ORIGINAL ARTICLE

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

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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 (O3) and nitrogen dioxide (NO2) 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 (CO2). A semi-quantitative method was used for risk assessment. Exposure to O3, NO2, CO, and CO2 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 O3, CO, CO2, while the maximum exposure to NO2 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 (O3), nitrogen oxides (NOx), carbon monoxide (CO), and carbon dioxide (CO2) 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 (NO2), can induce pulmonary disorders such as acute inflammation and pulmonary edema [8, 9].
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**

O₃ 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 O₃ sampling. Spectrophotometer UV-Vis (UV monitor) was used for analyzing samples. The method used for NO₂ 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 CO₂ gases. Instruments were included 1372 CO meter model and 1370 NDIR CO₂ 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±4.2 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. O₃, NO₂, CO, and CO₂ 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 O₃, CO, CO₂ among welders and maximum exposure to NO₂ 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, Filling cap, and Back weld groups had medium (M)

<table>
<thead>
<tr>
<th>Table 1. The values of welding gases concentrations in comparison with TLV-TWA (ACGIH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding Gases</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>O₃</td>
</tr>
<tr>
<td>NO₂</td>
</tr>
<tr>
<td>CO₂</td>
</tr>
<tr>
<td>CO</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Gases</th>
<th>O(_3)</th>
<th>NO(_2)</th>
<th>CO</th>
<th>CO(_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forman</td>
<td>Fitter</td>
<td>0.000±0.000</td>
<td>0.005±0.03</td>
<td>0.375±0.30</td>
<td>89.5±62.30</td>
</tr>
<tr>
<td>Co-Fitter</td>
<td></td>
<td>0.015±0.009</td>
<td>0.180±0.15</td>
<td>0.845±0.43</td>
<td>341.25±192.70</td>
</tr>
<tr>
<td>Full pass</td>
<td></td>
<td>0.018±0.016</td>
<td>0.440±0.277</td>
<td>1.102±0.92</td>
<td>591.39±254.90</td>
</tr>
<tr>
<td>Filling</td>
<td></td>
<td>0.024±0.020</td>
<td>0.580±0.50</td>
<td>1.591±0.282</td>
<td>792.78±300.36</td>
</tr>
<tr>
<td>Filling cap</td>
<td></td>
<td>0.020±0.019</td>
<td>0.440±0.282</td>
<td>1.782±1.710</td>
<td>678.00±222.64</td>
</tr>
<tr>
<td>Grinder</td>
<td></td>
<td>0.005±0.004</td>
<td>0.200±0.108</td>
<td>1.026±0.855</td>
<td>328.40±231.46</td>
</tr>
<tr>
<td>Back weld</td>
<td></td>
<td>0.037±0.032</td>
<td>0.550±0.199</td>
<td>4.330±1.845</td>
<td>1395.4±223.38</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Gases</th>
<th>O(_3)</th>
<th>NO(_2)</th>
<th>CO</th>
<th>CO(_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HR</td>
<td>ER</td>
<td>RR</td>
<td>R</td>
</tr>
<tr>
<td>Forman</td>
<td>Fitter</td>
<td>5</td>
<td>2</td>
<td>2.2</td>
<td>L</td>
</tr>
<tr>
<td>Co-Fitter</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3.2</td>
<td>M</td>
</tr>
<tr>
<td>Full pass</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3.2</td>
<td>M</td>
</tr>
<tr>
<td>Filling</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3.2</td>
<td>M</td>
</tr>
<tr>
<td>Filling cap</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3.2</td>
<td>M</td>
</tr>
<tr>
<td>Grinder</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3.2</td>
<td>M</td>
</tr>
<tr>
<td>Back weld</td>
<td></td>
<td>5</td>
<td>3</td>
<td>3.9</td>
<td>H</td>
</tr>
</tbody>
</table>


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**

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**REFERENCES**