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Occupational lead exposure in Finland

VI. Final report

by SAKARI TOLA, M.D., SVEN HERNBERG, M.D., and RITVA VESANTO¹

TOLA, S., HERNBERG, S. and VESANTO R. Occupational lead exposure in Finland: VI. Final report. *Scand. j. work environ. & health* 2 (1976) 115—127. Between 1970 and 1973, 2,209 workers representing 30 different types of work were studied in Finland for lead exposure. The indicator of lead exposure was the blood lead concentrations (Pb-B) of the workers. The highest recommended value for Pb-B in Finland, 70 $\mu\text{g}/100$ ml of blood, was exceeded in the following types of work: PVC plastic manufacturing, lead scrap smelting, metal founding, shipbreaking, storage battery manufacturing, storage tank manufacturing and repairing, machine shop work, treating metal surfaces, paint manufacturing, car radiator repairing, spray painting, machine shop work (railway), and storage battery repair. The types of work with the highest average exposure were lead scrap smelting (Pb-B median 79 $\mu\text{g}/100$ ml, range 35—118), storage battery manufacturing (Pb-B median 66 $\mu\text{g}/100$ ml, range 19—101), metal founding (Pb-B median 53 $\mu\text{g}/100$ ml, range 6—108) shipbreaking (Pb-B median 49 $\mu\text{g}/100$ ml, range 26—106) crystal glass manufacturing (Pb-B median 41 $\mu\text{g}/100$ ml, range 12—82), car radiator repairing (Pb-B median 38 $\mu\text{g}/100$ ml, range 17—83), and PVC plastic manufacturing (Pb-B median 37 $\mu\text{g}/100$ ml, range 10—126). During the past 5 years cases of clinical lead poisoning have occurred in all of these types of work, and the patients received workmen's compensation. The usefulness of the national poisoning register in predicting the relative hazard of lead exposure in the types of work studied was evaluated with the aid of rank order correlation statistics. The analysis showed that the poisoning register is a useful indicator of lead exposure in the most exposed types of work. However, the present survey also revealed work in which the hazard had escaped recognition in this country: metal founding, car repairing, and car radiator repairing, for example. Although it seems possible to predict the most heavily exposed work types from national poisoning registers only, the detection of workers with less severe manifestations of toxic effects, or sometimes even poisoning, in other types of work first requires a systematic survey of all types of work with possible lead exposure, and then regular monitoring of all exposed workers.

Key words: lead exposure, lead works, occupational medicine, blood lead.

Although the literature on lead poisoning is overwhelming (13), there are only a few surveys which describe occupational lead exposure in a systematic manner (6, 27,

28, 33). In fact most knowledge of the occurrence and intensity of exposure has come from industrial consumption statistics and national registers of occupational diseases (11, 12, 15, 20, 21, 27, 28, 30, 33, 34, 46, 47). In addition the abundant case reports and the surveys that do exist on specific types of work (1, 2, 4, 5, 7, 9, 10, 14, 22, 24, 29, 31, 35, 45) mainly describe the occurrence of clinical poisoning, not the milder effects. Hence they are incomplete

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and do not create a comprehensive picture of occupational lead exposure and its health effects on a nationwide scale.

The best known survey of industrial lead exposure was made in the U.S.A. in 1936 to 1939 (6). The survey showed that more than half of the workplaces concerned used lead or its compounds. However the survey was very crude, and no measurements of exposure were made. Although work methods have changed since the 30s and the hygienic conditions of most workplaces have improved, the total amount of lead used annually has increased steadily (32), and cases of poisoning still occur. Thus the lead problem is by no means merely a historical one.

Since a comprehensive picture of occupational lead exposure on a nationwide scale was lacking and occupational lead poisoning was still very much a problem, we decided to study occupational lead exposure in Finland in a systematic way. The main purpose of the survey, performed in 1970—1973, was to provide data for administrative and preventive activities, and a detailed report has been published in Finnish (39). However the survey strategy, as well as many of the results obtained, may be of more general interest, and therefore this summary report has been written. The survey had the following main objectives: (a) evaluation of the degree of exposure among different worker categories in various types of work with the concentration of lead in blood (Pb-B) as the indicator, (b) estimation of the need for health surveillance in different types of work, and (c) evaluation of the total number of workers occupationally exposed to lead in Finland and their distribution in various types of work and various exposure categories. The latter two objectives, being of national interest only, have not been dealt with in this summary, but they were included in the more detailed Finnish report (39).

MATERIAL

Selection of the types of work and the workplaces

One objective of the survey was to obtain representative Pb-B measurements from

all types of work with even the slightest potential health hazard. The sampling strategy is presented in fig. 1. Work in which the use of lead was occasional, insignificant, or completely safe was not considered to pose a risk and was therefore excluded. The following types of work were excluded: (a) work with mostly a historical interest and only a few workers still involved and (b) work in which the use of lead was unlikely, even though listed in the literature as lead-exposed, and for which a telephone inquiry confirmed that no lead was used in any stage of the process or elsewhere. Also some types of work with only negligible amounts of lead were excluded after the work process was evaluated. In addition some types of lead exposed work are not done in Finland, e.g., lead compounds such as lead tetraethyl and lead pigments are not produced, and consequently such work is missing from our data.

After the primary exclusions were made, two principal sampling methods were employed (fig. 1). First all known workplaces from a particular industry were included whenever lead exposure was estimated to be heavy enough to cause a danger of poisoning. From the register kept on occupational diseases at the Institute of Occupational Health and the literature, we selected the following industries from which all workplaces were included: storage battery manufacturing (3 factories), lead scrap smelting (2 smelteries), shipbreaking (2 workplaces), crystal glass manufacturing (3 factories), and PVC plastic production (10 plants).

Second we used different statistical sampling systems to select types of lead exposed work. For the sampling two sources of information were used, namely, the Enterprise Register of the Central Statistical Office of Finland for the Helsinki area, and the industrial statistics of the Central Statistical Office of Finland.

The Enterprise Register was checked for all the types of work considered to have some degree of exposure to lead. Forty-seven different types of enterprises and 898 workplaces were found. A random sample of 10 % was drawn from a group of workplaces doing the same type of work when there were more than 100 work-

Fig. 1. Sampling strategy of the study.

places in the group; when there were 10 to 99 similar workplaces in a group, the random sample comprised 10 workplaces; and, if there were less than 10 workplaces in which the same type of work was done, all of them were included. Altogether, 63 workplaces could not be located. Although most of them had probably gone out of business, only 33 such instances could be verified. For 21 different types of enterprises (152 workplaces) only a telephone inquiry was made. In these cases it was apparent that lead was not likely to cause any significant exposure. The following 26 types of enterprises, with a total of 91 workplaces, were selected from the Enterprise Register for further study: paint and varnish producers, chemical producers, china manufacturers, decorative ceramic makers, brass foundries, metal sheet manufacturers, sheet metal shops, treaters of metal surfaces, repair shops (general), industrial machine manufacturers, machine shops, machine repair shops, machine installers, radio and telephone manufacturers, electric lamp manufacturers, shipbuilders,

boat manufacturers, car manufacturers, car repair shops (general), car radiator repair shops, other specialized car repair shops, musical instrument manufacturers, sheet metal shops in the construction industry, plumbing firms, painting firms, service stations.

From the second sampling source, the industrial statistics of the Central Statistical Office of Finland, all workplaces in Finland which have used lead as a raw material during a given year can be located. All types of work in which the use of lead could be anticipated were included. The workplaces listed under the following headings were considered for inclusion in the study: lead oxides, red and orange; unprepared lead, not alloyed; white metal, lead; other unprepared, not alloyed lead; lead scrap; rods and shape rods, lead, lead wire; sheet and hoop, lead; thin sheet lead, lead powder and scales; pipes and hollow rods; other lead works; lead storage batteries. Altogether 169 workplaces were found, and an inquiry was sent to all of them. After two mailings, 166 (98 %) of

Table 1. Decile distributions and ranges of the blood concentrations ($\mu\text{g}/100\text{ ml}$) found in different types of work in Finland.

Type of work	Number of work- places	Number of workers	Deciles									Range
			10	20	30	40	50 (median)	60	70	80	90	
Lead scrap smelting	2	32	55	64	70	75	79	84	89	95	100	35—118
Storage battery manufacturing	3	137	46	51	55	59	66	71	76	80	86	19—101
Metal founding	7	45	19	27	40	46	53	66	76	82	93	6—108
Shipbreaking	2	13	31	37	42	45	49	54	60	67	77	26—106
Crystal glass manu- facturing	3	49	20	25	29	35	41	43	47	50	60	12— 82
Car radiator repair	5	56	21	24	27	32	38	41	45	48	55	17— 83
PVC plastic manu- facturing	10	157	17	22	26	30	37	45	54	64	76	10—126
Lead glazing	1	26	22	27	30	33	37	39	43	47	51	16— 58
Cable manufacturing	5	36	14	19	24	29	36	41	45	48	58	12— 68
Manufacturing and repair of storage tanks	10	48	13	17	21	29	34	40	49	56	64	11— 99
Storage battery repair	4	18	21	24	26	29	33	42	54	62	67	12— 70
Scrap metal shop work	10	30	22	27	30	32	33	35	42	48	56	15— 62
Treating metal surfaces	6	45	12	16	18	22	29	32	37	43	61	10— 97
Car repair	13	165	17	19	22	25	27	29	33	38	45	10— 80
Machine shop work (railroad)	5	130	12	16	19	21	26	32	36	40	48	6— 72
Ammunition manu- facturing	3	28	11	15	18	21	25	27	31	36	44	8— 62
Sheet metal work (construction industry)	7	53	15	19	22	24	25	28	31	35	39	10— 47
Paint manufacturing	12	88	13	15	18	21	24	27	32	37	57	5— 85
Shipbuilding	4	255	16	18	21	23	24	26	29	32	38	10— 65
Sheet metal work (miscellaneous)	8	47	12	15	18	20	22	25	27	30	36	9— 45
Machine shop work	13	206	13	15	17	19	21	23	26	29	38	9— 98
Iron and steel founding	8	42	15	16	17	20	21	24	29	37	45	11— 58
Painting	12	80	10	12	15	18	20	24	30	41	48	5— 72
Service station work	10	76	13	15	17	18	20	21	23	27	30	11— 40
Plumbing	8	92	12	14	16	18	19	20	23	26	31	5— 55
Manufacturing electric lamps	3	22	12	16	18	18	19	20	21	22	25	12— 33
Telephone repair and installation	1	67	10	12	14	15	17	18	21	23	28	7— 41
Manufacturing radio and telephone equipment	5	52	8	10	11	12	13	14	15	17	20	7— 32
Traffic police work	1	28	9	11	11	12	13	15	16	17	18	9— 20
Streetsweeping	1	86	9	10	10	11	12	13	14	15	18	7— 30
Total	182	2,209										

questionnaires had been returned. When necessary, the place in question was telephoned for additional information. On the basis of the information attained, 67 workplaces were selected for further study, but as many as 99 workplaces were judged to have no or insignificant lead

exposure. This somewhat surprising result is probably explained by the age of the statistics.

In addition to the sampling procedures described, 10 of the 38 scrap metal shops in Helsinki were included in the study by random sampling.

Selection of workers at the workplaces

The following groups of workers from a workplace were included in the study: (a) all workers from a workplace were included from such industries as storage battery manufacturing and lead scrap smelting and from the many small workplaces employing only a few workers, (b) workers doing a specific job in an enterprise were all included when former knowledge of the workplace or type of enterprise indicated that it was necessary, (c) all workers belonging to one work shift were sometimes included, and (d) various statistical sampling systems were applied in the selection of workers from large workplaces such as shipyards and cable manufacturers.

METHODS

Exposure was assessed entirely from Pb-B measurements, determined by atomic absorption spectrophotometry (18). Because of the well-known difficulties involved in this analysis (3, 8, 19), a strict method of control was applied. All the determinations were performed in duplicate (method error $2.1 \mu\text{g}/100 \text{ ml}$), and "spiked samples" were added to the analytical series from time to time. In addition we participated in an international control program, including parallel measurements with seven Scandinavian and one American laboratory. The results of these method controls have been published earlier (25, 26, 36). On the whole, the accuracy of the method was acceptable.

RESULTS

All workplaces involved in the same type of work were treated together irrespective of the sampling procedures applied in the selection of workplaces for the study. Thus workplaces doing the same type of work may have been selected with either of the sampling procedures. This difference does not influence the conclusions drawn from the results, however, since the method of sampling did not bias the selection.

Table 1 presents the Pb-Bs from the most important types of work as decile distributions and ranges, ranked according

to the highest median value. It should be emphasized that the hazard of exposure to lead should not be evaluated from median or average values only, since serious underestimates may then occur. The distribution is usually skewed, and hence the upper range, which is more informative of the risk of poisoning for individuals, is not readily evident from, e.g., standard deviations or quartiles. For this purpose, decile or percentile distributions are far more illustrative.

Pb-B values exceeding the highest recommended level for individual workers in Finland, $70 \mu\text{g}/100 \text{ ml}$, were found in PVC plastic production, lead scrap smelting, metal foundry work, shipbreaking, storage battery manufacturing, storage tank manufacturing and repair, machine shops, treating metal surfaces, paint production, car repair work, painting, and railroad machine shop work.

Table 2 shows the cases of lead poisoning compensated as occupational diseases in Finland during 1969 through 1974. Most, but not all, of the previously mentioned types of work are represented. During these years the number of cases increased steadily. One reason is the more effective surveillance resulting from the present survey. Another is a change in diagnostic criteria; quite mild cases are nowadays accepted for compensation (Vaaranen, to be published).

Table 3 shows the incidence density rates for lead poisoning in the most important types of work. These are crude estimates only because the number of exposed workers in every type of exposed work is not accurately known. However, it is quite evident that the incidence density is highest in lead scrap smelting.

In order to evaluate the usefulness of national poisoning registers in the assessment of the relative intensity of lead exposure in various types of work, we correlated the incidence densities of lead poisoning in different work during 1970–1973 to the medians and upper ranges of the Pb-Bs found in the present survey. The rank order correlations between the incidences and both the median values ($r = 0.59$) and the upper ranges ($r = 0.61$) of the Pb-Bs were statistically highly significant ($p < 0.001$). This result indicates that poisoning statistics may be useful in-

Table 2. Cases of lead poisoning compensated as occupational diseases in Finland during 1969 through 1974 according to the Occupational Disease Registry of Finland, kept by Institute of Occupational Health.

Year	Type of work	Number of cases	Year	Type of work	Number of cases
1969	Storage battery manufacturing	10	1972	Lead scrap smelting	16
	Lead scrap smelting	9		PVC plastic manufacturing	6
	PVC plastic manufacturing	7		Storage battery manufacturing	5
	Shipbreaking	4		Cable manufacturing	4
	Crystal glass manufacturing	4		Spray painting	2
	Plumbing	3		Plumbing	1
				Metal manufacturing	1
1970				Machine shop work (railroad)	1
				Metal founding	1
				Manufacturing and repair of storage tanks	1
	Total	37		Total	38
			1973	Lead scrap smelting	27
				Storage battery manufacturing	7
				Metal founding	7
				Machine shop work (railroad)	5
				PVC plastic manufacturing	3
				Plumbing	2
				Printing	1
1971				Total	52
	Lead scrap smelting	21	1974	Storage battery manufacturing	26
	Storage battery manufacturing	20		Lead scrap smelting	26
	Crystal glass manufacturing	3		Plumbing	15
	Plumbing	3		Metal founding	10
	Shipbreaking	2		Metal manufacturing	4
	Spray painting	1		Cable manufacturing	2
				PVC plastic manufacturing	1
1972				Chemical manufacturing	1
				Car radiator repair	1
				Shipbreaking	1
				Paint manufacturing	1
				Enameling	1
				Total	89
	Total	50			
1973	Storage battery manufacturing	19			
	Lead scrap smelting	18			
	PVC plastic manufacturing	5			
	Shipbreaking	2			
	Spray painting	1			
	Miscellaneous cleaning work	1			
	Cable manufacturing	1			
	Car radiator repair	1			
	Storage battery repair	1			
	Metallurgical research work	1			
	Car repair	1			
1974	Total	51			

indicators of lead exposure, at least for the most exposed types of work, and the statistics provide a means of assessing risk without cumbersome surveys.

SUMMARY OF FINDINGS FROM DIFFERENT TYPES OF WORK

Lead scrap smelting

Workers in lead scrap smelting are known to be heavily exposed to lead (28, 33, 34). In Finland several cases of lead poisoning have occurred among these workers annually, and the incidence density has been

extremely high (table 3). Between 24 and 52 % of all diagnosed cases have come from this industry from 1969 through 1974. The distribution of Pb-Bs presented in table 1 shows that approximately two-thirds of the values were above 70 µg/100 ml and half of them exceeded 80 µg/100 ml. These Pb-Bs correlate with the high rate of poisoning that has occurred. A more detailed report has been published earlier (37).

Storage battery manufacturing

Storage battery manufacturing is a recognized source of lead exposure (6, 45).

Table 3. Yearly incidence densities (cases/1,000 person-years) of lead poisoning in different types of work, 1969–1974.

Type of work	1969	1970	1971	1972	1973	1974	1969–1974
Storage battery manufacturing ^a	67	133	127	33	47	173	97
Lead scrap smelting ^a	180	420	360	320	540	480	383
Shipbreaking ^a	200	100	100	0	0	50	75
PVC plastic production ^a	35	0	25	30	15	5	18
Crystal glass manufacturing ^a	27	20	0	0	0	0	7.8
Plumbing ^b	6	6	0	2	4	30	8
Spray painting ^b	0	1.4	1.4	2.9	0	0	1.0
Cable manufacturing ^b	0	0	2.9	11	0	5.7	3.3
Metal founding ^b	0	0	0	0.5	3.4	4.9	1.5

^a The incidence density is considered to be a fairly accurate estimate.

^b The incidence density is considered to be less accurate because of uncertainties in the estimation of the denominator.

A detailed account of lead exposure in this industry in Finland has been published earlier (41). Of the workers in this study, 44 % had Pb-Bs exceeding 70 $\mu\text{g}/100\text{ ml}$. However, since the completion of the survey, the situation has changed considerably. The largest factory has been completely rebuilt, and health aspects were taken into consideration when the new factory was planned. A comparison of the results of the periodical health examinations made in 1971 and 1974 clearly illustrates the improved situation. In 1971 when 97 workers were examined, the mean value for Pb-B was 68 $\mu\text{g}/100\text{ ml}$, and 52 workers had Pb-Bs exceeding 70 $\mu\text{g}/100\text{ ml}$. In 1974 the mean Pb-B of 92 workers was 38 $\mu\text{g}/100\text{ ml}$, and only three values exceeded 70 $\mu\text{g}/100\text{ ml}$.

Metal founding

In metal founding, including brass founding, lead is used to make different alloys. At the time of this survey, no cases of lead poisoning had been reported from metal foundries in Finland and the hazard was considered *a priori* to be moderate only. However, a year later, the foundries in Finland were thoroughly surveyed (44) and lead in the workroom air was measured. Lead concentrations above the threshold limit value (TLV) of 0.15 mg/m^3 were found in 25 % of the measurements made from the breathing zone of the workers near the ovens. Since the

metal foundries are often small and their hygiene is poor, it is easy to understand that unacceptable Pb-B concentrations are common among their workers. Obviously, ignorance was the reason for the lack of reports of lead poisoning from this industry. Indeed, as a result of the present survey, more effective monitoring has revealed several cases of lead poisoning during the last few years (tables 2 and 3).

Shipbreaking

Shipbreaking exposes workers to high lead concentrations (24, 29). Exposure derives from welding and burning old ship structures containing lead, mostly old lead pigments. In Finland several cases of poisoning have been reported during the last few years (table 2 and 3), and the distribution of Pb-Bs found in the survey confirms that there is a real hazard. This hazard was further substantiated in 1975 when a small new enterprise began operation. The Pb-Bs after about 6 months of work revealed an unacceptable exposure of all five workers, the mean Pb-B being 99 $\mu\text{g}/100\text{ ml}$ (range 82–110 $\mu\text{g}/100\text{ ml}$).

Crystal glass manufacturing

At the time of the survey all three of the existing crystal glass factories were included in the study. Later the one with

the poorest hygiene went out of business. Hence the results reflect a somewhat higher exposure than exists today. In fact after 1970 no cases of poisoning have been reported from this industry. Since periodical health examinations including Pb-B measurements are performed four times a year and would certainly reveal poisoning if present, there is reason to believe that the two remaining factories are comparatively safe.

Car radiator repair work

The repair of car radiators is generally performed in small shops employing less than 10 workers. Hygiene is often poor, and there is a general ignorance of the hazards of lead exposure. Welding and soldering lead-containing material is risky under such conditions. In this survey only two Pb-Bs exceeded 70 $\mu\text{g}/100\text{ ml}$ however.

PVC plastic manufacturing

In PVC plastic manufacturing lead salts, mainly lead stearate, are used as stabilizers. The hazard mainly occurs during weighing and mixing, after which there is little or no exposure. The intensity of exposure in the different factories differed considerably. The highest median Pb-B was 63; and the lowest, 21 $\mu\text{g}/100\text{ ml}$. Values exceeding 70 $\mu\text{g}/100\text{ ml}$ were measured among the workers of four factories, which employed more than half of the workers concerned. Hence PVC plastic production involves a significant lead hazard. In addition the fact that one case of poisoning in 1973 came from the factory with the lowest median Pb-B emphasizes the limitations of a cross-sectional study in assessing health risks. A more detailed description of lead exposure in the PVC plastic industry has been published previously (38).

Lead glazing

The median Pb-B of 26 lead glazing workers was 37 $\mu\text{g}/100\text{ ml}$, and the highest value found was 58 $\mu\text{g}/100\text{ ml}$. Although no cases of lead poisoning have been reported from this operation, there appears

to be enough exposure to warrant regular monitoring.

Cable manufacturing

Cable manufacturing is the largest consumer of metallic lead in Finland. Nevertheless only a few cases of poisoning have occurred in this industry. In the present study no values exceeded 70 $\mu\text{g}/100\text{ ml}$. The highest values were associated with smelting lead and stripping the lead cover from the cables. The cases of poisoning that have occurred were not connected with covering the cables with metallic lead, which is an old procedure. Instead they have occurred in the production of the PVC plastic that is used for the same purpose in a more modern method. Thus, quite surprisingly, replacing lead with plastic has substantially increased the hazard of lead poisoning instead of reducing it.

Manufacturing and repairing storage tanks

In the manufacture and repair of corrosion resistant tanks the risk of exposure to lead is high when work is done inside the tanks and, conversely, low when it is done outside them. This situation is illustrated by the wide range of the Pb-B values found in this type of work.

Repairing storage batteries

Storage battery repair is associated with much less lead exposure than storage battery manufacturing (42). Even though the hygiene in small shops may be poor, the most dangerous operations of storage battery manufacturing, i.e., production of lead oxide and pasting, are not done in small repair shops. The highest Pb-B found was 70 $\mu\text{g}/100\text{ ml}$.

Scrap metal work

The scrap metal shops were small workplaces with a few workers only. A separate report on the lead exposure of scrap metal shops has been published previously (37). Exposure stems from smelting scrap metal, often in open kettles and mostly out-of-doors. We considered exposure to

be moderate since there were no Pb-Bs exceeding 70 $\mu\text{g}/100\text{ ml}$. However, in 1974 one case of lead poisoning occurred in a scrap metal shop after the smelting process had been moved indoors.

Treating metal surfaces

Treating metal surfaces was not in general a high risk job, but sometimes it was associated with heavy exposure resulting in Pb-Bs as high as 97 $\mu\text{g}/100\text{ ml}$.

Car repair work

Car repair work has been dealt with in more detail in a previous report (41). In ordinary repair shops exposure was occasionally high enough to result in unacceptable Pb-B values. Since this finding was unexpected, all workers with Pb-Bs exceeding 70 $\mu\text{g}/100\text{ ml}$ were examined with special emphasis on finding an explanation for why the Pb-Bs were so high. No cause other than the occupation could be found. The job with the highest exposure was cleaning the motor with compressed air since the burned remnants of gasoline contain much lead in a highly dispersed form. Other jobs with substantial exposure were various soldering and welding operations.

Service station work

In service stations without repair activities, lead exposure is mostly due to the exhaust gases and the handling of leaded gasoline. The highest Pb-B found was 40 $\mu\text{g}/100\text{ ml}$. Lead exposure is clearly insignificant at these workplaces.

Machine shop work

Two groups of machine shops were studied: railroad shops and others. Work in the railroad shops consists, among other things, of welding and burning old railroad cars, which are covered with layers of lead paint. This work is comparable to that done in shipbreaking, although exposure seems to be lower. After some cases of poisoning had occurred, work conditions were improved.

In the other group of machine shops the highest exposure occurred in the founding and welding work, as well as in spray painting with lead-containing paints. The Pb-B of two workers exceeded 70 $\mu\text{g}/100\text{ ml}$.

Manufacturing ammunition

Workers from three ammunition factories were studied. Two factories made lead shots. Only one Pb-B in these factories exceeded 40 $\mu\text{g}/100\text{ ml}$ (43 $\mu\text{g}/100\text{ ml}$). The Pb-Bs in the third factory had an upper range of 62 $\mu\text{g}/100\text{ ml}$. The workers making the explosive mass containing lead azide had the highest values.

Sheet metal work

Sheet metal work, either in the construction industry or "miscellaneous," did not show a high risk for lead exposure. The range of Pb-Bs was rather narrow.

Manufacturing paint

In paint factories exposure was low in general, but some values exceeding 70 $\mu\text{g}/100\text{ ml}$ were found among men employed in mixing and weighing lead-containing pigments. This work phase is obviously hazardous since pigments are usually in a powder form. Although the work methods have been improving continuously, one case of lead poisoning was recorded from paint production in 1974.

Shipbuilding

Four shipyards were included in the survey. More detailed data have been published earlier (40, 43). Exposure was surprisingly low in comparison with some previous reports (24, 29) from other countries. No Pb-B exceeded 60 $\mu\text{g}/100\text{ ml}$. The highest concentrations occurred among welders, painters, plumbers, and repairmen. Safe working methods may explain the fairly low exposure, e.g., substitution of lead-containing paint with less hazardous materials. In addition shipbreaking is not performed at ordinary shipyards in Finland.

Iron founding

In the iron foundries lead exposure was not high, but the Pb-B of some workers exceeded 40 $\mu\text{g}/100\text{ ml}$. A survey of Finnish foundries however showed lead in the air of iron foundries (44). Values exceeding the TLV of 0.15 mg/m^3 were found in 0–5 % of the measurements. Only workers near the ovens are exposed to lead fumes. The lead probably comes from the scrap metal used as a raw material.

Painting

Lead exposure in painting depends of course on both the paint and the method used. Only spray painters had elevated Pb-Bs, whereas painters painting with a brush or a roller invariably had values lower than 30 $\mu\text{g}/100\text{ ml}$. One of the spray painters had a Pb-B exceeding 70 $\mu\text{g}/100\text{ ml}$.

Plumbing

Plumbing is a classical "lead work." In Finland some cases of poisoning have occurred almost every year. Nevertheless, the exposure registered in the present study was relatively low. The main reason for the low level may be a random error from a too restricted sample.

Manufacturing electric lamps

In manufacturing electric lamps, lead exposure stems from soldering. Hygiene in these factories was usually good. Local exhaust systems were common, and the Pb-Bs were generally low.

Telephone repair and installation

Workers who install and repair telephones were studied in another survey (26). Exposure was slight and the highest Pb-B was 41 $\mu\text{g}/100\text{ ml}$. Although such work is usually done in places with inadequate ventilation, exposure does not seem to cause any health hazard.

Streetsweeping and traffic police work

The exposure of streetsweepers and traffic policemen mainly derives from automobile exhaust (22, 23). The results in table 1 are from Nordman's study (26); they clearly show that exposure from traffic is insignificant in Helsinki.

Printing

The printing industry had been studied previously (17). The study included a random sample of 10 % of the 275 printing shops in Helsinki. Only one value exceeded 70 $\mu\text{g}/100\text{ ml}$ and the mean Pb-B of the 105 workers studied was 29 $\mu\text{g}/100\text{ ml}$.

Chemical production

The workplaces registered as producing chemicals did not show significant lead exposure in the preliminary investigations. Only one workplace making glues and jointing materials was studied. No high values were found, and the median was 15 $\mu\text{g}/100\text{ ml}$.

General repair work

Repair shops were so miscellaneous that no generalizations could be made. The median Pb-B for 17 workers was 19 $\mu\text{g}/100\text{ ml}$ and no values exceeded 40 $\mu\text{g}/100\text{ ml}$. The median Pb-B for 19 workers from three different machine repair shops was 16 $\mu\text{g}/100\text{ ml}$, and none of the workers had a value exceeding 40 $\mu\text{g}/100\text{ ml}$.

Other types of work

In addition to the previously discussed work, one factory manufacturing matches, three small rubber factories, and one ice-hockey puck manufacturer were studied. The Pb-Bs of two workers making matches were 14 and 18 $\mu\text{g}/100\text{ ml}$. The median Pb-B for 11 rubber workers was 16 $\mu\text{g}/100\text{ ml}$; no value exceeded 40 $\mu\text{g}/100\text{ ml}$. The Pb-Bs of two ice-hockey puck makers were 14 and 16 $\mu\text{g}/100\text{ ml}$.

DISCUSSION

According to a Finnish survey of 1,581 persons (26), a Pb-B in excess of 40 $\mu\text{g}/100$ ml is always higher than the Pb-Bs of the general Finnish population. In the survey 23 $\mu\text{g}/100$ ml was the highest value measured, the mean being about 10 to 12 $\mu\text{g}/100$ ml.

It is well known that the effects of lead on the heme synthesis become measurable at 40 $\mu\text{g}/100$ ml as an accumulation of protoporphyrin in the erythrocytes and an increased excretion of σ -aminolevulinic acid and coproporphyrin III in the urine (16). Such effects are considered unacceptable in the sphere of public health (48), but in the sphere of occupational health it is assumed that a slight inhibition of heme synthesis has no adverse effect. This dualism is at least partly overcome by the requirement of regular monitoring of occupationally exposed workers and the belief that adverse effects should be revealed before any irreversible damage has occurred. Accordingly regular health surveillance is required as soon as functional disturbances occur or when the Pb-B exceeds 40 $\mu\text{g}/100$ ml.

If one takes into consideration that in industries with high exposure, e.g., storage battery manufacturing and lead scrap smelting, periodical examinations up to six times a year are prescribed by law (39), the present survey indicates that at least 20,000 health examinations should be made annually in Finland. As the number of Pb-B measurements in 1974 was about 6,000 only, approximately 70 % of the workers needing surveillance were neglected. In 1975 the situation had improved somewhat — the number of analyses rose to 8,000 — but still the premises for allowing Pb-Bs to be higher in occupationally exposed groups than in the general population were not fulfilled.

The validity of a survey on lead exposure relies on the accuracy and precision of the analytical methods. Therefore, a strict control was applied in the present study. As reported previously, its results were acceptable (25, 36).

Concomitantly with the present survey, the Pb-B of the general rural and urban

populations of Finland were studied (26). Thus a good reference was available, and it was possible to assess the contribution of occupational exposure to the average Pb-B. The highest mean Pb-B of the various urban and rural subgroups was 12.3 $\mu\text{g}/100$ ml, and the highest single value measured was 23 $\mu\text{g}/100$ ml. Consequently, if a group of workers has an average Pb-B significantly exceeding 12 $\mu\text{g}/100$ ml, at least some additional exposure from occupational activities must be present.

The representativeness of results from different types of work differs greatly in the survey. For some types of work all workplaces and even all workers were included in the survey. But for most types of work various statistical sampling procedures were applied, and the uniformity of the process involved can be criticized. The primary exclusion of work with historical interest only seems reasonable, but there might have been some weaknesses in the preliminary investigations. A telephone inquiry may be unreliable; it can even be completely erroneous if there is deliberate misleading. However such a practice does not seem likely because, if revealed, it could result in legal action. Nevertheless, results obtained from some workplaces included in the study suggest that false information may have been given out of ignorance. Moreover some types of work may have gone unnoticed in spite of all our efforts to be complete. However, consumption statistics suggest that they cannot pose any significance. In addition to the uncertainties in deciding which types of work should be studied, the sampling was not satisfactory for all types of work for two principal reasons. First the sampling based on the Enterprise Register had to be restricted to the Helsinki area, and second the statistics on small enterprises were outdated. New enterprises appear and old ones vanish so frequently that no central register can be up-to-date.

An estimate of the number of workers exposed to lead in various types of work would be valuable, but unfortunately the procedures applied in the study were not good enough to allow a reliable estimation of the number of workers ex-

posed to a given intensity of lead in the whole country. A conservative guess would be that some 15,000 to 20,000 workers have a Pb-B exceeding 40 $\mu\text{g}/100\text{ ml}$ at any given point in time. However the number of workers needing monitoring is considerably greater, because it is not possible to predict which Pb-Bs will actually exceed the limit in a group of unexamined workers. Hence the preceding estimate of an annual need of 20,000 Pb-B measurements is probably much too conservative. Unfortunately it was not possible to conduct the sampling in a way that would permit more reliable estimations of the national need for monitoring.

For the prevention of excessive exposure, good knowledge of where it occurs is important. The fact that the number of compensated cases of lead poisoning and the Pb-B values found in the present survey correlated well shows that the most dangerous types of work were already known, although not yet satisfactorily controlled. Nevertheless, some types of work with exposure high enough to cause poisoning would have remained unrecognized if only the poisoning register had been consulted. For example, metal foundries and car radiator repair shops showed high Pb-Bs, but no cases of poisoning had been reported in these types of work. However, the usefulness of a survey like the present one should not be judged merely from the point of view of finding new cases of poisoning. Occupational health of today should be able to prevent even less severe manifestations of toxic effects. Therefore it is important, as a first step, to identify all categories of workers who could be affected. Next an efficient health surveillance program must be organized. The ultimate solution of the problem of course is technical.

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