Field Report

Survey on the Health Effects of Chronic Exposure to Dioxins and Its Accumulation on Workers of a Municipal Solid Waste Incinerator, Rural Part of Osaka Prefecture, and the Results of Extended Survey Afterwards

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Abstract: In September 1998 the Ministry of Health and Welfare announced that high concentrations of dioxins were detected in the samples of soil near the incinerator and ash, drainage, sludge and others remained in the furnace and air pollution control devices of municipal solid waste incinerator (MSWI) in rural part of Osaka Prefecture. According to the results the Ministry of Labor immediately organized the “*Research and investigation committee on the dioxin problem of Toyono-gun Clean Center*” under Japan Industrial Safety and Health Association to investigate the health effects of chronic exposure to dioxins and its accumulation on workers of the incinerator plant. The investigation was carried out in Sept 1998 and from the results, the committee concluded that the concentrations of dioxin among the blood of the workers who had engaged in maintenance of the furnace, the electric dust collector, and the wet scrubber of the incinerator were higher compared with those of residents in surrounding areas. However, there were no signs or findings correlating to blood level of dioxins, and the level was not high enough to induce sufficient health effects from the review of published papers. According to the results of this survey the committee understood that the follow-up study of blood dioxins level of group III and IV workers was inevitable and concerned about the other MSWI workers in Japan who might also be exposed to similar level of dioxins. The Ministry of Labor decided to expand the survey to other MSWI workers in Japan as 3-year project from 1999. The summarized report on the project is appended in this paper.

Key words: Municipal solid waste incinerator, Dioxin, PCDD, PCDF, Blood dioxin

Introduction

In January 1997 flue gas was sampled from the stack of an incinerator in western Japan and dioxin content was analyzed. The measurement was 180 ng/Nm³, which highly exceeded the guideline (5 ng/Nm³) announced by the Ministry of Health and Welfare in January 1997. In same May second sampling was carried out and got 150 ng/Nm³¹⁾, which again exceeded

the guideline. Concerning environmental contamination, soil around the plant was sampled and found that there was high dioxin contamination among several samples. The Ministry of Health and Welfare organized a committee to clarify the cause and mechanism of dioxin pollution around the plant. The survey carried out by the committee revealed that dioxin concentrations of soil sampled near the fence around the incinerator plant were 0.39–8.8 ngTEQ/g, soil near the cooling

Fig. 1. Schematic diagram of the incinerator.

tank was 52,000 ngTEQ/g, drainage and sludge remained in the floor of wet scrubber were 3,000,000 ngTEQ/l and 96,000 ngTEQ/g respectively, inflammable residue in the furnace was 6.1 ngTEQ/g, fly ash from electric dust collector was 320 ngTEQ/g, and adhered sludge in fly ash solidifying machine was 1,500 ngTEQ/g²⁾. The results suggested that fly ash was contaminated by high concentration of dioxins and further concentrated in the wet scrubber. According to the results the Ministry of Labour immediately organized the *Research and investigation committee on the dioxin problem of Toyono-gun Clean Center* (chief: present author) under Japan Industrial Safety and Health Association to investigate the health effects of chronic exposure to dioxins and its accumulation on workers of the incinerator plant.

Summary of the Survey

Subjects

Subjects were the workers of a municipal solid waste incinerator (MWI) in western Japan (Fig. 1), which was mentioned above. Ninety-six workers, 92 males and 4 females, age ranged from 16 to 72, agreed to join the survey with the written informed consent.

Methods

Survey was carried out in September 1998. Questionnaire on life style was handed to subjects in advance and collected at the day of examination. After getting doctors interview subjects who have no contraindication for examination were

Table 1. Measurements carried out on subjects of the investigation

Blood tests
Red blood cell count, leukocytes count, hemoglobin, hematocrit, platelet count
Blood chemistry tests
Total protein, albumin, total bilirubin, AST, ALT, lactic dehydrogenase, alkaline phosphatase, γ -GTP, leucine aminopeptidase, creatine kinase, amylase, total cholesterol, HDL cholesterol, neutral fat, serum iron, urea nitrogen, creatinine, uric acid, and blood sugar.
Immunological function tests
Lymphocyte blastogenesis test by PHA and Con A, Natural killer cell activity, and lymphocyte subset analysis using monoclonal antigen (CD3, CD4, CD8, CD4/CD8 ratio, and CD56).
Dioxins
PCDD: 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, 1,2,3,4,6,7,8-HpCDD, OCDD
PCDF: 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,7,8,9-HpCDD, OCDF

preceded to health survey. About 200 ml of blood was drawn from ante-cubital vein of each subject. Blood, blood chemistry, and immunological function tests and concentrations of dioxins were measured (Table 1). The method of measuring dioxins is reported elsewhere³⁾. Then physical examination by a dermatologist and interview on occupational history by occupational health doctors were carried out.

Table 2. Blood dioxin level by each congener

	I-TEF	Mean	SD	Min	Max
2,3,7,8-TCDD pg/g-fat	1	4.5	2.6	0.5	13.4
1,2,3,7,8-PeCDD pg/g-fat	0.5	14.7	15.7	3.7	104.0
1,2,3,4,7,8-HxCDD pg/g-fat	0.1	14.9	26.4	1.3	157.0
1,2,3,6,7,8-HxCDD pg/g-fat	0.1	74.7	75.0	10.1	522.2
1,2,3,7,8,9-HxCDD pg/g-fat	0.1	19.3	33.7	1.6	252.0
1,2,3,4,6,7,8-HpCDD pg/g-fat	0.01	65.9	86.8	11.4	598.0
OCDD pg/g-fat	0.001	438.3	426.4	94.6	2100.0
2,3,7,8-TCDF pg/g-fat	0.1	3.4	10.8	0.5	104.0
1,2,3,7,8-PeCDF pg/g-fat	0.05	4.8	6.6	0.5	42.1
2,3,4,7,8-PeCDF pg/g-fat	0.5	66.6	101.9	10.8	644.0
1,2,3,4,7,8-HxCDF pg/g-fat	0.1	57.7	113.1	4.6	651.0
1,2,3,6,7,8-HxCDF pg/g-fat	0.1	97.5	203.4	4.1	1320.0
1,2,3,7,8,9-HxCDF pg/g-fat	0.1	5.2	11.8	0.5	68.9
2,3,4,6,7,8-HxCDF pg/g-fat	0.1	96.5	206.5	3.6	1340.0
1,2,3,4,6,7,8-HpCDF pg/g-fat	0.01	214.2	504.5	3.0	3040.0
1,2,3,4,7,8,9-HpCDF pg/g-fat	0.01	103.9	875.4	0.5	8404.0
OCDF pg/g-fat	0.001	12.2	21.0	5.0	117.0
Total dioxins pgI-TEQ/g-fat		84.8	130.2	13.4	805.8

Results and discussions

Among 96 workers 92 subjects including 89 males and 3 females, age ranged from 16 to 72, were able to collect blood sample.

Classification of subjects: Workers were grouped to the following categories. I; workers who did not work inside the incineration facility or handles ash produced from the incinerator (n=56, including 3 females, average age 45.7, average working duration in month 51.3). II; workers who had worked at the periphery of the facility and handled the non-flammable residues or solidified ash (n=8, average age 44.1, average working duration in month 38.0). III; workers who had worked inside the facility (n=13, average age 56.8, average working duration in month 37.8). IV; workers who had engaged in maintenance of the furnace, the electric dust collector, and the wet scrubber (n=15, average age 53.0, average working duration in month 57.1).

Diagnosis by dermatologists: Eight subjects were diagnosed as having acne vulgaris but not chloracne, judging from their density and distribution.

Level of blood dioxins: Total level of blood dioxins (blood dioxins level) was calculated using NATO TEFs (I-TEQ)⁴⁾, which consists of 7 PCDD and 10 PCDF. Blood dioxins level of subjects ranged from 13.4 to 805.8 pgI-TEQ/g-fat and their mean was 84.8 pgI-TEQ/g-fat (Table 2). Blood dioxins level of 253 persons from several parts of Japan measured by the Environment Agency 1998⁵⁾ ranged from 0.9 to 33 pgTEQ/g-fat (mean 19 pgTEQ/g-fat) adding 7 PCDD and 10 PCDF

Fig. 2. Total level of blood dioxins (pgI-TEQ/g-fat) of workers classified by four groups depending on their job history were plotted by employment period in month.

using WHO TEF (TEQ)⁶⁾. Blood dioxins levels of our subjects were higher than those of regular residents.

Relation between work duration and blood dioxins level: Mean blood dioxins levels of groups I, II, III, and IV were 34.2, 66.8, 93.3, and 323.3 pgI-TEQ/g-fat, respectively (Fig. 2). The measurement of group IV was significantly higher than those of the rest of three groups. Group IV had a significant correlation between blood dioxin level and working period at the plant.

Relation between life style factors and blood dioxins level:

There were no correlations between eating habit, smoking, and alcohol intake and blood dioxins level.

Relation between blood and blood chemistry tests and blood dioxins level: There were no correlations between blood and blood chemistry tests and blood dioxins level.

Immunological function tests and blood dioxins level: Considering the age there were no correlations between immunological function tests and blood dioxins level.

Conclusion

The committee concluded that the concentrations of dioxins among the blood of the workers who had engaged in maintenance of the furnace, the electric dust collector, and the wet scrubber of the incinerator were higher compared with those of residents in surrounding areas. However, there were no signs or findings correlating to blood dioxins level, and the level was not high enough to induce sufficient health effects from the review of published papers.

Further Investigation

According to the results of this survey the committee understood that the follow-up study of blood dioxins level of group III and IV workers was inevitable and also concerned about the other MSWI workers in Japan who might also be exposed to similar level of dioxins. The Ministry of Labor decided to expand the survey to other MSWI workers in Japan as 3-year project from 1999. The summary of the investigation will be seen in the Appendix.

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APPENDIX

Results of Investigation on Health Effects Related to Dioxins Exposure on Workers at Waste Incineration Plants (2001) —Workers of Waste Incineration Plants Including Toyono-gun Clean Center in Osaka Prefecture—

Ministry of Health, Labor & Welfare
Labor Standards Bureau, Safety and Health Department,
Chemical Substance Investigation Division

Executive Summary

1. The blood dioxins concentration of workers related to Toyono-gun Clean Center were decreasing year by year since 1998, and their mean value got from investigation in FY2001 decreased to 44.3% of that in FY1998.
2. The mean blood dioxins concentration of workers at waste incineration plants selected nationwide (104 workers from 6 plants) was about 21.3 pg-TEQ/g-fat, which was similar to the level of residents representing general people carried out by the Ministry of Environment in FY2000. In addition, the blood dioxins concentrations of workers at the demolition work site of a waste incineration plant (6 employees at 1 plant) before and after demolition work did not show significant difference, and all measurements were around 20 pg-TEQ/g-fat, which was similar to the level of general residents measured by the Ministry of Environment in FY2000.
3. According to the results of physical examination made by dermatologists and other examinations, there were no findings or signs relating to dioxins exposure among workers related to Toyono-gun Clean Center, workers at the other waste incineration plants, and workers at the demolition site.
4. Investigation on health effects related to dioxins exposure on workers at waste incineration plants nationwide had been carried out on 452 employees at 26 plants for three consecutive years starting from FY1999. No observable health effects induced by exposure to dioxins were detected among subjects investigated.
(Dioxins refers to polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzo-*f*-rans, and coplanar polychlorinated biphenyls)

Outline of Investigations

1. Follow-up study on workers related to Toyono-gun Clean Center

Subjects

Seventeen subjects were selected from present or former workers of Toyono-gun Clean Center (workers related to Toyono-gun Clean Center) who engaged in operations inside the incinerator-related facilities (n=14) or supported the operations outside but never worked inside the facilities (n=13) and who agreed to join the investigation. The candidates were workers who had high blood concentration of dioxins at the investigation in FY1998. Incinerator-related facilities refer to incinerator, electric dust collector, wet scrubber, and other related facilities.

Blood concentration of dioxins

The mean blood dioxins concentration of 17 subjects was 126.7 pg-TEQ/g-fat (ranging from 19.6 to 484.0 pg-TEQ/g-fat). These 17 persons had continually been examined from FY1998 and the average were decreasing year by year, which was 286.3 pg-TEQ/g-fat in FY1998, 256.1 pg-TEQ/g-fat in FY1999, 152.3 pg-TEQ/g-fat in FY2000, and in FY2001 it decreased to 44.3% level of FY1998 (Fig. 1).

History taking and dermatological examination

According to the results of history taking by medical doctors and the physical examination by dermatologists, which have been continually carried out since 1998, no person was suspected to have signs or findings caused by exposure to dioxins.

Blood and blood chemistry tests

Although the results of blood, blood chemistry, and

Fig. 1. Yearly change of the mean blood dioxins concentration of 17 workers related to Toyono-gun Clean Center.

immunological function tests showed that some examined values such as liver function tests exceeded the standard range, there was no evidence from blood dioxins concentration that those abnormal measurements were related to the effect of exposure to dioxins.

There was one person who was strongly suspected to have hepatitis, but it was rather related to his life style including the drinking habit of alcohol and not to the exposure to dioxins.

Summary

From the results of this investigation, there were no observable health effects due to dioxins exposure.

2. Investigation on health effects related to dioxins exposure on workers at waste incineration plants nationwide (2001)

Subjects

Subjects were 104 workers from 6 plants, including 3 municipal solid waste incinerating plants cooperated by local governments and 3 industrial waste incinerating plants cooperated through National Federation of Industrial Waste Management Associations. Survey was also carried out on 8 workers, who agreed to join the survey, at a demolition work site before and after demolition operation. Since 2 workers did not join post-operational survey, subjects were 8 before and 6 after the demolition.

Blood concentration of dioxins

The mean blood concentration of dioxins by each waste incineration plant (Table 1) of 104 workers was 21.3 pg-TEQ/g-fat (ranging from 3.5 to 66.7 pg-TEQ/g-fat), which was similar to the level of residents carried out by the Ministry of Environment in FY2000.

On the other hand, the mean blood dioxins concentration

Table 1. The mean blood concentration of dioxins by the plant workers from 6 waste incineration plants nationwide (unit: pg-TEQ/g-fat)

	Number of workers		Mean	Min.	Max.
Plant A	14	Total dioxins	17.7	8.5	34.1
		PCDDs + PCDFs	10.8	5.8	16.4
		(2,3,7,8-TCDD)	(0.7)	(0.1)	(1.3)
		coplanar-PCB	6.9	2.0	18.3
Plant B	16	Total dioxins	24.0	7.9	58.5
		PCDDs + PCDFs	14.1	4.9	30.6
		(2,3,7,8-TCDD)	(1.1)	(0.1)	(1.9)
		coplanar-PCB	9.9	1.5	27.9
Plant C	22	Total dioxins	21.5	8.0	66.7
		PCDDs + PCDFs	12.4	5.2	24.5
		(2,3,7,8-TCDD)	(1.1)	(0.1)	(2.6)
		coplanar-PCB	9.1	2.4	42.1
Plant D	11	Total dioxins	14.0	6.2	28.8
		PCDDs + PCDFs	8.4	4.8	18.0
		(2,3,7,8-TCDD)	(1.0)	(0.5)	(1.9)
		coplanar-PCB	5.6	1.3	16.8
Plant E	12	Total dioxins	18.3	3.5	43.1
		PCDDs + PCDFs	10.9	2.7	22.7
		(2,3,7,8-TCDD)	(0.7)	(0.1)	(1.5)
		coplanar-PCB	7.4	0.9	27.6
Plant F	29	Total dioxins	25.2	11.4	51.8
		PCDDs + PCDFs	14.8	8.0	29.3
		(2,3,7,8-TCDD)	(1.2)	(0.4)	(2.4)
		coplanar-PCB	10.4	3.4	22.5
Total	104	Total dioxins	21.3	3.5	66.7
		PCDDs + PCDFs	12.5	2.7	30.6
		(2,3,7,8-TCDD)	(1.0)	(0.1)	(2.6)
		coplanar-PCB	8.7	0.9	42.1

The mean of total dioxins is the summation of each mean value of PCDDs, PCDFs, and coplanar PCB.

of 8 workers engaged in demolition work was 20.8 pg-TEQ/g-fat (ranging from 7.4 to 60.2 pg-TEQ/g-fat) before demolition work. The two blood dioxins concentrations of 6 employees, except for 2 workers who did not join the after-demolition survey, were compared. The averages were 22.7 pg-TEQ/g-fat (ranging from 7.4 to 60.2 pg-TEQ/g-fat) before starting demolition work and 24.1 pg-TEQ/g-fat (ranged from 9.2 to 61.2 pg-TEQ/g-fat) after finishing demolition work. There was no significant difference between before and after demolition work, and both values were similar to the value of general residents measured by the Ministry of Environment in FY2000 (Table 2 and 3).

Table 2. Blood dioxins concentration of 8 workers at demolition work cite before engaging in demolition operation (unit: pg-TEQ/g-fat)

		Mean	Min.	Max.
Before demolition	Total dioxins	20.8	7.4	60.2
	PCDDs + PCDFs	10.6	6.0	24.6
	(2,3,7,8-TCDD)	(0.6)	(0.1)	(2.1)
	coplanar-PCB	10.2	1.3	35.6

The mean of total dioxins is the summation of each mean value of PCDDs, PCDFs, and coplanar PCB.

History taking and dermatological examination

According to the results of history taking (past history of diseases, present history of diseases, subjective symptoms, and so on) by medical doctors from Rosai Hospitals (Workmen's Accident Compensation Insurance Hospitals) and the examination by dermatologists, no person was suspected to have signs or findings caused by exposure to dioxins.

Blood and blood chemistry tests

Statistical analysis of the relation between blood, blood chemistry, and immunological function tests and blood dioxins concentration revealed that there was no evidence of relation between them.

Summary

From the results of this investigation, there were no observable health effects due to dioxins exposure during operations in incinerator related facilities.

3. The results of 3 years investigation on health effects related to dioxins exposure on workers at waste incineration plants nationwide

Investigations on workers of nationwide waste incineration plants were carried out for continually 3 years from FY1999 to FY2001 and total of 452 persons at 26 plants were examined. The mean blood dioxins concentration of 441 workers, excluding persons who could not evaluate blood level dioxins due to unsuccessful sampling or other reasons, was 22.5 pg-TEQ/g-fat (ranging from 3.5 to 133 pg-TEQ/g-fat).

Using the data of 412 persons, who had all results of tests and measurements and excluding women because of inducing difference by sex, the relation between blood dioxins concentration and results of tests and measurements were statistically analyzed. As a result, there were no observable health effects due to dioxins exposure during the operations in incinerator related facilities.

Table 3. Blood dioxins concentration of 6 workers at demolition work cite before and after engaging in demolition operation (unit: pg-TEQ/g-fat)

		Mean	Min.	Max.
Before demolition	Total dioxinse	22.7	7.4	60.2
	PCDDs + PCDFs	11.4	6.0	24.6
	(2,3,7,8-TCDD)	(0.7)	(0.1)	(2.1)
	Coplanar PCB	11.3	1.3	35.6
After demolition	Total dioxins	24.1	9.2	61.2
	PCDDs + PCDFs	12.8	7.2	26.2
	(2,3,7,8-TCDD)	(0.9)	(0.5)	(1.6)
	Coplanar PCB	11.3	2.0	35.0

The mean of total dioxins is the summation of each mean value of PCDDs, PCDFs, and coplanar PCB.

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Table 4. Blood dioxins concentrations of residents in the area of Nose, Osaka prefecture and those in the area of Saitama prefecture (unit: pg-TEQ/g-fat)

	Osaka Nose area		Saitama prefecture area		
	Area near incinerator	Control area	Area 1 near incinerator	Area 2 near incinerator	Control area
2000	28	33	23	24	22
1999 (ref.)	29	30	27	27	–

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References

- Examples of blood dioxins concentration measured on general residents (Table 4).
- Dermatological examination was carried out by dermatologists with focus on the following points.
 - ① Existence of dioxin induced chloracne-form eruption that was judged by the historical cases.
 - ② Dermal symptoms complained.
 - ③ Dermal symptoms observed on the exposed part of skin
- Following 25 blood and blood chemistry tests were examined.

Red blood cell count ($10^4/\mu\text{l}$), leukocytes count ($/\mu\text{l}$), hemoglobin (g/dl), hematocrit (%), platelet count ($10^4/\mu\text{l}$), total protein (g/dl), albumin (g/dl), total bilirubin (mg/dl), AST (IU/l), ALT (IU/l), lactic dehydrogenase (IU/l), alkaline phosphatase (IU/l), γ -GTP (IU/l), leucine aminopeptidase (IU/l), creatine kinase (IU/l), amylase (IU/l), total cholesterol (mg/dl), HDL cholesterol (mg/dl), neutral fat (mg/dl), serum iron ($\mu\text{g/dl}$), urea nitrogen (mg/dl), creatinine (mg/dl), uric acid (mg/dl), blood sugar (mg/dl), and HbA1c (%).
- The following immunological function tests were carried out after separating lymphocytes.

Lymphocyte blastogenesis test by PHA and Con A, Natural killer cell activity, and lymphocyte subset analysis using monoclonal antigen (CD3, CD4, CD8, CD4/CD8 ratio, CD19, and CD56).