Kor. J. Env. Hlth., Vol. 33, No. 6, pp 506~512(2007)

Assessment of Airborne Welding Fume Concentration for Some Manufacturing Industries in Busan

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(Received November 8, 2007/Accepted December 3, 2007)

Abstract: This study was conducted to describe the exposure levels of welding fumes by the type of manufacturers, work process, welding type and the size of manufacturers, and to find out the trend of chronological changes of airborne welding fume levels. The subjects of this study were 509 manufacturers, consisting of 11 types of manufacturers, 3 work processes, 7 welding types, in Busan from January, 1997 to December, 2005. Airborne concentration of welding fume was determined by manual of National Institute for Occupational Safety and Health (NIOSH), and the data were analyzed by using SPSS 10.0 for Windows program. The mean concentration of airborne welding fume in all manufacturers was 1.29 mg/m^3 (Range: 0.01~3.00 mg/m^3). The level of welding fume was the highest, as 1.96 mg/m^3, for manufactures of motor vehicles, trailers and semi- trailers, which was lower than 5.0 mg/m^3 of 8 hr-TWA in Korean permissible exposure limit for welding fume. There was a significant difference in the mean levels of welding fumes by work process, showing the highest in welding workshop (1.39 mg/m^3), followed by pipeline welding workshop (1.26 mg/m^3) and engineering workshop (1.20 mg/m^3). Among welding types, the mean level of welding fume was the highest in the type of CO_2 & arc welding, as 1.46 mg/m^3, followed by CO_2 welding (1.40 mg/m^3), shielded metal arc welding (1.31 mg/m^3), spot welding (1.27 mg/m^3), and so on. The highest mean level of welding fume was 1.58 mg/m^3 in work process of pipe line welding workshop for the manufacturers of basic iron and steel, and 2.27 mg/m^3 in the type of arc welding for the manufactures building ship and boats. By the size of manufacturers, the mean concentration of welding fume for manufactures in small scale with less than 50 workers was the highest as 1.45 mg/m^3 (Range: 0.07~3.00 mg/m^3). The mean level of welding fume was the highest as 1.39 mg/m^3 both in 1997 and in 2005, showing a trend of fluctuating periodically within a range of 1.10~1.39 mg/m^3. The above results suggested that more effective control program for work environment producing welding fumes should be developed and applied since there were significant variations in welding fume levels by the type of manufacturers, work processes, welding types, the size of manufactures, and by year.

Keywords: welding fume, manufacturers, welding type, work process, permissible exposure limit, chronological change

Introduction

Welding, the process of joining metals together, has long been an issue in the field of occupational safety and health due to its hazardous constituents produced during welding processes, including welding fumes with some metals such as iron oxides, gases such as ozone, nitrogen dioxide, carbon monoxide and phosgene, and hazardous ultraviolet radiation.[1,2)]

The exposure to welding fumes depends on many factors such as the composition and the type of welding rods, the composition and the paint of parent metals, work spaces, work loads, duration and the type of works, welding types, ventilation status, and so on.[3)]

It has been reported that welding fumes produce adverse health effects mainly including siderosis resulted from the deposit of irons, the major component of welding fumes, in pulmonary tissues, and also including metal fever, emphysema, chronic bronchitis, lung cancer, visual disorder, lead poisoning, metal poisoning including manganese poisoning, etc.[4-12)]

In Korea, the siderosis[13)] and cases of some job-related factors[14,15)] have been reported as health hazards due to welding fumes. There also have been several reports for exposure levels of welding fumes in workplace, including airborne levels of welding fumes in shipyards,[16-18)] airborne concen-

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trations of welding fumes and metals at confined workplace in shipyards,[2] and the levels of welding fumes and exposure status in some manufacturers.[1]

In addition, several more studies have been done, including airborne levels of welding fumes and metals by the type of welding process,[19] fume size distribution,[20] the change of metal contents in welding fumes,[21] the assessment of exposure levels to welding fumes and metals among welding workers,[22] and, however, there have not been many studies concerning chronological changes of welding fume levels in workplace, especially airborne levels of welding fumes by the type of industry, welding processes, welding types and so on.

Thus this study was conducted to describe the exposure levels of welding fumes by the type of manufacturers, welding processes, welding types and the size of manufacturers, and to find out the trend of chronological changes of airborne welding fume levels in welding-related workplace among some manufacturing industries in Busan, so that the results could be used to provide basic information for the control of work environments and for the prevention of occupational diseases for the welding workers.

Materials and Methods

Subjects of the Study

A total of 509 welding-related workplace was selected for the subjects of this study, including 11 types of manufacturer, 3 welding processes, and 8 welding types, among target manufacturers for the measurement of work environments in Busan according to Industrial Safety and Health Act[23] for a period of 9 years from January, 1997 to December, 2005. Samples were collected from target manufacturers and were analyzed to measure the concentrations of welding fume by the same measurement team specializing in the measurement of work environment in a university hospital. The data of total 1203 samples were used for data analysis, and the type of manufacturer was classified according to Korean Standard Classification of Occupations (KSCO).[24]

Sampling and Analysis

The concentration of welding fume in the air was measured according to National Institute of Occupational Safety and Health (NIOSH) manual.[25] After a PVC filter with a diameter of 37 mm and pore size of 5.0 μm was fixed into three piece cassette and connected to the personal air-sampling pump (Gilian, USA), air sample was collected at breathing zone of workers for 350 to 380 minutes. The flow rate of sample collection was 2.0 lpm, calibrated with Gilibrator (Gilian, USA) before and after measurement.

PVC filters were stored to dry for more than 24 hours in desiccator before collecting samples, and measured using Electronic Auto Balance (Sartorius, Germany) in the lab for the use collecting samples. Filters after collecting samples were also stored for more than 24 hours in desiccator for measurement. The amount of welding fume was determined by weight analysis measuring the difference of the filter weight before and after sampling calibrated with empty sample and then divided by the flow.

Data Analysis

Data were analyzed by using SPSSWIN Version 10.0 program. Since the data showed log-normal distribution, geometric means and standard deviations were used to describe the data. Analysis of variance (ANOVA) was used to test the significance of differences in mean airborne concentrations by the type of industry, work process, welding type, the number of workers and the year.

Results and Discussion

Occurrence of Welding Fumes by Type of Manufacturers

Table 1 shows the mean airborne concentrations of welding fume by the type of manufacturers, classified as 11 manufacturers including the manufacture of wood, cork, straw and plating materials, and so on. The mean concentration of welding fume was 1.29 mg/m^3 for a total of 1,203 samples from all manufacturers, and was the highest in manufacturers of motor vehicles, trailers and semi-trailers while the others ranged between 0.97 to 1.51 mg/m^3 on the average.

The airborne concentration of welding fume for all manufacturers ranged from 0.01 to 3.0 mg/m^3, lower than 5.0 mg/m^3 of 8 hour permissible exposure

Table 1. Mean airborne concentrations of welding fume by type of manufacturers (unit : mg/m^3)

Type of manufacturers	n	GM	GSD	Range
Wood, cork, straw and plating materials	4	0.97	1.07	0.81~1.16
Basic iron and steel	60	1.21	1.03	0.63~3.00
Casting of metals	21	1.23	1.09	0.61~2.56
Structural metal products, tanks, reservoirs and steam generators	170	1.28	1.03	0.07~2.45
Other fabricated metal products, and metal working service activities	26	1.27	1.06	0.67~1.69
General purpose machinery	213	1.35	1.02	0.06~2.86
Other special purpose machinery	104	1.29	1.06	0.01~2.41
Electricity distribution and control apparatus	66	1.20	1.05	0.11~1.87
Electric lamps and lighting equipment	12	0.97	1.34	0.04~1.66
Motor vehicles, trailers and semi-trailers	127	1.96	1.03	0.17~2.76
Building ships and boats	400	1.51	1.02	0.02~2.86
Total	1203	1.29	1.09	0.01~3.00

n: Number of samples, GM: Geometric mean, GSD: Geometric standard deviation

limit[26] for welding fume. These levels were lower than the levels reported by Shin *et al.*,[3] including 3.0 mg/m^3 for manufacturers assembling motor vehicles, 7.8 mg/m^3 for manufacturers of motor vehicle accessories and 13.2 mg/m^3 for shipbuilding yard, the level of 5.2 mg/m^3 for shipbuilding manufacturers reported by Kwak *et al.*,[2] and the level of 4.11 mg/m^3 reported by Kang *et al.*[18] also for shipbuilding yard. These differences were probably due to the differences in the type of manufacturers, work process, and sampling time.

However, they were similar to the levels of 2.99 mg/m^3, reported by Choi *et al.*[22] and 2.49 mg/m^3 in case of operating ventilation apparatus, reported by Lee *et al.*[19]

Generally it is recommended to apply control measures to reduce the direct exposure to welding fumes, such as using portable fans, adjusting work positions, etc., and, however, these applications might be of limited use practically due to work efficiency and difficulties in adjusting work positions.

Occurrence of Welding Fumes by Work Process

Mean airborne levels of welding fumes are shown in Table 2 by work process of welding. Welding work process was classified to 3 types of workshop, including engineering workshop conducting irregular welding and repair works, welding workshop conducting main welding works, and pipe line welding workshop cutting and welding of pipes.

The highest level was observed in welding shop (1.39 mg/m^3), followed by pipeline welding shop (1.26 mg/m^3) and engineering work shop (1.20 mg/m^3) on the average. There was a significant difference in the mean level of welding fumes among work process (P=0.02), suggesting that different control measures should be applied to each welding process.

Occurrence of Welding Fumes by Welding Type

Table 3 shows the occurrence of welding fume by welding type on the average. Among 7 types of welding, the mean level of welding fume was the highest in the type of CO_2 & arc welding (1.46 mg/m^3), followed by CO_2 welding (1.40 mg/m^3), shielded metal arc welding (1.31 mg/m^3), spot welding (1.27 mg/m^3), O^2 and arc welding (1.25 mg/m^3) and TIG welding (1.14 mg/m^3). Airborne

Table 2. Mean airborne concentrations of welding fume by work process (unit : mg/m^3)

Work process	n	GM	GSD	Range	P-value
Engineering workshop	64	1.20	1.04	0.27~3.00	0.02
Welding workshop	959	1.39	1.01	0.01~2.86	
Pipe line welding workshop	180	1.26	1.02	0.04~1.96	

n: Number of samples, GM: Geometric mean, GSD: Geometric standard deviation.

Table 3. Mean airborne concentrations of welding fume by welding type (unit : mg/m³)

Welding type	n	GM	GSD	Range	P-value
O_2	87	1.25	1.05	0.02~2.07	0.007
Arc	107	1.25	1.02	0.60~2.49	
Shielded metal arc	72	1.31	1.06	0.06~2.86	
CO_2 & arc	34	1.46	1.04	0.90~2.13	
CO_2	861	1.40	1.01	0.01~3.00	
Spot	18	1.27	1.07	0.72~1.77	
TIG	24	1.14	1.10	0.33~1.77	

n: number of samples, GM: geometric mean, GSD: geometric standard deviation, TIG: Tungsten inert gas welding.

Table 4. Mean airborne concentrations of welding fume by work process and welding type for each type of manufacturers (unit : mg/m³)

Industry	Work process					Welding type				
	Process	n	GM	GSD	P-value	Type	n	GM	GSD	P-value
BIS	Engineering work	44	1.26	1.04	0.04	Arc	29	1.19	1.04	0.21
	Welding	15	1.05	1.06		Shielded metal arc	7	1.05	1.05	
	Pipe line welding	1	1.58	-		CO_2	24	1.29	1.07	
COM	Welding	21	1.23	1.50	-	Shielded metal arc	3	1.55	1.02	0.29
						CO_2	18	1.18	1.10	
SMP	Welding	23	1.16	1.06	0.73	Arc	14	1.24	1.07	0.29
	Pipe line welding	3	1.24	1.03		CO_2	12	1.10	1.10	
GPM	Engineering work	3	1.37	1.10	0.88	O_2	1	1.07	-	0.45
	Welding	161	1.25	1.03		Argon	10	1.20	1.09	
	Pipe line welding	49	1.24	1.02		Arc	1	1.00	-	
VSP		213	1.25	1.02		Shielded metal arc	27	1.40	1.05	0.40
						CO_2 & arc	170	1.26	1.02	
						CO_2	4	0.47	1.26	
SPM	Engineering work	2	1.09	1.16	0.98	Arc	28	1.11	1.03	0.91
	Welding	87	1.19	1.07		Shielded metal arc	9	1.15	1.03	
	Pipe line welding	15	1.18	1.03		CO_2	56	1.19	1.11	
						TIG	10	1.36	1.08	
EDCA	Welding	45	1.00	1.06	0.02	Arc	45	1.00	1.06	0.02
	Pipe line welding	21	1.28	1.04		CO_2	21	1.28	1.04	
MVT	Engineering work	2	1.00	1.20	0.40	O_2	16	0.92	1.12	0.01
	Welding	99	1.29	1.03		CO_2	73	1.37	1.02	
	Pipe line welding	6	1.16	1.02		Spot	18	1.27	1.07	
BSB	Welding	355	1.40	1.02	0.004	O_2	71	1.27	1.06	0.014
	Pipe line welding	45	1.17	1.04		Arc	4	2.27	1.04	
						Shielded metal arc	16	1.48	1.06	
						CO_2 & arc	7	1.23	1.05	
						CO_2	292	1.40	1.02	
						TIG	10	1.08	1.09	

VSP: Manufacture of wood, cork, straw and plaiting materials, BIS: Manufacture of basic iron and steel, COM: Casting of metals, SMP: Manufacture of structural metal products, tanks, reservoirs and steam generators, MWS: Manufacture of other fabricated metal products' metal working service activities, GPM: Manufacture of general purpose machinery, SPM: Manufacture of other special purpose machinery, EDCA: Manufacture of electricity distribution and control apparatus, ELE: Manufacture of electric lamps and lighting equipment, MVT: Manufacture of motor vehicles, trailers and semi-trailers, BSB: Building of ships and boats, n: Number of samples, GM: Geometric mean, GSD: Geometric standard deviation.

welding fume concentration ranged from 0.01 to 3.00 mg/m^3 in the type of CO_2 welding, showing the biggest difference as compared to other welding types. This level seemed to be a little lower or similar to the result reported by Choi *et al.*,[21] including CO_2 welding 3.84 mg/m^3, shielded metal arc welding 2.09 mg/m^3, submerged arc welding 1.36 mg/m^3, spot welding 0.15 mg/m^3, TIG welding 2.23 mg/m^3.

Occurrence of Welding Fumes by Work Process and Welding Type for Each Type of Manufacturer

Table 4 shows mean levels of airborne welding fumes by work process including engineering workshop, welding workshop and pipe line welding workshop, and by welding type such as O_2, argon, arc, shielded metal arc, CO_2 & arc, CO_2, Spot, TIG (tungsten inert gas welding) for each type of manufacturer.

The highest mean level of welding fume was 1.58 mg/m^3 observed in pipe line welding workshop for the manufacturers of basic iron and steel, followed by 1.40 mg/m^3 in welding workshop for the manufacturers building ship and boats.

There were significant differences in mean levels of welding fumes among work process for the manufacturers of basic iron and steel (P=0.04), electricity distribution and control apparatus (P=0.02), and building ships and boats (P=0.004).

The mean concentration of welding fume by welding type was the highest, as 2.27 mg/m^3, in arc welding for the manufactures building ship and boats, followed by 1.55 mg/m^3 in shielded metal arc welding for the manufacturers of casting metals. Significant differences were shown in the mean levels of welding fumes by the welding type for manufacturers of electricity distribution and control (P=0.02), motor vehicles, trailers and semi-trailers (P=0.01,) and building ships and boats (P=0.014).

Occurrence of Welding Fumes by the Size of Manufacturers

Fig. 1 depicts mean levels of airborne welding fumes according to the number of workers working at every manufacturer. The mean concentration of fume was significantly different among manufacturers

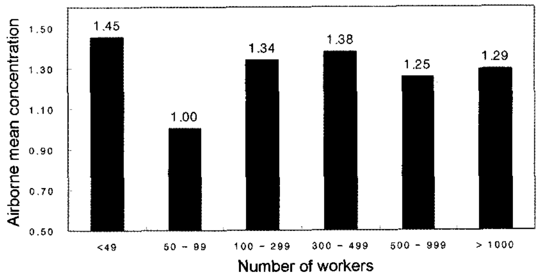

Fig. 1. Mean airborne concentrations of welding fume by number of workers in manufacturers (unit: mg/m^3).

by the number of workers (P=0.001), and was the highest, as 1.45 mg/m^3, at the group of small-sized manufacturers with less than 50 workers, followed by the manufactures with 300 to 499 workers (1.38 mg/m^3) and the manufactures with 100 to 299 workers (1.34 mg/m^3). However, the lowest mean level, 1.00 mg/m^3, was observed at the group of manufacturers with 50 to 99 workers.

Therefore it is suggested that it should be dealt with an important issue to provide efficient control measures for work places in small scale since it is difficult to establish and operate ventilating installation for work environments in manufacturers of small scale.

Occurrence of Welding Fumes by Year

Mean airborne concentrations of welding fumes are shown by year for a period of 9 years from 1997 to 2005 in Fig. 2. The mean level of welding fume was the highest as 1.39 mg/m^3 in 1997, showing a trend of decreasing gradually to 1.10 mg/m^3 by 2002. However, the level increased to 1.39 mg/m^3 in 2003 and started to decrease a little

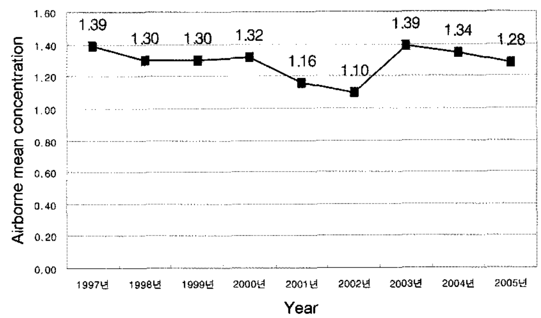

Fig. 2. Chronological change of mean airborne concentration of welding fume by year (unit: mg/m^3).

during the last three years, up to 1.28 mg/m^3 in 2005. There was a trend in mean levels of welding fumes, decreasing after increasing periodically every three years within the range of 1.10~1.39 mg/m^3, This change is probably due to differences in sample size and in the type of manufacturers included each year.

Consequently it seems that work environments related to welding fume have been improving continuously, and, however, it is not certain that exposure levels of workers to welding fumes have been decreasing with the improvement in work environments. It is suggested that work environments still should be controlled more efficiently.

Conclusion

This study was conducted to describe the exposure levels of welding fumes by the type of manufacturers, work process, welding types, the size of manufacturers and by the year for the 509 manufacturers in Busan, and the following conclusions were obtained.

Mean concentration of airborne welding fume in all manufacturers was 1.29 mg/m^3 (Range: 0.01~3.00 mg/m^3). The level of welding fume was the highest, as 1.96 mg/m^3, for the manufactures of motor vehicles, trailers and semi-trailers. There was a significant difference in the mean levels of welding fumes by work process, showing the highest in welding workshop (1.39 mg/m^3), followed by pipeline welding workshop (1.26 mg/m^3) and engineering workshop (1.20 mg/m^3). Among various welding types, the mean level of welding fume was the highest in the type of CO_2 & arc welding, as 1.46 mg/m^3, followed by CO_2 welding (1.40 mg/m^3), shielded metal arc welding (1.31 mg/m^3), spot welding (1.27 mg/m^3), and so on. The highest mean level of welding fume was 1.58 mg/m^3 in work process of pipe line welding workshop for the manufacturers of basic iron and steel, and 2.27 mg/m^3 in the type of arc welding for the manufactures building ship and boats.

By the size of manufacturers, the mean concentration of welding fume was the highest, as 1.45 mg/m^3 (Range: 0.07~3.00 mg/m^3), for the manufactures of small scale with less than 50 workers. The mean level of welding fume was the highest as 1.39 mg/m^3 both in 1997 and in 2005, showing a trend of fluctuating periodically within a range of 1.10~1.39 mg/m^3.

In conclusion, airborne levels of welding fumes occurring during welding process varied significantly by the type of manufacturers, work process and welding type, and, especially, manufacturers in small scale revealed the highest level of welding fumes. Moreover there was a trend of periodical fluctuation in mean airborne levels of welding fumes without showing any consistent decreasing or increasing trends, suggesting that more effective work environment control program should be developed.

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