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# CALCULATION OF TOTAL RESPIRATORY DOSES FOR WORKERS EXPOSED TO CADMIUM IN AIR

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**ABSTRACT**

In a study performed in 1977, 17 Cd-Ni-battery workers were intensively studied during 11 consecutive weeks. A total of 181 observations with personal samplers gave an arithmetic average of 7.3 μg Cd/m³ air. It was assumed that the average inhalation was 10 m³/workday, the absorption rate 25% and that there were 225 working days per year. Assuming half-times of 10, 20 and 30 years, the total accumulated doses were computed for each worker, based on the start of employment for each individual. The estimates did not take into account the cadmium that had been ingested due to contamination of hands, face and cigarettes, or the cadmium inhaled due to smoking of cigarettes or pipe tobacco. The total accumulated doses were in the ranges 8–87 mg Cd, assuming constant exposure.

However, a detailed analysis of exposure duration, taking into account the changes in working conditions over the years, showed quite a different picture. There had been a remarkable reduction of the number of working hours over the decades. In the 1940's the number of working hours per week was 48 and paid vacations were only two weeks. In the 1970's the number of working hours per week had decreased to 40 and paid vacations had risen to four weeks. Time-cards for all employees were available from 1966 on. It was found that the workers had been at work on an average 97% of the scheduled time but the individual's working time had varied between 61 and 110% of the scheduled time. All workers were interviewed about the kind of work and the hiring dates were checked. The levels of air-borne cadmium dust in the working environment had decreased from about 5 000 μg Cd/m³ in 1946 to about 7 μg Cd/m³ in 1976. Products of the number of working hours and cadmium concentration were computed for each worker each year. The total accumulated doses were then calculated under the same assumptions of biological half-times, respiration volumes and percentage uptake as above. The doses thus computed were 5–3 007 mg cadmium.

The correlation rates between the two estimates were around 90%, but the second estimates were 0.6 to 35 times the first estimates.

When estimating dose-response relationships for cadmium the methods available today make it possible to get relatively good estimates of the response. The degree of kidney involvement can be determined by the determination of total protein, the electrophoretic examination of urine proteins and the quantitative determination of a specific low molecular weight protein, e.g $\beta_2$-microglobulin.

The difficulties in measuring the dose have been very large. This is mainly due to the fact that, because of the long biological half-time of cadmium, the life--time exposures must be evaluated.

If cadmium intake via the oral route is neglected, the dose can be approximated by a function of the concentration of respirable cadmium particles in air, the time spent in the work-room, the quantity of inhaled air per unit time, the pulmonary absorption and the biological half-time of cadmium.

In estimating industrial exposure, the current concentrations of cadmium are used. It is doubtful if these concentrations accurately reflect environmental conditions in earlier days, since it is obvious that there have been great changes in working conditions over the years. These problems have been discussed by Kjellström[4] and Nordberg[5]. Kjellström[4] and Adamsson[1] investigated the changes over time in the same battery factory described by Friberg in 1950[2]. They found that, in this factory, the concentrations of cadmium oxide dust in work-room air are now 100 to 500 times lower than in the 1940's.

When calculating permissible concentrations in industrial air, it is generally assumed that a worker works 225 eight-hour days a year[3].

However, over the decades there has been a remarkable reduction in the number of working hours. In the 1940's the number of working hours per week was 48, with only two weeks of paid vacation per year. After deducting Sundays and holidays the number of eight-hour workdays was around 290 in the 1940's. In the 1970's the number of working hours per week decreased to 40 and paid vacations increased to four weeks resulting in 228 workdays in 1976.

The average inhalation during an eight-hour workday is generally assumed to be 10 $m^3$ air and absorption of inhaled cadmium compounds are, based on animal experiments, 10–40%[3].

## SUBJECTS AND METHODS

Seventeen male workers, aged 28–60 years, without any clinical or subclinical signs of renal tubular damage were studied. Two estimates of the total respiratory dose were computed for each worker. Both estimates were computed for three levels of biological half-times, 10, 20 and 30 years. An absorption rate of 25% and inhalation of 10 $m^3$ air/8 hours were assumed. Hiring dates were obtained from the administration department of the company.

The first estimate was based on 225 eight-hour workdays per year and the concentration of cadmium dust currently found in air. From 181 observations with personal samplers on the 17 workers from January to March 1977 it was determined that the average concentration was 7.3 $\mu g$ Cd/$m^3$.

The second estimate was based on time-cards from 1966 to 1976, personal interviews with the worker and concentrations of air-borne cadmium dust from earlier measurements, evaluated by the author[1]. The date of the start of work was checked with the worker and he was also asked about the kind of work and use of respiratory mask. The efficiency of protection masks was supposed to be 50%.

## RESULTS

From the time-cards it was found that the workers had been at work on an average of 97% of the scheduled time, but the individual's yearly working time had varied between 61% and 110% of the scheduled time.

The interviews revealed that three workers – N, O and P – had been employed at the company during an earlier period. P started to work already in 1940 and since no data on air concentrations of cadmium dust before 1946 exist and a different method of manufacturing alkaline batteries was used in the early 1940's, P was excluded from further comparisons. Q was employed in 1957 and O in 1960, but both manufactured lead batteries during the first years of employment and were not exposed to cadmium oxide dust before 1963. Only three workers, O, P and R, used protection masks regularly.

The first estimates gave accumulated doses in the ranges of 8–51 mg, 8–75 mg and 8–87 mg cadmium, while the second estimates were in the ranges of 5–1 284 mg, 6–2 410 mg and 6–3 007 mg cadmium (Table 1). The correlation rates between the two series of estimates were around 90% but the second estimates were 0.63–25, 0.75–32 and 0.75–35 times the first estimates.

## DISCUSSION

The amount of 200 μg Cd/g wet weight in adult kidney cortex corresponds to a body burden of 120 mg cadmium in man. However, at high exposure levels, the liver will contain a larger proportion of the total body burden[3].

TABLE 1
Accumulated respiratory doses of mg cadmium, 1977.

| Case | Age 1977 | Years of employment | Biological half-time, in years | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Estimate I | | | Estimate II | | |
| | | | 10 | 20 | 30 | 10 | 20 | 30 |
| A | 30 | 2 | 8 | 8 | 8 | 5 | 6 | 6 |
| B | 28 | 2 | 8 | 8 | 8 | 8 | 8 | 8 |
| C | 43 | 3 | 11 | 12 | 12 | 27 | 29 | 30 |
| D | 57 | 3 | 11 | 12 | 12 | 40 | 43 | 44 |
| E | 56 | 4 | 14 | 15 | 16 | 41 | 44 | 46 |
| F | 31 | 4 | 14 | 15 | 16 | 45 | 49 | 50 |
| G | 53 | 4 | 14 | 15 | 16 | 56 | 60 | 62 |
| H | 42 | 4 | 14 | 15 | 16 | 58 | 63 | 64 |
| I | 58 | 5 | 17 | 19 | 19 | 103 | 115 | 119 |
| K | 34 | 7 | 23 | 25 | 26 | 204 | 236 | 248 |
| L | 48 | 9 | 27 | 32 | 33 | 260 | 313 | 333 |
| M | 60 | 12 | 33 | 40 | 43 | 433 | 546 | 590 |
| N | 46 | 13 | 35 | 43 | 46 | 604 | 862 | 978 |
| O | 53 | 17 | 41 | 53 | 58 | 532 | 749 | 848 |
| P | 58 | 20 | 44 | 59 | 66 | ? | ? | ? |
| Q | 58 | 20 | 44 | 59 | 66 | 582 | 784 | 869 |
| R | 56 | 29 | 51 | 75 | 87 | 1 284 | 2 410 | 3 007 |

If the critical concentration of cadmium in human kidney is assumed to be 200 μg/g, the kidney weight 300 g and the renal content 10% of body burden, the body burden might be as high as 600 mg cadmium without any clinical or subclinical signs of renal damage. The critical concentration limits for a compound are set to protect the most sensitive human being from disease. Thus, workers might have body burdens well above 600 mg without any signs of damage.

The absolute magnitudes of the doses estimated in this investigation are not reliable. The data on concentrations of cadmium dust in work-room air in earlier days are based on only a few, poorly defined measurements and the efficiency of protection masks might be higher or lower than 50%. The pulmonary absorption was assumed to be 25%. If 12.5% had been chosen instead, all estimates would have been reduced by a factor of 2. The biological half-time of cadmium might be shorter at high exposure levels and there is a possibility that the percentage of absorbed cadmium decreases with a higher exposure. Further, the respiratory dose constitutes only a part of the body burden. Much cadmium could be ingested by intake of contaminated food or fluids. Contaminated hands, face and cigarettes are also thought to be sources of significant exposure[6].

However, all these objections do not change the proportions between the two estimates. From this study it is clear that, when individual doses are to be computed, not only changes in the atmospheric concentration of the pollutant but also the actual time the worker has spent in the plant, should be taken into consideration.

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