

## Exposure of arc-furnace-plant workers to polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)

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### Introduction

In occupational studies, at present, except for the great occupational concern had been focused on the PCDD/F exposure of workers in municipal waste incinerator (Bakoglu et al., 2004; Hours et al., 2003; Hu et al., 2003), serious PCDD/F exposure was also found in the industrial emissions, for example, secondary copper-melting plants, electric arc furnaces for the steel industry (Anderson and Fisher, 2002), and secondary aluminum smelters (Chen et al., 2004). This study therefore aimed to evaluate the distribution of serum PCDD/F levels in electric arc furnace workers according to their corresponding occupational exposure. In addition, ambient air measurements of PCDD/F concentrations outside the work environment were made to provide additional support for the exposure and accumulation inside the electric arc furnace work space. The outcomes of these investigations should make recommendations possible for proactive occupational preventive programs in the various departments of electric arc furnaces.

### Materials and Methods

Forty-five workers were recruited from different departments of an electrical arc furnace plant in Taiwan. We assigned them by job title to one of three groups: high-exposure (workers in department of electric arc furnace and casting or they worked more than 10 years in other areas), and low-exposure (workers in departments of operated electric machinery, machinery, crane, arrangement, quality control, and administration for less than 10 years). PCDD/Fs levels of ambient samples in the work environment and serum from workers were analyzed in this study. Information obtained from the questionnaire included personal characteristics, life style, occupational history.

### Results and discussion

In an electric arc furnace, most material is recycled metal waste, and it probably contains oils, plastics, or other organic pollutants. The abundant PCDDs and PCDFs might be absorbed with the particles during the high-temperature smelting process. Workers in the high-exposure groups had a significantly higher mean age and lipid content than those in low-exposure groups. Table 1 showed the concentration difference (pg WHO-TEQ/g lipid) of specific PCDD/Fs congener among low to high PCDD/Fs exposure groups. Significant higher levels of 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, and 2,3,4,6,7,8-HxCDF were found in high exposure groups than those of the low one ( $p < 0.05$ ), as well as for 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, and total PCDD/Fs levels. Workers in the high-exposure group had worked significantly ( $P < 0.05$ ) longer than those in the low-exposure group (Table 2). Higher serum PCDD/F levels were found in electric-arc-furnace workers in the high-exposure than in the low-exposure group, despite their having worn dust masks during the working period. In the preliminary walk survey, the high-exposure group was categorized according to their chances for exposure to PCDD/Fs in the working areas, such as when the cover of the furnace opened to accept steel-making materials. PCDD/F concentrations obtained from this study for high-exposure workers are comparable to those by Kumagai et al. (2003) in incineration plants, but lower than those reported by Fierens et al. (2003) for both rural and urban subjects residing near incinerators. Serum PCDD/F levels in electric-arc-furnace workers were higher than those in residents living within 5 km of municipal waste incinerators in Taiwan (Chen et al., 2004b). We also found higher levels of specific PCDFs than PCDDs in both particle- and gas-phase ambient samplings, except for 2,3,7,8-TCDD. Ambient PCDD/F concentrations inside the electric arc furnace were 5-24-fold higher than those obtained from outside (Table 3). In addition, workers in jobs with high exposure to dioxins accumulate higher average PCDD/F levels than workers in jobs with lower exposure to dioxins. We hypothesize that elevated ambient PCDD/F levels around electric arc furnaces accounted for dioxins breathed in workers, and we recommend that occupational hygiene be taken more seriously concerned inside electric arc furnace plants.

### Acknowledgements

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### References

1. Bakoglu M., Karademir A., and Ayberk S. (2004) J Occup Health 46: 156-164.
2. Hours M., Anzivino-Viricel L., Maitre A., and Chan CC et al. (2003). Int Arch Occup Envir Health 76, 467-472.
3. Hu SW, Cheng TJ, Chang-Chien GP, and Chan CC (2003). J Occup Envir Med 45, 601-608.
4. Anderson DR., and Fisher R. (2002) Chemosphere 46: 371-381.
5. Chen, C.M. (2004) Chemosphere 54: 1413-1420.
6. Fierens S., Mairesse H., Hermans C., and De Pauw E. (2003) J Envir Health Part A 66: 1287-1293.
7. Kumagai S., Koda S., and Oda H. (2003). Industrial Health 41: 167-174.
8. Chen S.J., Lee W.S., and Hu M.T. 2004b. Atmospheric Environment 38, 3729-3732.

Table 1 Difference of PCDD/Fs levels for each congeners of 45 workers of arc furnace plants among high to low exposure to PCDD/Fs (Wilcoxon Rank-Sums test)

	Exposure Categories		P-value
	High (n=10) <sup>1</sup>	Low (n=18) <sup>2</sup>	
2,3,7,8-TCDF	0.161 (0.06) †	0.139 (0.04)	0.256
1,2,3,7,8-PeCDF	0.079( 0.04)	0.054 (0.02)	0.051+
2,3,4,7,8-PeCDF	10.2 (5.59)	4.84 (2.32)	0.001*
1,2,3,4,7,8-HxCDF	0.730 (0.30)	0.432 (0.13)	0.001*
1,2,3,6,7,8-HxCDF	0.817 (0.31)	0.473 (0.16)	0.001*
2,3,4,6,7,8-HxCDF	0.228 (0.09)	0.148 (0.05)	0.002*
1,2,3,7,8,9-HxCDF	0.262 (1.06)	0.028 (0.02)	0.097
1,2,3,4,6,7,8-HpCDF	0.233 (0.141)	0.183 (0.131)	0.055
1,2,3,4,7,8,9-HpCDF	0.006 (0.003)	0.004 (0.003)	0.180
OCDF	0.000 (0.00)	0.000 (0.00)	0.588
2,3,7,8-TCDD	2.81 (0.85)	2.00 (0.54)	< 0.001*
1,2,3,7,8-PeCDD	5.67 (2.39)	3.64 (1.62)	< 0.001*
1,2,3,4,7,8-HxCDD	0.324 (0.15)	0.187 (0.07)	< 0.001*
1,2,3,6,7,8-HxCDD	1.78 (0.68)	1.23 (0.67)	0.007*
1,2,3,7,8,9-HxCDD	0.359 (0.13 )	0.247 (0.13)	0.002*
1,2,3,4,6,7,8-HpCDD	0.255 (0.12)	0.196 (0.11)	0.089
OCDD	0.038 (0.02)	0.028 (0.02)	0.064
Total PCDFs	0.36 (0.13 )	0.25 (0.13)	0.002*
Total PCDDs	2.47 (0.89)	1.67 (0.83)	0.003*
Total PCDD/Fs	24.0 (9.45)	13.8 (5.14)	0.001*

<sup>1</sup> workers in department of electric arc furnace and casting or they worked more than 10 years in other areas

<sup>2</sup> workers in departments of operated electric machinery, machinery, crane, arrangement, quality control, and administration for less than 10 years

§: mean (standard deviation), \*: p value <0.05

Table 2 Differences in working histories of 45 workers in the electric-arc-furnace plant

Variables	Exposure Categories		P-value
	High (n=22) <sup>1</sup>	Low (n=23) <sup>2</sup>	
Work years of this job §	12.6 (4.8)	7.6 (5.3)	0.006*
Total work years in arc furnace plants §	13.8 (5.5)	8.2 (6.1)	0.009*
Occupational exposure history			
Exposure time (hrs/day)	5.4	5.2	0.739
Protect equipment			
Used (%)	95.5	100.0	0.489
Using time (hrs/day)	5.3	5.6	0.822
Types of respiratory			

protective equipments

Gas mask (%)	18.2	13.0	0.699
Active carbon mask (%)	36.4	65.2	0.076
Cotton mask (%)	72.7	60.9	0.530

<sup>1</sup> Workers in the Electric Arc Furnace Department and Casting Department, and workers who had spent more than 10 years in other areas of the plant. <sup>2</sup> Workers in the Operated Electric Machinery, Machinery, Crane, Arrangement, Quality Control, and Administration departments for less than 10 years. § Mean (standard deviation); \* Wilcoxon rank-sum test.

Table 3 Comparison of ambient PCDD/F levels collected from indoors in the Electric Arc Furnace and Casting departments of the electric-arc-furnace plant and the nearby outdoors

Locations	PCDD/Fs TEQ levels	
	pg/Nm <sup>3</sup>	pg I-TEQ/Nm <sup>3</sup>
Inside		
electric arc furnace	30.153	1.557
casting furnace	20.100	1.917
Outside		
Area 1 n=4	1.28-3.26	0.102-0.118
Area 2 n=4	0.88-2.64	0.084-0.104
Area 3 n=4	1.35-3.54	0.080-0.343
Area 4 n=4	1.9-3.96	0.187-0.385
Average	2.24	0.167

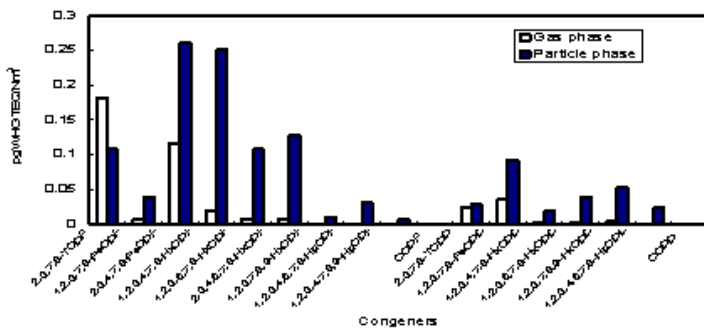


Figure 1 Distribution of ambient PCDD/F levels in gas and particle phase inside the Arc Furnace Department

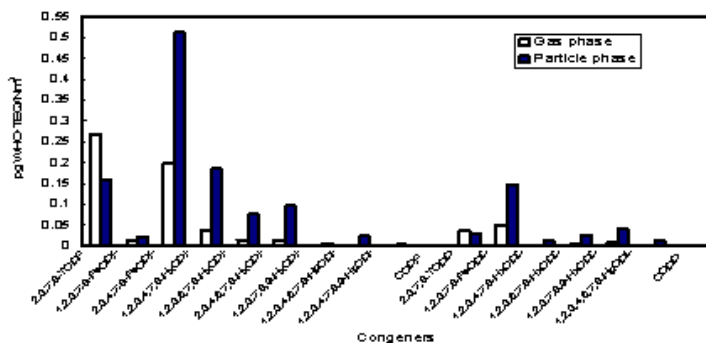


Figure 2 Distribution of ambient PCDD/F levels in gas and particle phase inside the Casting Furnace Department