause health adverse effects. Risk assessment is a useful tool for good assessment of exposed workers. The purpose of this study was to determine the risk levels for exposed welders to welding gases. Welders (n=239) were selected from Iranian Natural Gas Transmission Pipelines Industry from four regions in Iran including Assaluyeh, Omidieh, Loshan, and Borujen. Ozone (O_3) and nitrogen dioxide (NO_2) samples were collected according to the OSHA ID-214 method and the NIOSH analytical method 6014, respectively. Direct reading instruments were used for sampling of carbon monoxide (CO) and carbon dioxide (CO_2). A semi-quantitative method was used for risk assessment. Exposure to O_3, NO_2, CO, and CO_2 ranged 0-0.0371, 0.01-0.58, 0.375-4.33, and 89.5-1395.44 ppm, respectively. Among welders, Back weld group had the maximum exposure to O_3, CO, CO_2, while, the maximum exposure to NO_2 was seen for Filling group and then for Back weld group. Although average exposure values were significantly lower than Threshold Limit Values-Time Weighted Average (TLV-TWA) ($p<0.05$), the results of risk assessment showed that, control approaches should be applied for welders specially in Full pass, Filling, Filling cap, and Back weld groups due to their medium (M) and high (H) rank of risk.

Keywords: *Exposure, Welding gases, Risk assessment, Iran, Gas, Pipelines Industry*

INTRODUCTION

Welding is a common process used to joint metals. Various hazardous agents especially fume and gases are produced during welding processes. Exposure to agents released by welding processes may cause adverse health effects [1, 2]. Several gases including ozone (O_3), nitrogen oxides (NO_x), carbon monoxide (CO), and carbon dioxide (CO_2) are generated during arc welding operations [3, 4]. Ozone is produced by reaction between ultraviolet light generated during arc welding and oxygen in the air. The amount of formed ozone varies in different wavelengths and intensity of ultraviolet radiation [4]. Ozone is recognized as a powerful oxidant that can cause decreases in lung function, DNA damage has been reported to increase cardiopulmonary mortality and lung cancer risk [5-7]. Exposure to high concentrations of oxidant gas, nitrogen dioxide (NO_2), can induce pulmonary disorders such as acute inflammation and pulmonary edema [8, 9].

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Table 1. The values of welding gases concentrations in comparison with TLV-TWA (ACGIH)

Welding Gases	Concentrations ppm(mean ± SD)	TLV-TWA (ACGIH) (ppm)	*p* value
O_3	0.018±0.02	0.05	$p<0.01$
NO_2	0.397±0.35	3	$p<0.01$
CO_2	613.16±351.50	5000	$p<0.01$
CO	1.477±1.40	25	$p<0.01$

Carbon monoxide is a colorless, odorless, tasteless, and nonirritating toxic gas. The lethality of CO due to exposure to high concentrations is well known [10]. After inhalation of CO, it is "readily absorbed from the lungs into the bloodstream, where it forms a tight but slowly reversible complex with hemoglobin (Hb) known as carboxyhemoglobin (COHb)" [11]. The presence of COHb in the blood causes hypoxia that it can be deadly [10, 11]. Carbon dioxide is not harmful at normal atmospheric levels, but at high concentrations such as confined spaces environments, it is a dangerous gas and may cause death [12]. Welding process is an important operation in developing of natural gas transmission pipelines, so, its welders are frequently exposed to hazardous agents.

Risk assessment is the foundation for recommended occupational exposure limits designed to protect the safety and health of workers. The risk assessment process includes many phases including hazard identification, dose–response assessment, exposure assessment, and risk characterization. The risk assessment is a useful tool to improve occupational health and safety policy and decision-making process for control approaches [13]. Control approach is type of approach needed to achieve adequate control [14].

The purpose of this study was to determine the risk levels for welders exposed to welding gases in Iranian Natural Gas Transmission Pipelines Industry.

MATERIAL AND METHODS

Study Population

Welders were randomly selected from Iranian Natural Gas Transmission Pipelines Industry from four cities in Iran including Assaluyeh (Bushehr Province), Omidieh (Khuzestan Province), Loshan (Gilan Province), and Borujen (Chaharmahal and Bakhtiari Province). All participants were male. The tasks under study were divided in 8 groups including Foreman, Fitter, Co-fitter, Full pass, Filling, Filling cap, Back weld, and Grinder.

Welding Type

Manual Metal Arc Welding (MMAW), also known as Shielded Metal Arc Welding (SMAW) is a welding method commonly used in natural gas transmission pipelines industry in Iran.

Air Sampling and Analysis

O_3 samples were collected at the breathing zone of welders using treated glass fiber filters (GFF) (37-mm diameter; SKC Corp) in personal air samplers according to the OSHA ID-214 method. SKC pumps (model 222, SKC Inc. U.S.A.) operated at a constant flow rate of 0.2 L/Min were used for the O_3 sampling. Spectrophotometer UV-Vis (UV monitor) was used for analyzing samples. The method used for NO_2 was based on the NIOSH analytical methods 6014. Analysis was performed using Spectrophotometer UV-Vis (540 nm). It should be noted that, all pumps were calibrated before and after sampling. We used direct reading instruments known as real time instruments for sampling of CO and CO_2 gases. Instruments were included 1372 CO meter model and 1370 NDIR CO_2 meter model (TES Company).

Risk assessment method

Risk assessment for various task groups in this study was assigned by using a semi-quantitative method to assess occupational exposure to harmful chemicals that is introduced by Occupational Safety and Health Division, Ministry of Manpower, Singapore [15].

Statistical analyses

SPSS (V. 17) software was used for all statistical analyses. The level of significance was taken as $p<0.05$.

RESULTS

Two hundred and thirty nine welders participated in this study. The mean of age and work history in the study group were 30.5±8.12 and 5.59±5.42 years, respectively. Average exposure values were significantly lower than Threshold Limit Values-Time Weighted Average (TLV-TWA) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for all of welding gases ($p<0.05$), (Table 1). Welders in various task groups were exposed to different concentrations of welding gases. Table 2 shows the mean values of exposure to welding gases based on various task groups. O_3, NO_2, CO, and CO_2 concentrations ranged 0-0.0371, 0.01-0.58, 0.375-4.33, and 89.5-1395.44 ppm, respectively. Back weld group had maximum exposure to O_3, CO, CO_2 among welders and maximum exposure to NO_2 was seen for Filling group with arithmetic mean of 0.58±0.508 ppm and then for Back weld group with arithmetic mean of 0.55±0.199 ppm. The results of Risk assessment (Table 3) show that Fitter, Co-Fitter, Full pass, Filling, Filling cap, and Grinder workers had medium (M) rank of risk for exposure to ozone. Back weld group had high (H) rank of risk for ozone exposure. Full pass, Filling,

Table 2. Concentrations (ppm) of welding gases in various task groups

Tasks \ Gases	(Mean ± SD)			
	O_3	NO_2	CO	CO_2
Forman	0.000±0.000	0.005±0.003	0.375±0.308	89.50±62.300
Fitter	0.010±0.009	0.180±0.153	0.845±0.438	341.25±192.70
Co-Fitter	0.003±0.004	0.095±0.060	0.675±0.479	217.08±102.37
Full pass	0.018±0.016	0.440±0.277	1.102±0.922	591.39±254.90
Filling	0.024±0.020	0.580±0.508	1.591±1.282	792.78±300.36
Filling cap	0.020±0.019	0.440±0.282	1.782±1.710	678.00±222.64
Grinder	0.005±0.004	0.200±0.108	1.026±0.855	328.40±231.46
Back weld	0.037±0.032	0.550±0.199	4.330±1.845	1395.4±223.38

Table 3. The results of risk assessment based on various task groups

Tasks \ Gases	O_3				NO_2				CO				CO_2			
	HR	ER	RR	R	HR	ER	RR	R	HR	ER	RR	R	HR	ER	RR	R
Forman	5	1	2.2	L	4	1	2	L	4	1	2	L	2	1	1.4	N
Fitter	5	2	3.2	M	4	1	2	L	4	1	2	L	2	2	2	L
Co-Fitter	5	2	3.2	M	4	1	2	L	4	1	2	L	2	1	1.4	N
Full pass	5	2	3.2	M	4	2	2.8	M	4	1	2	L	2	2	2	L
Filling	5	2	3.2	M	4	2	2.8	M	4	1	2	L	2	2	2	L
Filling cap	5	2	3.2	M	4	2	2.8	M	4	1	2	L	2	2	2	L
Grinder	5	2	3.2	M	4	1	2	L	4	1	2	L	2	2	2	L
Back weld	5	3	3.9	H	4	2	2.8	M	4	2	2.8	M	2	2	2	L

*HR: Hazard Rating, ER: Exposure Rating, RR: Risk Rating, R: Ranking, N: Negligible, L**:** Low**,** M**:** Medium**,** H**:** High

Filling cap, and Back weld groups had medium (M) rank of risk for exposure to NO_2. Rank of risk was medium (M) for exposure to CO in Back weld group. For other cases, risk ranks were in low (L) and negligible (N) ranks (Table 3).

DISCUSSION

Exposure to hazardous agents produced during welding processes is an occupational health concern. The results of risk assessment can help us to have better decisions and solutions to provide control interventions. Most of studies have shown concentrations of welding gases and the use of risk assessment for assessment of exposure to welding gases is not well documented. However, previous studies presented various concentrations for exposed workers. In our study, gases' concentrations varied for various tasks and exposure for Back weld group was considerable among understudy groups, because they work in confined space. However, the studied welders' exposure to welding gases in comparison with TLVs-TWA (ACGIH) showed that their exposures were lower than TLVs-TWA. Such findings may be due to gases dilution in atmospheric air, because the welding operations were performed in outdoor environment. On the other hand, variable welding durations as well as environmental factors such as wind direction, humidity, and ambient temperature may have significant role on welder's exposure to welding gases. Schoonover et al. [16] in a study on production welders and non-welders reported that welders were exposed to higher concentrations of NO_2 and O_3 but not significant statistically. Exposures to O_3 and CO were higher than their corresponding occupational exposure limit values [17]. There are some studies that focus on related health effects of exposure to NO_2 and O_3. The number of studies on health effects of exposure to NO_2 and O_3 are considerable and most of these studies focused on pulmonary function and respiratory tract injury or inflammation. Jenkins et al. [18] studied the effect of exposure to NO_2 and O_3 on the airway response of atopic asthmatics to inhaled allergen. Exposure to O_3 was associated with a statistically significant increase in bronchial responsiveness and also decreases in pulmonary functions [19]. Exposure to O_3 can cause airway inflammation [20]. Exposure to O_3 is associated with greater respiratory tract injury and inflammation among exposed subjective with asthma rather than normal people [21]. A systematic review of effects of NO_2 on human health was conducted by Latza et al. [22]. CO toxicity is well-known, so monitoring and controls should be done carefully. Carbon dioxide (CO_2) is a danger when present in enclosed spaces at high concentrations [12]. Halpern et al. reported transient cardiopulmonary morbidity with no mortality among exposed workers to extremely high concentrations of CO_2 [23]. In our study, risk rank of exposure to CO_2 was in low (L) and negligible (N) ranks. Although average exposure values were significantly lower than TLV-TWA ($p<0.05$), the results of risk assessment showed that control approaches should be applied for some task groups due to their medium (M) and high (H) rank of risk. Control approaches are required including effective engineering control, conduct air monitoring, training for employees, adopt respiratory protection program, develop and implement safe and correct work procedures, provide first-aid and emergency procedures and finally reassess the risk after all the controls have been done [15].

CONCLUSION

Although average exposure values were significantly lower than the Threshold Limit Values-Time Weighted Average (TLV-TWA), the results of risk assessment showed that, in some task groups the rank of risk was medium (M) and even high (H), thus, it is necessary to apply control approaches for such task groups.

ACKNOWLEDGEMENTS

This project was financially supported by the Iranian Gas Engineering and Development Company (IGEDC). The authors wish to thank Mr. Mirghani Seyed Somea and Mrs. Razieh Divani for their technical assistance during this research. The authors declare that there is no conflict of interests.

REFERENCES

1. Antonini JM, O'Callaghan JP, Miller DB. Development of an animal model to study the potential neurotoxic effects associated with welding fume inhalation. *Neuro Toxicology* 2006; 27(5): 745-751.
2. Yu KM, Topham N, Wang J, et al. Decreasing biotoxicity of fume particles produced in welding process. *Journal of Hazardous Materials* 2011; 185(2-3): 1587-1591.
3. Sriram K, Lin GX, Jefferson AM, et al. Dopaminergic neurotoxicity following pulmonary exposure to manganese-containing welding fumes. *Archiv Toxicolo* 2010; 84(7): 521-540.
4. National Institute for Occupational Safety and Health. Nomination of welding fumes for toxicity studies February 2002.
5. Palli D, Sera F, Giovannelli L, et al. Environmental ozone exposure and oxidative DNA damage in adult residents of Florence, Italy. *Environmental Pollution* 2009; 157(5): 1521-1525.
6. Yamauchi T, Shima M, Kuwaki T, et al. Acute effects of ozone exposure on lung function in mice sensitized to ovalbumin. *Toxicology* 2002; 172(1): 69-78.
7. Elsayed NM. Diet restriction modulates lung response and survivability of rats exposed to ozone. *Toxicology* 2001; 159(3): 171-182.
8. Ayyagari VN, Januszkiewicz A, Nath J. Pro-inflammatory responses of human bronchial epithelial cells to acute nitrogen dioxide exposure. *Toxicology* 2004; 197(2): 148-163.
9. Papi A, Amadesi S, Chitano P, et al. Bronchopulmonary inflammation and airway smooth muscle hyperresponsiveness induced by nitrogen dioxide in guinea pigs. *Eur J Pharmacol* 1999; 374(2): 241-247.
10. Raub JA. Health effects of exposure to ambient carbon monoxide. Chemosphere - Global Change Science 1999; 1(1-3): 331-351.
11. Raub JA, Mathieu NM, Hampson NB, Thom SR. Carbon monoxide poisoning -- a public health perspective. *Toxicology* 2000; 145(1): 1-14.
12. Scott JL, Kraemer DG, Keller RJ. Occupational hazards of carbon dioxide exposure. *Journal of Chemical Health and Safety* 2009; 16(2): 18-22.
13. Curran CP, Park RM, Ho SM, Haynes EN. Incorporating genetics and genomics in risk assessment for inhaled manganese: From data to policy. *Neuro Toxicology* 2009; 30(5): 754-760.
14. Zalk DM, Nelson DI. History and evolution of control banding: a review. *J Occup Environ Hyg* 2008; 5(5): 330-46.
15. Ministry of Manpower, Occupational Safety and Health Division. A semi-quantitative method to assess occupational exposure to harmful chemicals., Singapore, 2005.
16. Schoonover T, Conroy L, Lacey S, Plavka J. Personal exposure to metal fume, NO2, and O3 among production welders and non-welders. *Ind Health* 2011; 49(1): 63-72.
17. Saito H, Ojima J, Takaya M, et al. Laboratory measurement of hazardous fumes and gases at a point corresponding to breathing zone of welder during a CO2 arc welding. *Ind Health* 2000; 38(1): 69-78.
18. Jenkins HS, Devalia JL, Mister RL, Bevan AM, Rusznak C, Davies RJ. The effect of exposure to ozone and nitrogen dioxide on the airway response of atopic asthmatics to inhaled allergen: dose- and time-dependent effects. *Am J Respir Crit Care Med* 1999; 160(1): 33-9.
19. Kreit JW, Gross KB, Moore TB, Lorenzen TJ, D'Arcy J, Eschenbacher WL. Ozone-induced changes in pulmonary function and bronchial responsiveness in asthmatics. *J Appl Physiol* 1989; 66(1): 217-22.
20. Aris RM CD, Hearne PQ, Kerr K, Finkbeiner WE, Balmes JR, Ozone-induced airway inflammation in human subjects as determined by airway lavage and biopsy. *Am Rev Respir Dis* 1993; 148(5): 1363-72.
21. Scannell C, Chen L, Aris RM, et al. Greater ozone-induced inflammatory responses in subjects with asthma. *Am J Respir Crit Care Med* 1996; 154(1): 24-9.
22. Latza U, Gerdes S, Baur X, Effects of nitrogen dioxide on human health: Systematic review of experimental and epidemiological studies conducted between 2002 and 2006. *Int J Hyg Environ Health* 2009; 212(3): 271-287.
23. Halpern P, Raskin Y, Sorkine P, Oqanezov A. Exposure to extremely high concentrations of carbon dioxide: A clinical description of a mass casualty incident. *Ann Emerg Med* 2004; 43(2): 196-199.