

Occupational lead exposure in Finland

IV. The polyvinyl chloride plastic industry

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TOLA, S. Occupational lead exposure in Finland: IV. The polyvinyl chloride plastic industry. *Scand. j. work environ. & health* 1 (1975) 173—177. One hundred and fifty-two workers from ten polyvinyl chloride (PVC) plastic factories were studied for lead exposure. Blood lead (Pb-B) concentration was measured for all the workers, urinary δ -aminolevulinic acid (ALA) for 130 workers, erythrocyte δ -aminolevulinic acid dehydratase (ALA-D) activity for 59 workers, and blood hemoglobin concentration or 93 workers. The median Pb-B for all the workers was 37 $\mu\text{g}/100\text{ ml}$, and the highest median found for one factory was 63 $\mu\text{g}/100\text{ ml}$. The highest single Pb-B value found was 126 $\mu\text{g}/100\text{ ml}$. The jobs with the heaviest lead exposure were those of mixing and weighing lead stearate powder. It is assumed that replacing the powder with a granule form of lead stearate will diminish the hazard of lead exposure in the future. Urinary ALA concentrations and erythrocyte ALA-D activities corresponded well with the Pb-B concentration, but the hemoglobin values did not show any relation to lead exposure. It is concluded that in the PVC plastic industry of Finland the risk of exposure to lead is high and regular health examinations should be performed.

Key words: polyvinyl chloride, plastic, lead, blood.

Although cases of lead poisoning associated with the handling of lead stearate when manufacturing polyvinyl chloride (PVC) plastic had already been reported by the end of the 1950s (1, 2, 3, 4, 7, 11), this hazard did not arouse serious attention in Finland until 1969 when seven cases of lead poisoning were diagnosed at a PVC plastic factory in southern Finland. During the preceding 10 years all the diagnosed cases of occupational lead poisoning in Finland had been relatively mild, e.g., not a single case of lead palsy had been found. It was therefore somewhat shocking to find that the most serious cases of lead poisoning in 1969 came from a factory in which the lead hazard

had been neglected, obviously because of ignorance. When the cases of lead poisoning in that particular factory were evaluated, it became evident that there might be quite a few small PVC plastic factories in Finland with an unrecognized lead hazard. Therefore in 1971 and 1972 a survey was made of all Finnish PVC plastic factories. The results of the survey are reported in this article.

MATERIAL

Ten PVC plastic factories were located by the Institute of Occupational Health. Although all PVC plastic factories were to be included, it is possible that the attempt was not entirely successful since some factories were small and so recently founded that they did not appear in any register. In fact most of the factories located were not yet listed in the official

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industrial statistics of Finland at the time of the survey.

A total of 152 workers (147 men, 5 women) were studied. Their median age was 30 years (first and third quartiles, $Q_I = 23$, $Q_{III} = 43$ years, respectively). Their exposure time is shown in table 1, and their occupational distribution in table 2.

METHODS

As a measure of lead exposure, blood lead (Pb-B) concentration was determined for all the subjects. In addition the concentration of urinary δ -aminolevulinic acid (ALA) was measured for 130 subjects, blood hemoglobin for 93 subjects, and the activity of erythrocyte δ -aminolevulinic acid dehydratase (ALA-D) for 59 subjects. The laboratory methods and method controls have been described previously (5, 8). Information concerning age, occupation, and exposure time was collected with a questionnaire.

RESULTS AND DISCUSSION

Median values and ranges for the Pb-B concentrations of subjects from different factories are shown in table 3. The highest median was 63 $\mu\text{g}/100$ ml and the lowest, 21 $\mu\text{g}/100$ ml. The highest single

Table 1. Exposure times.

Exposure time	Number of workers
1—6 months	40
7—11 »	15
1—2 years	35
3—5 »	28
6—9 »	20
10—20 »	11
> 20 »	0
Not known	3
Total	152

Pb-B concentration found was 126 $\mu\text{g}/100$ ml. In four of the ten factories values exceeding the highest recommended level in Finland (70 $\mu\text{g}/100$ ml) were found. More than half of the subjects were employed in these four factories. This finding alone indicates that a high risk for lead poisoning exists within the PVC plastic industry. It should also be emphasized that a cross-sectional study such as the present one underestimates risk. Some of the most exposed workers may be on sick leave or may have been transferred to other jobs because of unacceptable Pb-B values and are thereby not represented in the group under study. Furthermore, the incidence of any extreme value during a period of time is always higher than the prevalence at a specified point in time.

The differences in Pb-B concentrations

Table 2. Blood lead concentrations ($\mu\text{g}/100$ ml) in workers from different occupational groups, along with the medians, quartile values Q_I and Q_{III} , and ranges.

Occupational group	Number of workers	Median	Q_I	Q_{III}	Range
Workers in factory C ^a	7	57	38	106	30—111
Weighers and mixers	58	53	30	73	11—126
Foremen	9	51	27	58	15—79
Packers in factory C ^a	4	42	35	50	34—53
Plastic mass preparers	13	32	20	54	16—78
Plastic machine workers	53	28	22	38	10—100
Workers performing miscellaneous activities, e.g., dishing, color making	6	18	15	38	14—37
Cleaner	1	17	..	..	
Clerk	1	12	..	..	
Total	152	37	24	58	10—126

^a Factory C only.

Table 3. Blood lead concentrations ($\mu\text{g}/100\text{ ml}$) of workers from different factories, along with the medians, quartile values Q_I and Q_{III} , and ranges.

Work place	Number of workers	Median	Q_I	Q_{III}	Range
A	13	63	43	77	29—126
B	41	55	39	76	24—101
C	18	54	37	75	11—111
D	9	38	35	48	11—59
E	7	37	27	52	25—60
F	1	37	..	..	..
G	9	31	18	48	11—63
H	6	28	35	48	23—71
I	20	23	20	28	14—44
J	28	21	15	27	10—62
Total	152	37	24	58	10—126

could be attributed, as anticipated, to the differences in the working methods and safety routines of the factories. The most crucial step seemed to be the handling of lead stearate powder during mixing and weighing (table 2).

Factory A, a cable factory in which PVC plastic was made for covering special cables, had the heaviest exposure. It is interesting to note that the median Pb-B concentration for workers in five cable factories in Finland was $36\text{ }\mu\text{g}/100\text{ ml}$ only, with a maximum value of $68\text{ }\mu\text{g}/100\text{ ml}$ (9). All five factories handled metallic lead only and had no PVC plastic production. Hence the major lead hazard in cable factories is nowadays more associated with the production of PVC plastic than with the handling of metallic lead.

Factory B, in which seven new cases of lead poisoning occurred in 1969, was the stimulus for the present survey. Although some technical improvements had already been made by the time of the survey, exposure was still unacceptable. The median for Pb-B was $55\text{ }\mu\text{g}/100\text{ ml}$, and the highest value was as high as $101\text{ }\mu\text{g}/100\text{ ml}$.

If only average Pb-B concentrations, in this case medians, are considered, it would erroneously seem that some of the factories had no serious lead hazard. However, the highest recommended Pb-B value, $70\text{ }\mu\text{g}/100\text{ ml}$, is meant for individuals and not for groups of workers. Recommended levels for groups of workers

are not used, but it is evident that such limits should be considerably lower than the accepted Pb-B of the individual. Because of the skewed distribution in occupationally exposed populations, average values are not very informative. Percentile distributions are to be preferred. The drawback of using mere average values is clearly illustrated in the present study. In 1973, when three cases of lead poisoning were reported from the entire PVC plastic industry (table 4), one came from factory J, which had the lowest median Pb-B concentration.

In Finland $40\text{ }\mu\text{g}/100\text{ ml}$ has been suggested (9) as a threshold for requiring periodical monitoring. In other words, if even one worker has a Pb-B value exceeding $40\text{ }\mu\text{g}/100\text{ ml}$, all exposed workers in the factory should be regularly monitored. According to this criterion all the PVC plastic factories included in this

Table 4. Cases of occupational lead poisoning in Finland from 1969 through 1973.

Year	Total number of cases	Number of cases in the PVC plastic industry
1969	37	7
1970	51	0
1971	51	4
1972	38	6
1973	55	3
Total	232	20

study required periodical monitoring of workers. However, most of the workers had not had any such examinations before the survey. This state of affairs illustrates the general ignorance of the lead hazard that prevailed in the PVC industry. However, although regular health examinations have been prescribed by law for lead exposed industries in Finland since 1962, the PVC plastic industry was not included in the list of lead exposed industries until 1971. This fact can to some extent explain the ignorance.

The Pb-B concentrations found in workers from different occupations are shown in table 2. In the table the workers from factory C are shown separately because the factory differed greatly from the others and it would not have been justified to include its workers in categories with the other workers. The factory is a department of the largest petrochemical plant in Finland. Today the most dangerous step of PVC plastic production is mainly located there, i.e., lead stearate powder is converted to a granule form. The procedure reduces the risk associated with mixing and weighing the powder by making it possible for other factories to use the granule form. It is therefore easy to understand that most cases of lead poisoning in the PVC plastic industry during recent years have emerged from this plant. Its safety control has been improving continuously however. Hence it seems advantageous to allocate the dangerous handling of lead stearate powder to only one location, where special attention is paid to safety problems, rather than to have it dispersed all over the country.

Among the occupations in the other factories, it was evident that the most dangerous jobs were the mixing and weighing. Both are procedures in which exposure to lead stearate powder dust is difficult to avoid. After the plastic mass is finished, working at the plastic machines is not associated with a high exposure to lead, and the single high Pb-B values found among these workers are more an illustration of the fact that they were also engaged in the mixing and weighing procedures.

Pb-B concentration is generally ac-

cepted as the best single test for determining lead exposure, while ALA and ALA-D are considered useful supplementary tests — although the high sensitivity of ALA-D has been claimed to make it impractical in occupational medicine. However, the hemoglobin value is too insensitive (8, 10). The results of the present study confirm these viewpoints. Hemoglobin values could not be used to differentiate between worker groups or factories and did not bear any relation to lead exposure. The median hemoglobin value for 93 workers was 15.3 g/l (range 11.6—18.0 g/l). ALA-D activities showed a close negative correlation to the concomitant Pb-B values. The median value for the ALA-D of 59 workers was 235 μ mol PBG/h/l RBC (range 25—1,156 μ mol PBG/h/l RBC). The medians and ranges of the ALA concentrations in the different factories are shown in table 5. The work place with the highest median exposure, as judged from the Pb-B concentrations, was the only factory with a median ALA value which exceeded the "normal" upper limit for individuals determined for this laboratory (9 mg/l). The highest single values were also found at the factories at which the Pb-B values were the highest. Factory J was the only exception. One of its workers had a high ALA concentration. It was the factory with the lowest median value for Pb-B. However, a case of lead poisoning was diagnosed there 2 years later. Such events support the opinion that more than one laboratory test

Table 5. Urinary δ -aminolevulinic acid concentrations (mg/l) of workers from different factories, along with the medians and ranges.

Work place	Number of workers	Median	Range
A	40	12	5—44
B	28	7	2—70
C	..	..	..
D	13	9	3—12
E	6	7	5—11
F	8	7	3—6
G	20	6	1—9
H	9	3	4—9
I	4	5	3—11
J	2	..	1—24
Total	130	7	1—70

should be used for monitoring. In Finland the measurement of urinary ALA is recommended in addition to the Pb-B measurement, which is considered an obligatory test.

In conclusion, the present survey confirmed that the PVC plastic industry in Finland is a high risk industry with respect to lead. Although there are considerable differences between factories and most of the exposure is associated with a few operations, regular monitoring in this industry seems necessary.

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