Designing, Constructing and Installing a Local Exhaust Ventilation System to Minimize Welders' Exposure to Welding Fumes

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Background & Aims of the Study: Welder's exposure to welding fumes can cause occupational diseases. The current study sought to examine exposure to welding fumes among welders who work in the repair shop of Sarcheshmeh Copper Complex and design a local exhaust ventilation system to control exposure to welding fumes.

Materials & Methods: This applied analytical study was conducted in the summer of 2016 among welders working in the repair shop of Sarcheshmeh Copper Complex. The study comprised three phases; in the first one, welders' exposure to welding fumes was assessed at the beginning of the study. After that, a local exhaust ventilation system was designed and installed in the aforementioned repair shop. In the final stage, welders' exposure to welding fumes was assessed again after installation of the ventilation system. The procedure recommended by NIOSH (method number 7300) was used for individual sampling of welders.

Results: Based on the obtained findings, before installing the ventilation system, welding technicians were exposed to 0.3 mg/m^3 of copper fumes and 0.04 mg/m^3 of chromium fumes. Journeyman welders were also exposed to 2.16 mg/m^3 of manganese fumes, while stellar welders were exposed to 6.9 mg/m^3 of iron fumes. In the light of these measurements, a local exhaust ventilation system was designed and installed. Subsequently, measurement of exposure to welding fumes showed a significant reduction. That is, welding technicians were exposed to 0.17 mg/m^3 and 0.015 mg/m^3 of copper and chromium fumes respectively. Additionally, journeyman welders were exposed to 0.86 mg/m^3 of manganese fumes, whereas stellar welders were exposed to 4.3 mg/m^3 of iron fumes.

Conclusions: A comparison of standard limits of exposure to welding fumes and the results obtained from measurements in sampling stations before and after the installation of the local exhaust ventilation system reveals that this controlling measure was very effective in the repair shop of Sarcheshmeh Copper Complex.

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Background

Many adverse effects of chemicals, gases, radiation, smoke, and other harmful agents have been identified for human body. It is therefore essential to design safety instruments and technologies that will minimize the harmful impact of abovementioned agents (1). During welding operation, various harmful agents such as fumes, gases, heat, noise, and ultraviolet light are produced. From the perspective of occupational health, fumes constitute one of the main harmful agents (2). Fumes consist of solid metals floating in the air; as a result of extreme heat or pressure in processes like welding, metals are converted to steam, which is then condensed upon cooling and turn into floating solid materials (3). Workers' exposure to welding fumes can cause occupational diseases in some body organs like lungs (occupational asthma), kidney, liver, and brain (4,5). Inhalation of harmful agents can also lead to some other complications including pneumonia caused by nitrogen oxides, allergy to irritating substances, pulmonary emphysema, renal failure, skin cancer, and lung cancer (6,7). Studies on the effects of welding on humans have demonstrated that chromium (IV) changes the sperm status, hence affecting workers' reproduction ability (8). Production of fumes usually causes chemical reactions like oxidation. Fumes are very small particles with diameters of 0.2 to 0.3 micron. Thus, they easily enter lungs through inhalation and reach the lower parts of the respiratory system. Fume is produced in all welding procedures, but the amount of produced fumes depends on the type of welding operation (4). Fumes are mainly produced because of the evaporation of elements or oxides from the arc welding area and rapid condensation of steam. According to the classification proposed by the International Agency for Research on Cancer (IARC), welding fumes belong to group 2B (possibly carcinogenic to humans). It is thus necessary to use local exhaust ventilations to reduce the harmful effect of such fumes (3,9). In industry, welding is essential for connecting metals together. It is regarded as a particular technology that is used for all metal structures (10). Welding operation results in the production of numerous fumes which consist of metal fumes, silica, fluoride, carbon monoxide, ozone, etc (9). The amount of fume produced in welding depends on various factors such as the power supply voltage, length of the electric arc, electrical flow rate, welding electrode diameter, electrode polarity type of shielding gas, mixture of argon and carbon dioxide, welder's experience, wire feed speed, humidity, welding position, type of welding operation, material of the workpiece, coating of the workpiece, ambient air temperature, and temperature of the welding flame (11). It has been demonstrated that using local exhaust ventilation can be an effective way and a preliminary engineering method for controlling welding fumes. There are some guidelines for designing such ventilation systems (12,13). Research has demonstrated that local exhaust ventilation systems may decline the amount of exposure to welding fumes (e.g. manganese, chromium, etc.) far beyond available standard limits (14). Two types of local exhaust ventilation systems (mobile and fixed) have been designed to control welding fumes. The fixed type is used for small, manual welding machines, while the mobile one is applied for various types of automatic welding machines (14). The efficiency of the ventilation system depends on the quality of its design, installation, maintenance, and use. It is also influenced by the type of published contaminants, process properties, and workplace (15). Some of the parameters that must be taken into account for designing the ventilation system for welding are the amount of produced steam, the distance between the respiratory tract and the welding arc, welding procedure, and type of workers' exposure to the source of producing fume. There are various welding-based parameters that determine the amount of produced fumes and their compounds. All these criteria should be taken into consideration while designing a local exhaust ventilation system (16,17).

Aims of the study:

As mentioned above, it is essential to control welding fumes following the principles of occupational health engineering. Thus, the present study was designed to:

1. Assess welders' exposure to welding fumes before designing and installing the ventilation system

2. Design, construct, and install a local exhaust ventilation system
3. Measure the amount of welding fumes produced after designing and installing the ventilation system (hence, evaluating the effectiveness of the controlling measures).

Materials & Methods

Sampling procedure

This applied analytical study was conducted in the summer of 2016 and aimed at controlling welders' exposure to welding fumes. It focused on three groups of electric arc welders: Journeyman welders, welding technicians, and stellar welders, who worked in the repair shop of Sarcheshmeh Copper Complex. Figure 1 illustrates the place where welding operations were conducted in the mine's repair shop.

Figure 1) place where welding operations

Collecting samples of air

At first, we had to measure the amount of welders' exposure to welding fumes. In recent years, standard limits have been proposed in terms of workers' amount of exposure to each type of element in welding fumes. The best strategy to reduce exposure to fumes largely depends on every particular working condition. Important parameters in sampling are selecting target workers for individual evaluation, length of sampling time, number of samples required. The majority of measurements are accomplished for a particular length of time via personal monitoring systems, which include a pump with an appropriate flow rate connected to a holder membrane filter (18,19). The National Institute of Occupational Safety and Health sampling and analysis procedure (NIOSH-7300) was used to evaluate welders' exposure to welding fumes produced in the repair shop of the mine. Based on this procedure, individual sampling was carried out from workers' respiratory area by the use of a pump with a flow rate of 1 to 4 l/m and a ester cellulose membrane filter with a diameter of 37 mm and a power size of 0.8 micron (20).

When sampling was completed by the use of filters that collected welding fumes, these filters were transferred to the central library of Sarcheshmeh Copper Complex with utmost care. Then, the filters were prepared by the use of Acidic Ashing via Atomic Amission Spectrometer. Analyses were conducted by the use of the standard procedure (NIOSH-7300) (18,19).

Before each sampling, the sampling pump was calibrated by the use of Basic Input Output System (BIOS) calibrator. The results of data analysis revealed that iron, manganese, copper, and chromium could be found in the collected sample of welding fumes. Standard limits for the amount of copper, manganese, iron, and chromium are presented in Table 1 (21).

Table 1) Standard limits recommended for iron, copper, manganese, and chromium fumes

Material	TLV-TWA (mg/m^3)
Iron (fe)	5
Copper (cu)	0.2
Manganese (mn)	0.2
Chromium (cr)	0.05

Designing and installing a local exhaust ventilation system

Local exhaust ventilation systems are preferred to general ventilation systems (e.g. ceiling fans) because the formers collect pollution on the spot where it is produced, hence preventing its spread to the surrounding environment. Some ceiling fans have been installed in the repair shop of Sarcheshmeh Copper Complex. However, the shortcoming of using this system is that, in order to get out via the ceiling fans, welding fumes should pass through the air in which welders breathe. Inspired by the VS-90-

01 standard proposed by the American Conference of Governmental Industrial Hygienists (ACGIH), we designed a local exhaust ventilation system to control welding fumes in the place where they are produced (22). In this procedure, all losses (friction and dynamic loss) are regarded as a factor for the pressure system speed. Because of the specific features of the repair shop, we used elbows, inlets, and other connections, which can cause pressure loss. Their pressure loss was calculated in terms of pressure speed using a set of presented tables. All calculations were recorded in some particular sheets designed by ACGIH (23). Based on the number of welding stations that were simultaneously active, four flexible suction channels leading to a regulating chamber were designed and used. As a result, four welders could simultaneously work within a particular distance and angle from the central suction system (Fig 2).

Figure 2) The central local exhaust suction system

According to the type of welding process, the distance between the welding station, suction openings and simple openings, suction hood, and the data presented in VS-90-01 standard, the flow rate of each sucker branch was found to be 1200 m^3/hr. In order to have an air speed of 3000 fpm at the beginning of each sub-channel, their diameters were set at 15 cm. Upon conducting all calculations, a centrifugal ventilator machine (with a standard air flow rate of 4800 m^3/hr, static pressure of 780 pa, and an electromotor with a power of 3hp) was used to provide the necessary suction of pollutants (22).

Results

The results of sampling, measurement, and analysis for journeyman welders, welding technicians, and stellar welders before installing the local exhaust ventilation system are presented in Table 2. A comparison of obtained values and the standard exposure limits indicates that the welders were exposed to excessive amounts of manganese, copper, and iron. Their exposure to chromium, however, was not higher than the standard limit.

Table 2) The measurement results for journeyman welders', welding technicians', and stellar welders' exposure to various elements prior to installing the local exhaust ventilation system

Fume type / Job title	Cu (mg/m^3)	Cr (mg/m^3)	Fe (mg/m^3)	Mn (mg/m^3)
Welding technician	0.3	0.033	5.6	2.16
Journeyman welder	0.09	Tr	1.37	2.05
Journeyman welder	0.09	Tr	0.97	2.18
Stellar welder	0.26	0.066	4.6	1.16
Stellar welder	0.33	Tr	2.7	2.263
Journeyman welder	0.066	Tr	1.5	0.66
Stellar welder	0.4	0.033	3.9	0.53
Stellar welder	0.39	0.033	6.9	2.82
Welding technician	0.2	0.40	3.9	2.75
Welding technician	0.15	Tr	2.2	1.23

Table 3) The measurement results for journeyman welders', welding technicians', and stellar welders' exposure to various elements after installing the local exhaust ventilation system

Fume type / Job title	Cu (mg/m^3)	Cr (mg/m^3)	Fe (mg/m^3)	Mn (mg/m^3)
Welding technician	0.17	0.015	2.4	0.86
Journeyman welder	0.03	Tr	0.95	0.01
Journeyman welder	0.04	Tr	0.65	0.02
Stellar welder	0.18	Tr	2.5	0.86
Stellar welder	0.19	Tr	1.8	0.150
Journeyman welder	0.046	Tr	0.83	0.020
Stellar welder	0.25	Tr	2.1	0.28
Stellar welder	0.21	0.013	4.3	0.96
Welding technician	0.12	0.015	1.9	0.52
Welding technician	0.09	Tr	0.95	0.96

To evaluate the effectiveness of installing the local exhaust ventilation system in controlling weldres' exposure to fumes, necessary measurements were conducted after installation based on the ACGIH standard. The results of these measurements are illustrated in Table 3.

Figures 3 and 4 have been respectively taken before and after installing the local exhaust ventilation system. A comparison of these two pictures clearly illustrates the effectiveness of this system.

Figure 4) After designing and installing the local exhaust ventilation system

Discussion

This study set out to assess exposure to welding fumes among welders working in the repair shop of Sarcheshmeh Copper Complex and design a local exhaust ventilation system to control exposure to welding fumes. Prior to designing and installing the local exhaust ventilation system, welders' amount of exposure to the fumes of three metals (i.e. manganese, copper, and iron) was higher than the standard limit. Nonetheless, after designing and implementing the local exhaust ventilation system, the amount of exposure to the abovementioned fumes reduced to within standard limits. Based on the obtained findings, before installing the ventilation system, welding technicians were exposed to 0.3 mg/m^3 of copper fumes and 0.04 mg/m^3 of chromium fumes. Journeyman welders were also exposed to 2.16 mg/m^3 of manganese fumes, while stellar welders were exposed to 6.9 mg/m^3 of iron fumes. In the light of these measurements, a local exhaust ventilation system was designed and installed. Subsequently, measurement of exposure to welding fumes showed a significant reduction. That is, welding technicians were exposed to 0.17 mg/m^3 and 0.015 mg/m^3 of copper and chromium fumes respectively. Additionally, journeyman welders were exposed to 0.86 mg/m^3 of manganese fumes, whereas stellar welders were exposed to 4.3 mg/m^3 of iron fumes. A comparison of standard limits of exposure to welding fumes and the results obtained from measurements in sampling stations before and after the installation of the local exhaust ventilation system indicates that this controlling measure was very effective in the repair shop of Sarcheshmeh Copper Complex (17). More specifically, welders' exposure to different types of fumes did not exceed the standard limit after installing the local exhaust ventilation system. Ziadi et al. designed and constructed a local exhaust ventilation system to reduce welders' exposure to fumes. They concluded that local exhaust ventilation systems are able to decrease exposure to welding fumes by 88%, a finding which is very similar to the results of the current study (11). Susan et al. argued that local exhaust ventilation system is an effective and efficient controlling measure for reducing welding fumes (24). Meeker et al. aimed at reducing welders' exposure to chromium (VI) during welding operations. They designed a local exhaust ventilation system and concluded that it could reduce welders' exposure to chromium (VI) by 68%. This significant reduction further proves the high efficiency of local exhaust ventilation system. The finding of their study is also in line with the one obtained in the current research (25). Kapanen et al. focused on reducing welders' exposure to fumes by designing a local exhaust ventilation system while keeping the pressure inside welders' face shield constant. They concluded that local exhaust ventilation systems are highly efficient in controlling welding fumes and other types of dust (12). In another study, Meeker et al. focused on controlling exposure to manganese and other metal fumes in constructing buildings. They showed that using local exhaust ventilation system reduces exposure to welding fumes, a finding that resonates with the results of the current study (26). Hosseini et al. carried out a study to investigate the effect of using a portable local exhaust ventilation system in controlling surgical smoke and steam. They concluded that the portable local exhaust ventilation system can be one of the most effective procedures for controlling smoke and other harmful materials. Based on their findings, it can be claimed that using local exhaust ventilation systems is one of the main procedures to reduce workers' exposure to pollutants in the working environment (27).

Conclusion

Based on the findings of this study, welders' exposure to fumes significantly decreased after installing the local exhaust ventilation system. Therefore, exposure to various materials was within the standard limit as indicated by measurements after installation. A comparison of standard limits of exposure to welding fumes and the results obtained from measurements in sampling stations before and after the installation of the local exhaust ventilation system indicates that this controlling measure was very effective in the repair shop of Sarcheshmeh Copper Complex.

Footnotes

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Conflict of Interest:
The authors declared no conflict of interest.

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