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Gravimetric and Analytical Evaluation of Welding Fume in an Automobile Part Manufacturing Factory

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Abstract

Background: Welding is one of the most exercised industrial processes which welders are exposed to chemical and physical Hazardous agents. This study was conducted to evaluate occupational and environmental exposures to aerosols generated by welding processes in a factory.

Methods: A total of 28 samples of aerosols were collected at 4 different locations including indoor, outdoor, source of welding and the stacks using a high volume pump with a volumetric flow rate of 112 lit/min calibrated with a dry gas meter. The samples were collected on round 110 mm fiber glass filters, measured gravimetrically, extracted using nitric acid and analyzed with atomic absorption spectroscopy method for heavy metals including Fe, Mn, Ni, Cr^{3+}, Cr^{+6}, Co, and Zn.

Results: Gravimetric measuring has shown the mean values of indoor air: 1.33 mg/m^3, breathing zone of the welders using coated electrodes and CO2: 7.25 mg/m^3 and 6.45 mg/m^3 respectively and in ventilation exhausts: 95.07 mg/m^3. The mean values of Fe, Mn, and Ni were 0.8, 0.041, and 0.00 mg/m^3 in indoor air, 2.7, 0.18, and 0.15 mg/m^3 in breathing zone of welders used coated electrodes, and 1.75, 0.08, and 0.22 mg/m^3 in breathing zone of welders used CO_2 welding respectively. The concentrations of Cr^{3+}, Cr^{+6}, Co, and Zn were too low to be detected.

Conclusion: The welders were exposed to high concentration of metallic fumes, which raise the risk of pulmonary dysfunction and other health disorders. Using suitable respiratory masks and Appling the effective local ventilation system may improve the working condition.

Keywords: *Particulate maters, Heavy metal, Welder exposure, Aerosol*

Introduction

Welding is one of the most important and industrial expertise known to man and one cannot imagine all the industrial developments without it. Unfortunately welding practices involves a lot of chemical and physical dangers which threatens technicians' and experienced experts' health that is the most valuable resource of an industry. It is believed that welding fumes would eventually lead to cancer and other serious lung deceases such as occupational asthma but enough proof and experimental tests on animals which proving welding fumes alone being responsible for the symptoms above, are not available (1). Fumes, which are a mixture of metal oxide compounds, Silicates and fluorides, are produced when metals are heated to their boiling point temperature and this process is achieved continuously in welding. In other words, they are solid particles, which are generated following compression of metallic vapors in the air after vaporization or sublimation of melted matters. These particles are so small with a diameter of 0.2 to 0.3 micron that, they would be able to get to the ending parts of the respiratory organs thus causing a wide range of respiratory problems (2).

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Generally, welding fumes are oxides of welded material and used electrodes and in case of coated or painted materials, additional substances means more toxicity and in this case more protecting considerations should be taken into account concerning the technicians' and possibly exposed people. All kinds of welding processes produce fumes but the concentrations would vary for different processes. In different studies, main sources of fume in welding processes are the metal being welded, electrode, flux material, coatings, oils, greases, rust, solution paints, and the lining on the original metal respectively (3).

Pires have revealed in his studies that arc welding in CO_2 produces more fumes compared to that in Argon and generated fumes contain more iron, Manganese, silica, titanium and sodium oxide (4). The results of studies on full time welding technicians showed that they have suffered more from bronchitis, respiratory irritation, lung disorders, and cancer (5). Similar studies also have shown that generated fumes using arc welding in CO_2, contains more iron and manganese (6). Analysing of generated fumes from arc welding in an automotive industry indicated higher concentrations of zinc, iron, manganese and chromium as more notable compounds (7). Research on acute symptoms of welding fumes on lung, indicated a 6 day period of onset in mice and contrary to the past belief, solubility of fumes in water is not an effective parameter in its toxicity and the more important factor would be the ability to release free radicals in lung tissues (8).

Materials and Methods

Location of the study

The present study was carried out in a welding workplace of an automobile part manufacturing industry, producing a vehicle axles and located 10 kilometers away from west of the Tehran. This factory included 7 enclosed halls with an area of approximately 77000 m^2 and its welding department had 26 welding technicians and the same number of other workers. Welding operations on automobile axel shells have been done in two separate ways using coated electrodes and uncoated ones in CO_2. There were 14 operational stations with a cluttered layout which resulted in difficult movement of personnel and also intensified emission of pollutions in the workplace.

Sampling and measuring total particulate concentrations:

To determine total concentration of particulates, NIOSH 7200 gravimetric method based on taking samples using filters and weighting them was employed. Samples were taken using fiber glass filters with a diameter of 110 mm and high volume sampler pump with a flow rate of 112 lit/min (9). A laboratory balance made by Sartorius Company, Germany, with a resolution of 0.0001 grams was used for weighting the samples. Even though the filters were placed in a desiccator before and after sampling and before weighting for 24 h, but in order to control weighting related errors, for every three sampling filters, one was considered as a blank.

Totally 28 samples of four categories including welders' breathing zone, hall, exhaust shaft of the ventilation system and outside air were taken. The height of sampling in the hall and outside was 170 cm equivalent to people's standing breathing height. Sampling points in the hall have been chosen according to the number of workers and busyness and in the outside air, according to the wind blow at the upside and downside during the sampling period. Duration of the sampling was 20 min for each sample and sampling process were carried out during welding technicians' normal activity.

Sample analysis using atomic absorption

Measuring concentration of heavy elements is usually done using atomic absorption spectroscopy in most studies so the atomic absorption spectroscopy method based on ASTMD 4185 has been used in this study (10). According to similar researches, heavy metals like iron, zinc, cobalt, nickel, manganese, +3 and +6 valance chromium (Cr^{3+}, Cr^{6+}, Mn, Ni, Co, Zn, Fe) have the highest probability of being present in welding fume (4, 6, 7). In the mentioned method, first the samples are laid out in a suitable beaker and 2 ml of nitric acid is added and the beaker is placed in a hot water bath in order to dissolve and digest contained material. The filter is rinsed with acid and is separated. 2 ml of hydrogen peroxide is added to the resulted acidic solution and is heated for elucidation until a couple of drops remains. Eventually the sample will get up to volume in a 50 ml volumetric flask. Acquiring standard solutions in different concentrations containing mentioned elements, the amount of absorption compared to unknown samples using atomic absorption spectroscope is measured. Comparison of the amount of absorption of the samples compared to standard solution will result in concentrations of the elements (10).

Results

Fig. 1 shows the average concentration of total suspended solids in the hall and breathing zone of the welders through two processes of electric welding using coated electrodes in Manual Metal Arc (MMA) welding and uncoated electrodes with CO_2 in Metal Inert Gas (MIG) welding methods. As the mean of the data indicates, the concentration of particulate matter released at the source of welding using coated and uncoated electrodes in CO_2 was higher than the standard limits of TLVs proposed by American Conference of Governmental Industrial Hygienists (ACGIH) (11) and also that of Iranian Technical Committee of Occupational Health (ITCOH) (12). In contrast the indoor concentrations in the halls were lower than those limits.

Fig 2. Shows iron concentration in evaluated locations. It is noticeable that the Fe concentration at the indoor environment was low but at the sources of MIG and MMA has exceeded from the proposed standard limit of ACGIH, 1mg/m^3, and also and also that of ITCOH. The interesting trend was the higher concentration of both Fe fumes and particulate matters in electric welding using coated electrodes compared to that of CO^2 technique. It seems that using CO^2 in welding point not only improves the quality and durability of welding, but decreases the emission of pollutants. This is an appropriate reason for substitution of this method of welding instead of other electric arc welding techniques in industries. This improvement can be referred to the fact that using CO_2 welding, this gas will aggregate around the melted point and will hinder oxygen from reaching to the point which will result in oxidation of iron atoms. Basically carbon will be the product of the reaction which is resistant to the high temperatures experienced during the welding process and will remain intact. The only problem would be inhalation of CO_2 itself which will result in dilution of oxygen in breathing air, increasing red blood cells and hemoglobin or polycythemia in the workers and combating this issue requires local ventilation and creating a flow pattern from the worker to the welding point.

One of the heavy metals which can be found in welding electrode compounds and also in the metal pieces going through the welding process and possibly in their coatings is manganese. This metal is considered highly toxic, with an allowable concentration of 0.2 mg/m3 according to ACGIH. The measured manganese concentrations in the samples were lower than allowable limits in all three groups of samples including MIG, MMA and indoor halls. Off course the mean concentration for using coated electrodes was more than 2 times as big as that for welding processes of MIC in CO_2 which can be related to the electrodes being coated in this method which may lead to production of other (Fig. 3).

Fig. 4 shows the nickel concentrations in evaluated locations. As the graph is shown, the concentration of nickel in the hall, indoor air, has been undetectable. For the source of MIG and MMA welding methods it was detected

but of very low order. Analyzing of welding fumes taken from all locations have shown that there were no reasonable amount Cr^{+3}, Cr^{+6}, Zn, and Co.
The concentrations of environmental emissions of particulate matters through the stacks were also measured (Fig. 5). As the figure has shown, the particulate emissions for 2 stacks were lower and the third one was higher than 100 mg/m^3 that ped as emission standard for this kind of industrial activity by Iranian Department of Environment (IDE) (13). The significant emission rate of particulate matter from the stacks can affect the outside environment. In order to evaluate this effect, concentrations of particulate matter in the ambient air at upward and downward of the hall's stacks according to the direction of the wind blow have been measured (Fig. 6). Fortunately measured concentrations were lower compared to the exposure standard level of 150 µg/m^3 proposed by EPA (14) and also IDE. Comparing downward and upward concentrations indicates the effects of stacks' emissions from the welding hall in increasing outside particulate concentrations to a level of about 10%.

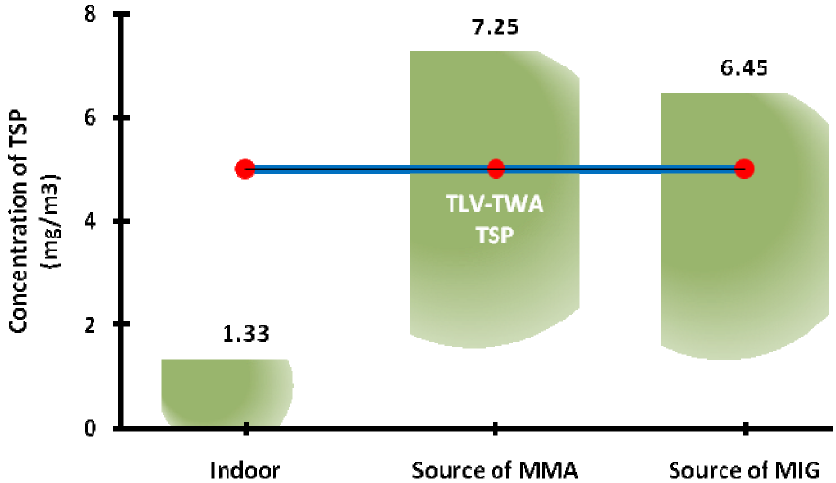

Fig. 1: The concentration of particulate matter in evaluated locations

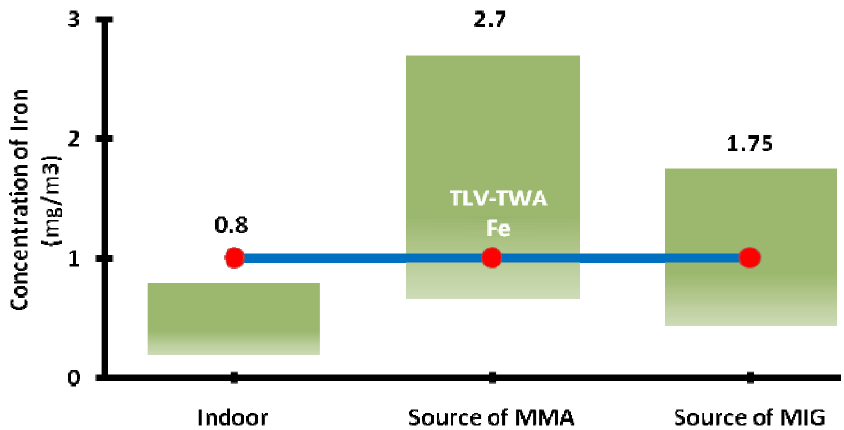

Fig. 2: The concentration of iron in evaluated locations

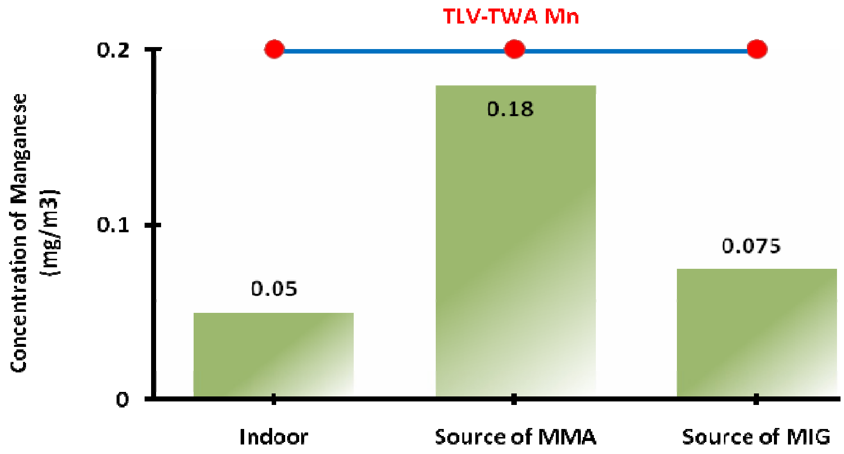

Fig. 3: The concentration of manganese in evaluated locations

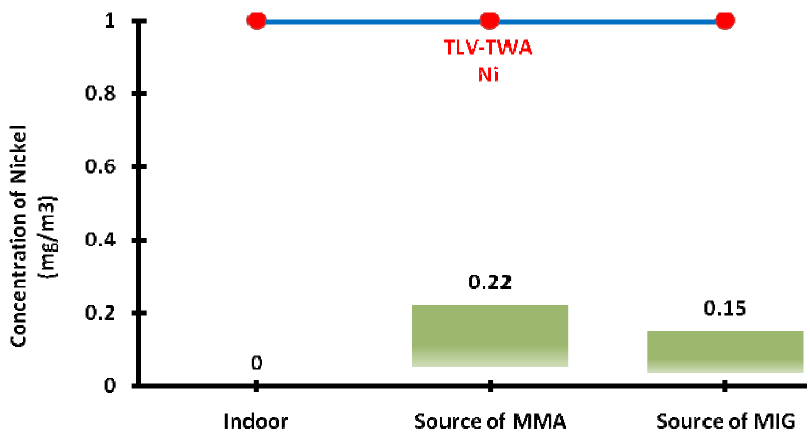

Fig. 4: Nickel concentrations in evaluated locations

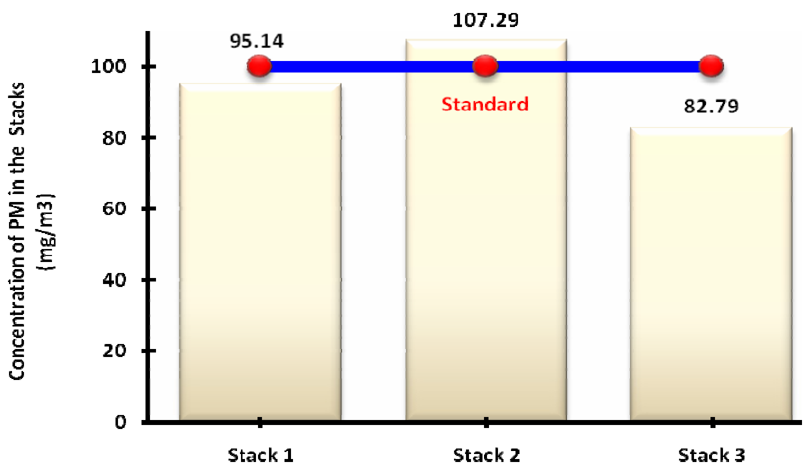

Fig. 5: Particulate concentrations measured at the stacks of the welding hall

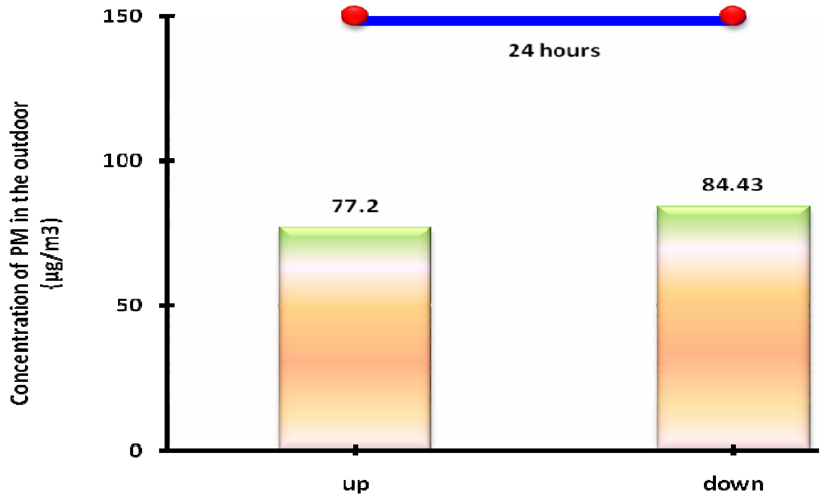

Fig. 6: Outside air particulate concentrations (µg/m^3)

Discussion

The results of this study have showed that the welding technique which used CO2 is safer than that use coated electrode. The second one produce more heavy metals oxides so can damage the welder to their toxic effects. Off course there is some new welding technique such as that is done in argon gas which is safer the CO2 technique too. Pires in his studies, in 2006, has revealed that the arc welding in argon gas produces less fumes compared to arc welding in CO_2 that generate fumes contain more iron, manganese, silica, titanium and sodium oxide (4). Also according to studies done by Korczynski in 2000, generated fumes using arc welding in CO_2, contains more iron and manganese comparing with welding in argon gas (6). Although the work related diseases history of welders weren't searched in this study but many of them have complained from their respiratory problems in conventional interview during the sampling period. This is well according with James M. Antonini and Hunnu et al. results in their researches which demonstrated the fact those full time welding technicians have suffered more from asthma, bronchitis, respiratory irritation, lung problems, and cancer (5, 15). The fig. 1 shows the higher particles emitted from sources of welding and this can endanger the welders to many disorders such as pneumonia and lung cancer. As research on acute symptoms of welding fumes on lung has indicated, the results of a 6 day period of exposure in mice to welding fumes showed that, contrary to the past belief, solubility of fumes in water is not an effective parameter in its toxicity and the more important factor would be the ability to release free radicals in lung tissues (8).

Generally, it can be stated that the concentrations of particulate matter at welders' breathing zone is hazardous. The majority of particulates in the factory consist of fumes generated during melting of metals which have diameters less than 0.5 micrometers and are able to penetrate to the most vulnerable ending parts of the respiratory system or the alveoli. the welders usually used the personal mouth dust mask, but because of high toxic heavy metal such as nickel, chromium and manganese in the welding fumes which have a risk of producing cancer, changing the welding technique to less emission ones may be noted. Also due to higher price of good quality dust masks in the market, the factories owners prefer to buy cheaper ones which don't have enough efficiency to prevent fine particle to inhale with welders, so controlling the emission of pollutants in order to prevent related symptoms in the workers would be necessary. Also the analysis of heavy metal fume concentrations including iron, manganese and nickel in the samples in the region of welders' breathing zone, indicated that electric welding using coated electrodes generate more pollutants compared to uncoated electrode welding in CO_2 So substituting of welding process with coated electrode with welding using inert gas such as argon or CO2 is recommended. Considering lower standard limits of present heavy metals in welding fumes reveal their high toxicity which makes development of safer welding procedures by industries and supervising bodies unavoidable. Even though workers were not exposed to high concentrations of pollutants, using qualified masks, periodic physical examination and implementation of an efficient local ventilation system is recommended. As the factory is located at the near distance from the west of Tehran that usually suffer from air pollution related to rising levels of particulate matter, the industries in this area have additional responsibilities to control their air emissions so considering the high content of pollutants in the ventilation exhaust system, designing a filtering device such as a wet scrubber in order to eliminate the particulate matter of exhaust air suggested.

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The authors declare that they have no conflict of interests.

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