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CADMIUM CONCENTRATION IN THE BLOOD AND URINE IN CADMIUM EXPOSED WORKERS

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ABSTRACT

Concentration of cadmium in the blood and urine of exposed and non-exposed workers was measured. The relation between these data and the degree of exposure in the workplace was studied in order to find out if these data could be a good index of environmental cadmium exposure.

A significant positive correlation was observed between concentration of cadmium in blood and urine. Concentration of cadmium in blood was found to be well related to environmental cadmium over 30 $\mu g/m^3$ of exposure. A sudden increase of urinary excretion of cadmium in workers exposed to more than 30 $\mu g/m^3$ of environmental cadmium over six months was also observed. There were no signs of renal tubular damage in these workers. The urinary excretion of cadmium did not decrease for a long time after cessation of exposure.

From the results of this study it may be concluded that urinary excretion of cadmium is partly correlated to relatively recent exposure. The concentration of cadmium in blood is a more direct indicator of exposure than is urinary cadmium excretion.

Cadmium concentrations in the blood and urine have been studied by many investigators to determine the degree of exposure of cadmium in workplaces. It is recognized that cadmium concentration in the blood mostly reflects the state of exposure because it increases promptly and decreases shortly after the cessation of contact with cadmium. However, urinary cadmium excretion does not increase for some time after engagement in cadmium work and has a different type of reduction. These phenomena are due to the period of exposure to cadmium and its concentration in the air. Nevertheless, it is not yet sufficiently clear if these data could be used as an index of health examinations for cadmium exposed workers.

The authors, having measured the concentration of cadmium in the blood and urine of exposed and non-exposed workers, studied the relationship between these data and the degree of exposure to cadmium in the workplace to find out whether cadmium concentration in the blood and urine could be a good index of environmental cadmium exposure.

SUBJECTS, MATERIALS AND METHODS

The subjects in this study were divided into two groups, male and female workers in a factory of cadmium sulphide pigments and at a battery making plant. Work in the factory consisted of melting metal cadmium and making, blending, pulverizing and bagging cadmium sulphide. The environmental cadmium exposure in this group was relatively high and not constant. The cadmium concentration in the air ranged from 0.001 to 7.265 mg/m³ at ceiling value. The time weighted concentration (TWC) was found to be 0.37 to 0.87 mg/m³ in the sintering work and 0.078 to 0.313 mg/m³ in the blending work respectively. In other workplaces the time weighted concentration was not measured, but the ceiling value suggested it was the same or lower than the value at the blending workplace. (The time weighted concentration of these places was measured in 1974, before improvement of environmental exposure.) The second group worked in a cadmium battery plant including the making of electrode plate and battery assembling. The cadmium content in the air was relatively low, from 0.004 to 0.0015 mg/m³ at ceiling value. Out of all workers 92% were exposed to cadmium below 20 μg/m³ while 74% of the workers were exposed to cadmium below 10 μg/m³ of time weighted concentration.

Cadmium in the blood was analyzed by dithizone extraction atomic absorption method and the urinary cadmium content was measured by APDC--MIBK extraction atomic absorption method. The deutrium lamp technique was applied.

The following instruments were used in both analyses: atomic absorption analyzer and Hitachi AAS-308. The liver function tests were performed with an automatic analyzer Hitachi 706-D. Urine analysis such as measurement of creatinine and phosphorus was carried out by the Folin-Wu and other methods.

RESULTS

The findings of the determination of cadmium concentration in the blood and urine of exposed workers in the manufacture of cadmium sulphide pigments in 1974 are shown in Table 1. The workers No 11 to 16 in the table were car drivers or office workers who were little exposed to cadmium. The concentrations of cadmium in the blood of these workers were below 1.00 μg/100 g and those of urine were under 6.1 μg/l. These data were very low as compared with those of the workers No 1 to 10. The worker No 17 was promoted to the post of supervisor of cadmium workers after doing sintering work for over six years, and thus afterwards was exposed to a very low concentration of cadmium. The cadmium concentration in the blood of this worker was therefore low while the urinary cadmium excretion was still high. The worker No 18 was exposed to a relatively high amount of cadmium for a short time after his engagement. This fact explains why cadmium concentration in the blood was high and that in the urine was low.

Figure 1 reveals the relationship between the amount of cadmium in the blood and urine in two groups of workers, No 1 to 10 and No 11 to 16 from Table 1. A high coefficient of correlation was obtained in both groups.

TABLE 1
Cadmium concentration in the blood and urine of workers of cadmium sulphide pigments (May, 1974).

Worker	Cd-B (µg/100g)	Cd – U	
		µg/l	µg/g-creatinine
1	2.52	31.5	36.6
2	3.53	49.2	40.0
3	3.68	69.2	42.2
4	1.60	11.1	7.9
5	2.10	14.7	17.1
6	2.54	52.3	20.4
7	2.61	35.9	27.2
8	3.04	53.8	35.6
9	2.00	15.9	18.1
10	2.84	31.1	23.9
11	0.54	3.0	2.1
12	0.52	4.7	2.7
13	0.34	5.6	3.7
14	1.00	4.5	3.8
15	0.72	3.3	2.3
16	0.79	6.1	2.3
17	2.20	25.5	53.1
18	2.30	2.6	1.7

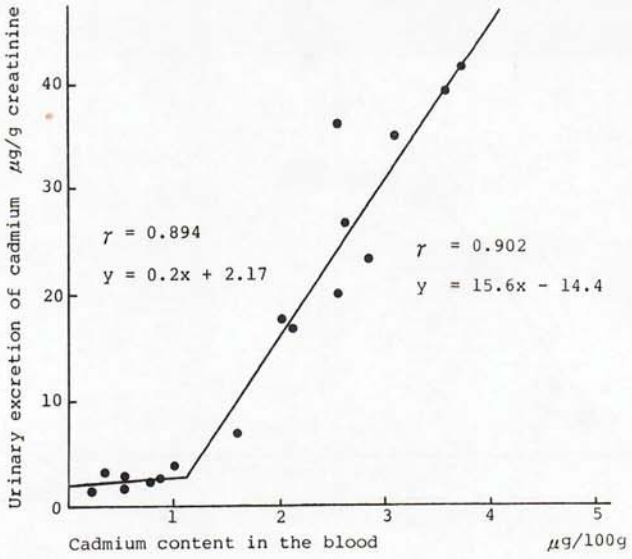

FIG. 1 – Relationship between cadmium content in the blood and urinary excretion of cadmium in workers employed in a factory of cadmium sulphide pigments (see Table 1).

Figure 2 shows the relationship between cadmium concentration in the blood and urine among another 11 workers who were exposed to cadmium, based on the investigation in January 1975. As this figure shows, the cadmium concentration in the blood of two workers was below 1 μg/100 g. One was a colour mixing worker and the other was a supervisor of workers. They were exposed to a very low concentration of cadmium. Therefore, cadmium concentrations in the blood as well as in urine were also low. The calculated coefficient of correlation was high.

Cadmium concentration in the blood and urine of the same group of workers at different times after the first clinical investigation in 1972 is shown in Figure 3. As shown in this figure, the amount of cadmium in the blood decreased promptly with the dissociation of exposure to cadmium. However, urinary

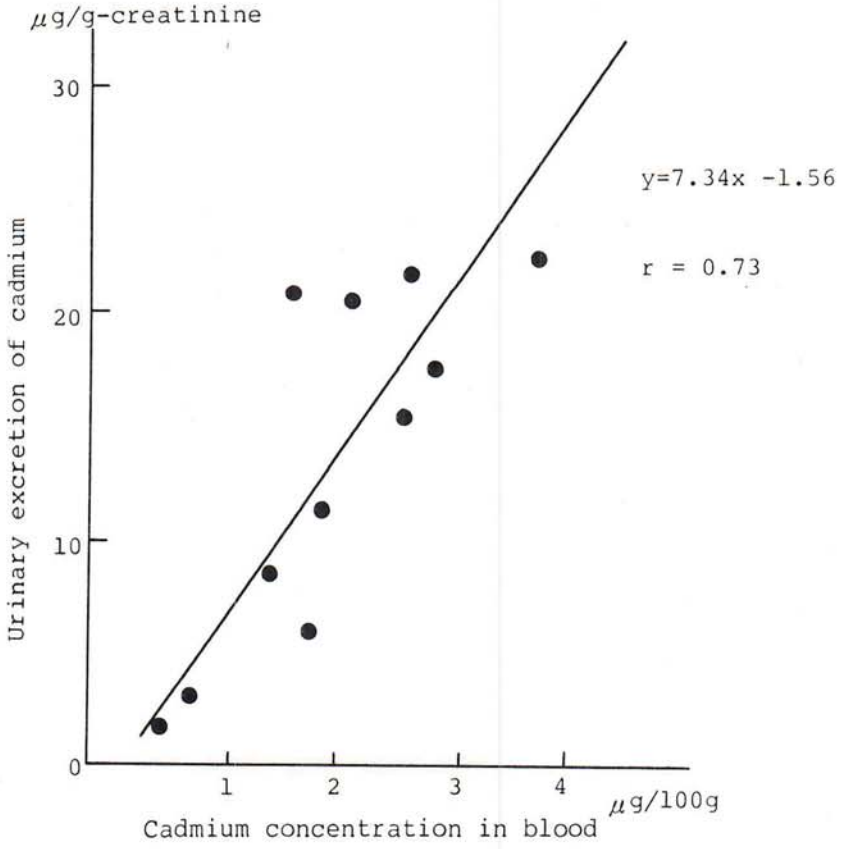

FIG. 2 – Relationship between cadmium concentration in the blood and urinary excretion of cadmium in workers employed in a factory of cadmium sulphide pigments (January, 1975).

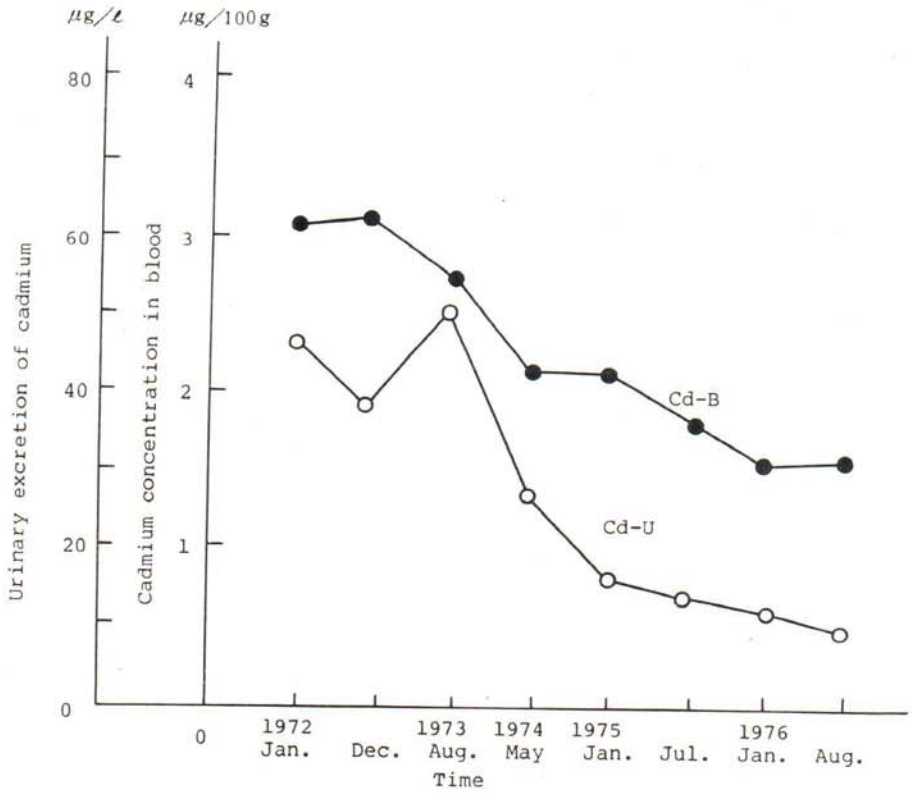

FIG. 3 – Changes of mean cadmium concentration in the blood and urine in 11 exposed workers employed in a factory of cadmium sulphide pigments.

cadmium excretion decreased only slowly. The output of this factory went down in 1974 and at the end of 1976. This led to a decrease of exposure to cadmium in workplaces.

A second study was carried out on female workers aged 18 to 28, who were constantly exposed to cadmium in a battery making plant. One group of 126 workers was exposed to cadmium for up to six months, and another group of 348 workers for over six months. The urinary excretion of cadmium of a control group of 106 females of the same age was measured. The results are shown in Figures 4 and 5. The cadmium concentration in the urine of the workers in both groups was well related to the content of cadmium in the air of the workplaces.

Even with a cadmium level of 5 $\mu g/m^3$ in the air, urinary cadmium was found to be higher in workers exposed for up to six months than in those not working with cadmium at all (mean $\pm$ S.D. $= 2.9 \pm 2.0$ $\mu g/m^3$). When the cadmium levels in the air were below 30 $\mu g/m^3$, a small difference was observed

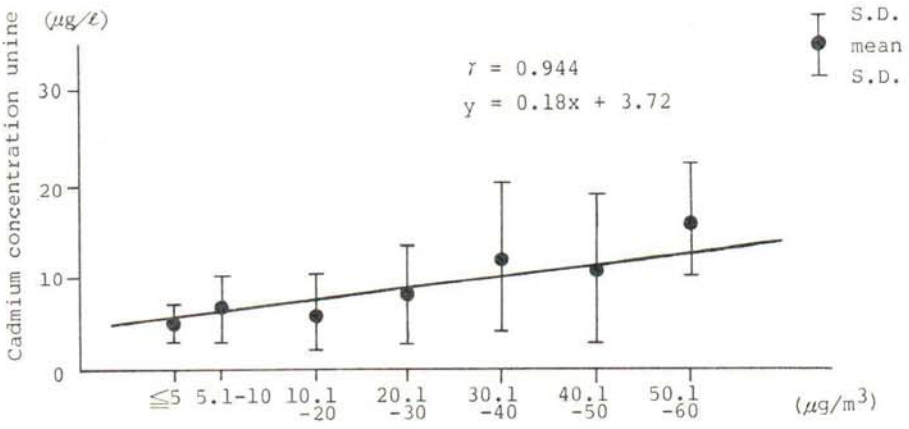

FIG. 4 – Relationship between cadmium content in the air of battery plant and cadmium content in the urine of workers exposed to cadmium up to six months.

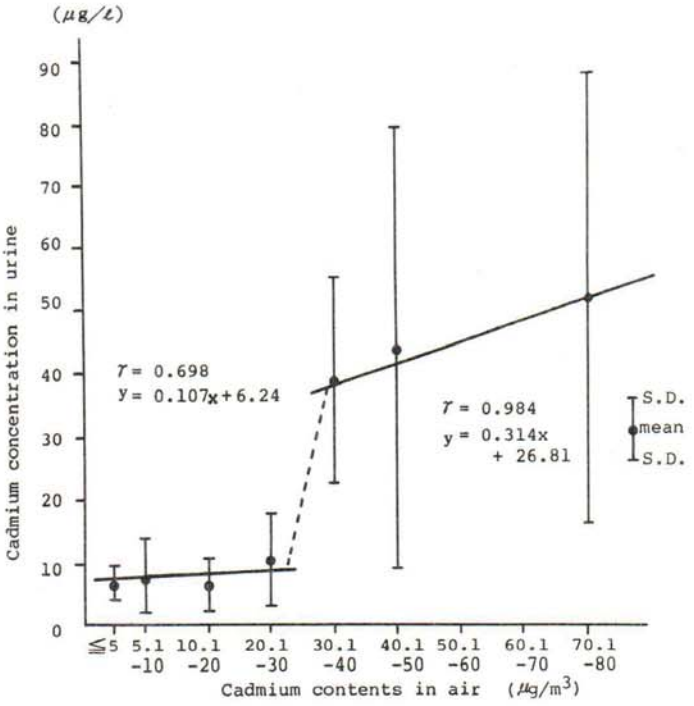

FIG. 5 – Relationship between cadmium content in the air at a cadmium battery factory and cadmium content in the urine of workers exposed to cadmium for more than six months.

TABLE 2

Change of cadmium concentration in the air (Cd-A) and urinary cadmium excretion (Cd-U) in a cadmium battery plant.

Plant	Workplace	May, 1975				August, 1975				March, 1976			
		Cd-A µg/m³	n	Cd-U (µg/l)		Cd-A µg/m³	n	Cd-U (µg/l)		Cd-A µg/m³	n	Cd-U (µg/l)	
				Range	Mean			Range	Mean			Range	Mean
Electrode plate*	Press	51.9	19	1.7–13.2	3.5	33	12	1.5–8.1	4.5	55	11	1.6–10.2	5.4
	Dipping	13.3	7	2.0–5.6	3.8	11	7	2.0–4.6	3.1	15	6	1.6–7.6	4.0
	Coil transformation		4	1.4–7.5	3.5	5–9	4	1.4–4.5	2.8	5–11	4	1.2–6.5	3.8
	Transformation	2.9	9	1.3–5.3	2.9	2–5	10	0.6–3.8	2.3	2–7	9	0.8–5.7	3.4
	Washing after transformation	1.9	7	1.4–4.4	2.6	2	9	0.6–3.1	2.2	2–3	7	1.1–5.3	2.9
	Laboratory		17	0.6–8.5	3.2		14	0.9–4.3	2.9		13	0.6–7.5	3.4
	Non-cadmium workers in workshop		38	1.3–15.2	4.2		35	0.6–8.8	2.0		34	0.4–6.9	2.2
	Workers transferred from cadmium to non-cadmium workshop		3	2.7–9.2	5.8		3	5.6–15.9	9.0		3	6.1–15.0	9.2
Battery assembling**	Spot welding	16	7	2.2–11.6	4.5	5–7	9	1.7–6.1	3.2	5–16	7	1.7–10.9	4.4
	Electrode plate winding	14	23	1.5–5.9	3.2	3–6	23	1.5–4.3	2.6	3–10	20	1.7–10.9	3.3
	Electrode plate inserting	9–10	16	0.7–8.2	3.1	2–4	17	1.8–5.6	2.4	2–10	16	1.5–6.5	3.0
	Cover placing	4–6	13	1.3–5.6	2.8	2–5	8	2.0–6.4	3.0	3–7	9	1.6–7.2	3.1
	Curling press	2–3	18	1.0–6.0	2.2	2–4	12	1.7–5.4	2.7	2–5	12	1.2–6.8	2.9
	Supervisors of cadmium workers		7	2.3–12.3	6.3		8	1.5–7.6	3.6		7	1.8–10.7	5.2
	Supervisors in office		10	1.0–2.3	2.3		23	1.9–6.3	2.6		20	0.6–4.2	2.4
	Non-exposed		n = 106			Mean ± S.D. = 2.9 ± 2.0 µg/l							

* Cadmium in the atmosphere (Cd-A) = ceiling value; ** Cadmium in the atmosphere (Cd-A) = time weighted concentration

between the group exposed for up to six months and the group exposed to cadmium for more than six months. When the cadmium concentration in the air was higher than 30 $\mu g/m^3$, a remarkable difference was observed between the groups. In workers exposed for more than six months, the urinary cadmium excretion increased rapidly and considerably. Such an increase was absent in those exposed for up to six months.

Table 2 shows the change of cadmium concentration in the air at a cadmium battery making plant and urinary cadmium excretion among exposed and non-exposed workers in 1975 and 1976. As this table shows urinary cadmium excretion also increased or decreased according to the concentration of cadmium in the workplaces.

A third study was carried out on 164 workers at a cadmium battery making plant. The degree of exposure to cadmium was measured by a personal sampler for TWC. Five workers were exposed to more than 40 $\mu g/m^3$ cadmium, while about 60% of the workers were exposed to less than 10 $\mu g/m^3$.

Figures 6 and 7 show the relationship between the concentration of cadmium in the blood and urine of these workers and the cadmium in the air of

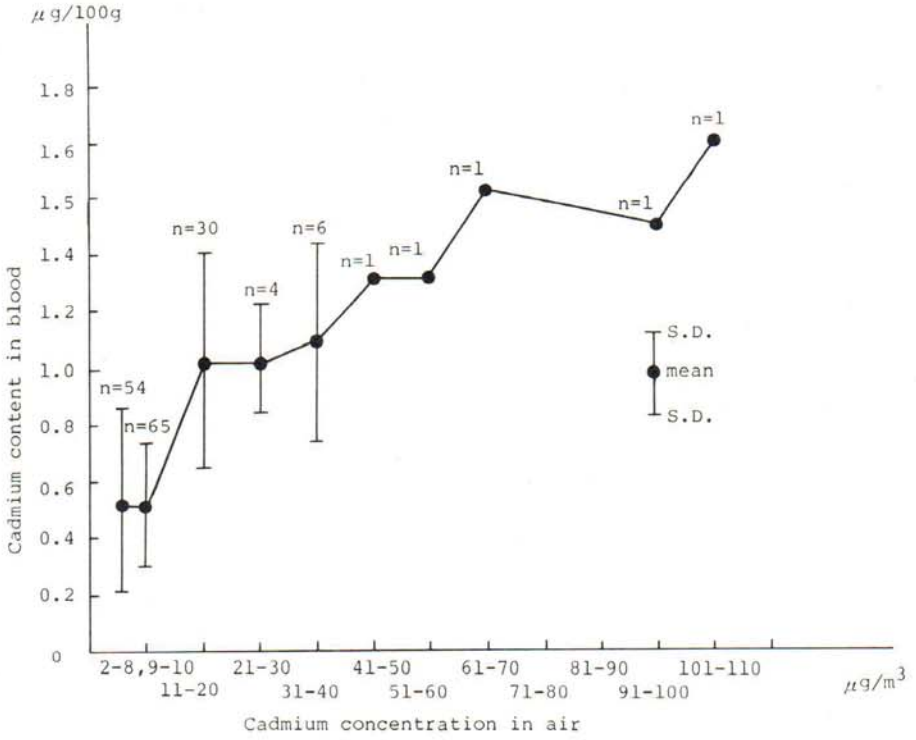

FIG. 6 – Relation between cadmium concentration in blood and air on time weighted concentration.

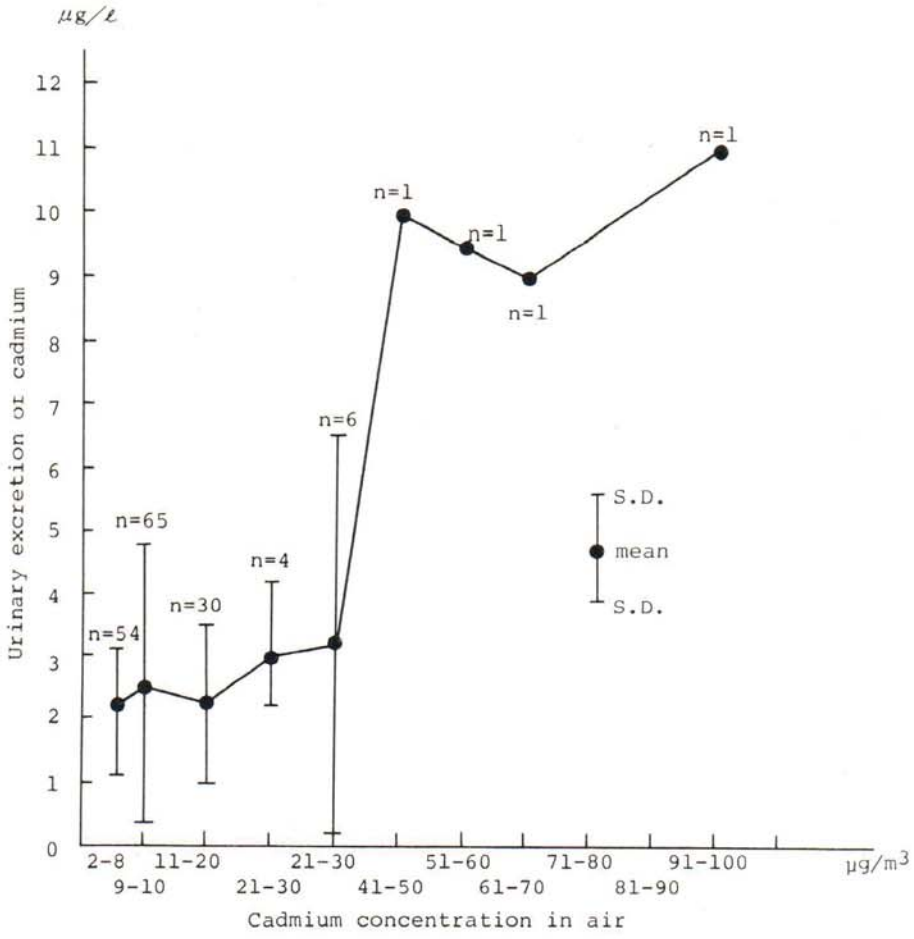

FIG. 7 – Relation between urinary excretion of cadmium and cadmium concentration in the air on time weighted concentration.

their workplaces. When environmental exposure was below 10 μg/m³, the blood cadmium concentration of the workers was similar to normal value increasing promptly with exposure exceeding 20 μg/m³.

The urinary excretion of cadmium increased slowly up to 30 μg/m³ of exposure to rise suddenly with cadmium concentration in the air reaching 30 – 40 μg/m³. The estimation curve based on this study is seen in Figures 8 and 9. The blood cadmium increased in almost direct proportion to the degree of exposure to cadmium. However, urinary cadmium excretion showed a different pattern of increase.

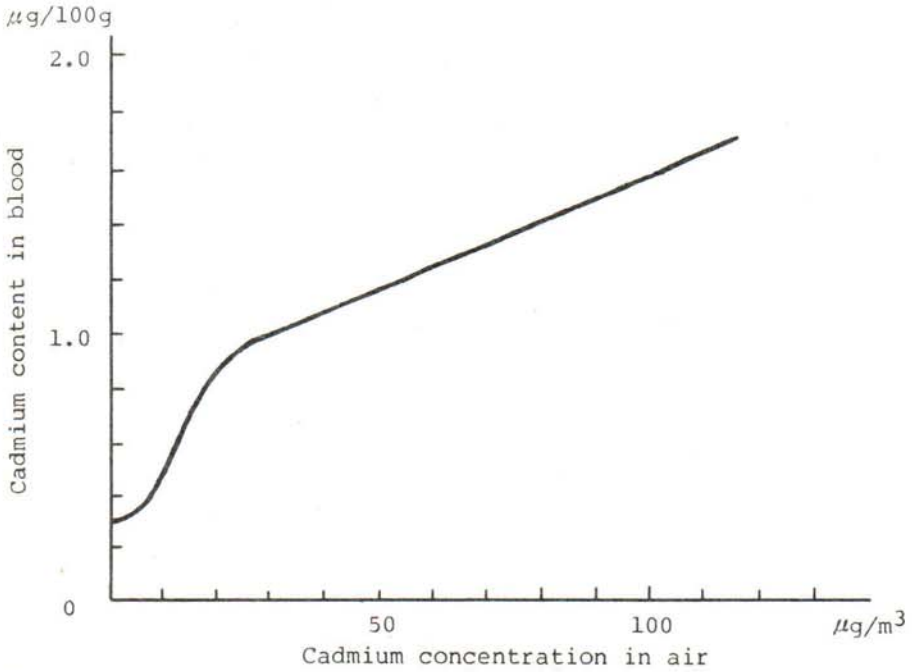

FIG. 8 – Relation between cadmium content in the blood and cadmium concentration in the air on time weighted concentration. Estimation curve based on data from Figure 6.

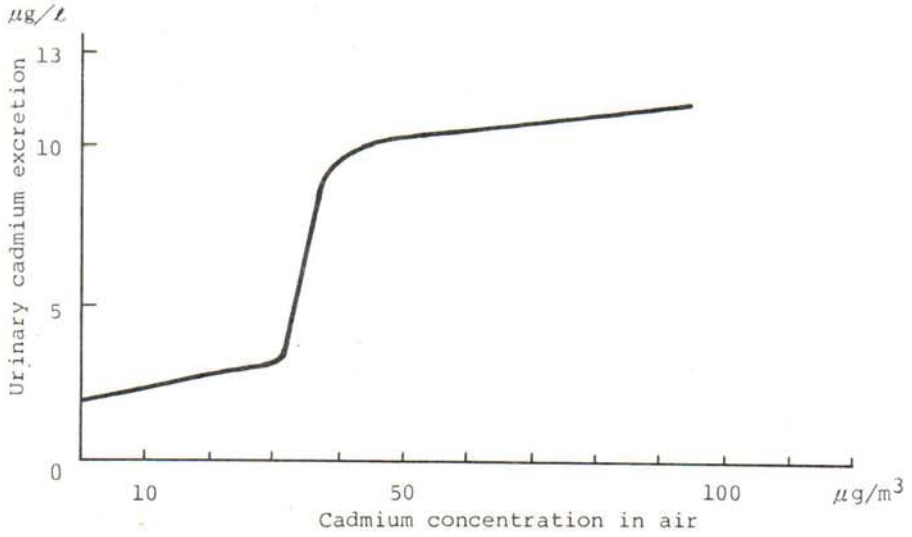

FIG. 9 – Relationship between urinary excretion of cadmium and concentration of cadmium in the air on time weighted concentration. Estimation curve based on data from Figure 7.

No significant alterations were observed in liver function tests, and urine analysis of cadmium workers, and the occurrence of anaemia among these workers was not higher than that among non-cadmium workers.

DISCUSSION

The determination of cadmium in the blood and urine has been useful in the health examination of cadmium exposed workers and people living in cadmium polluted areas. In order to clarify the usefulness of cadmium concentration in the blood and urine as an indicator of environmental exposure, it is important to find out in what measure levels of cadmium in the blood and urine reflect the body burden and degree of recent exposure respectively.

It should be pointed out that the amount of cadmium in the blood increases according to the period of engagement in cadmium work and maintains a high level during the period of exposure to cadmium. Many dissociation patterns have been reported about the concentration of cadmium in the blood of workers after contact with cadmium ceases. One is the rapid-decrease type, the other the slow--decrease type, and another the long-retention type as pointed out by Friberg and co-workers[1] and Tsuchiya[9].

According to some reports, cadmium concentration in the blood does not decrease so rapidly after the cessation of long-term exposure because cadmium is released slowly into the blood from the critical organs. The animal studies by Nordberg[6] seem to indicate that blood cadmium levels partly reflect the exposure and partly the organ contents of cadmium. According to the results of this study, the concentration of cadmium in the blood of exposed workers resulted from the daily intake of cadmium including environmental exposure rather than from the amounts accumulated within the body.

The concentration of cadmium in the urine of workers does not increase for a while after engagement in cadmium work but increases promptly when the workers continue to be in contact with cadmium for a long time[2]. It has also been stated that urinary excretion of cadmium does not decrease after cessation of exposure and remains on a high level for a long period. These phenomena have been described by many researchers on the basis of animal experiments and of data from investigations of exposed workers[7].

In this study the urinary excretion of cadmium in exposed workers had a smilar course as in the studies mentioned above. This fact suggests that the release of cadmium from the liver, renal cortex and other organs might have been responsible for the high excretion values. Therefore the concentration of cadmium in urine may correlate linearly with the whole body burden (i.e. the total amount of cadmium in the body).

When renal tubular damage occurs, the urinary excretion of cadmium increases dramatically as shown by studies on rabbits and mice[3,7].

In this study too a sudden increase of urinary excretion of cadmium in workers exposed to more than 30 $\mu g/m^3$ of environmental cadmium over six

months was observed. However, there were no signs of renal tubular damage in the urine analysis of these workers. This phenomenon was the same as that reported by Friberg and co-workers[1]. They observed that a high and relatively short-term exposure (six months to two years) might give rise to a high urinary excretion of cadmium without renal tubular damage. Lauwerys and co-workers[4] as well as Singerman[8] have presented results which confirm these findings.

According to Nomiyama[5], it may thus be suggested that the accumulation of cadmium in the renal cortex induces a change in the clearance of cadmium, while urinary cadmium excretion increases consequently as shown in this study. Nomiyama also pointed out that the urinary excretion of cadmium is related to the accumulation of cadmium in the renal cortex.

A significant positive correlation was observed in this study between concentrations of cadmium in the blood and urine of exposed workers since blood concentrations are considered to reflect recent exposure.

On the basis of this study it may be stated that the urinary excretion of cadmium is partly correlated with relatively recent exposure when high and long occupational exposure is involved. The concentration of cadmium in blood is a more direct indicator of recent exposure than is urinary cadmium excretion.

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