Carcinogenic Chemicals in the Occupational Environment

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Abstract: A survey of occupational carcinogens by the Institute of Occupational Health, Finland shows that more than 100 000 workers are exposed to carcinogenic substances. The most common exposures are silica, wood dust, tobacco smoke and lead compounds. Based on biological monitoring of workers over the years it appears that overall lead exposure has decreased but exposure to styrene, trichloroethylene and tetrachloroethylene has decreased only slightly or remained constant. The biological monitoring data are based on samples sent by the workplaces on their initiative presenting no scientifically selected sampling. Thus due caution is needed in the interpretation of the trends.

For more than half of the chemicals or agents, classified by the International Agency for Research on Cancer as human carcinogens (International Agency for Research on Cancer, 1987), the evidence is coming from occupational exposure. In addition to specific chemicals or agents IARC has considered several occupations causing a risk of cancer even though the chemicals or agents have not been specified, usually due to exposure to a mixture of chemicals.

Cancer is caused by exposures one or more decades ago, due to a long latency in the development of the disease. Thus many occupational carcinogens, classified by IARC, were detected among workers who were exposed usually between the 1920's and 1960's. Even though many principles in technology have not dramatically changed over the decades in western industrialized countries, the arrangement of work has. Automation, closed systems and robots have in many instances decreased the exposures dramatically in spite of increased output.

The aim of this paper is to give an overview of the knowledge of occupational exposure to carcinogenic substances in Finland. It is important but difficult, due to sparsity of data, to review exposure time trends. On the other hand many new chemicals, with unknown toxicological properties, have been taken into use. As typical present day exposures are to low concentrations of many chemicals, short term tests for genotoxic activity and molecular epidemiology studies in exposed workers are recommendable tools in future cancer prevention (Farmer et al., 1987; Perera, 1987; Bartsch et al., 1988).

Occupational Exposure to Carcinogens

Finland (population 5 million, total work force 2.4 million) instituted legislation concerning registration of workers exposed to listed carcinogens (IARC classes 1, 2A and 2B compounds with some important omissions such as formaldehyde) since 1978 (Alho et al., 1988). Employers are sending the reports annually to the Institute of Occupational Health where the registry (ASA) is maintained. The number of registered workers has increased steadily, probably indicating improving coverage. However, there are still severe underreporting in some areas, such as construction (asbestos being the main carcinogen), whereas in some other areas reporting is vigilant, e.g. laboratory personnel has been notified to the register even if small amount of a carcinogen have been used as a standard compound in well-controlled circumstances. Over the years the reporting principles have become more uniform, but, of course, the register only gives some idea on important carcinogens and their users.

In 1989 altogether 17 118 workers from 1899 departments were announced in the Finnish ASA registry. Fig. 1 shows the most commonly notified jobs in 1989 (Institute of Occupational Health, 1991). The most common occupations are engine repair men (17 % of the total), welders (14 %), metal plate workers (7 %) and engine installers (7 %). Miscellaneous job titles constituted 44 % of all the jobs.

Fig. 2 shows the most commonly reported carcinogenic agents which are chromium 6-valent compounds, nickel compounds, asbestos and benzene.

The ASA registry is an administrative institution and does not, due to underreporting, give a true number of the exposed workers. An extensive project at the Finnish Institute of Occupational Health has been carried out aiming at estimates of chemical exposure in the workplaces in Finland. Table 1 is using the data from this project, as far as available, in the estimation of the number and extent of exposure to suspected carcinogens in the Finnish workplace. Table 1 only lists

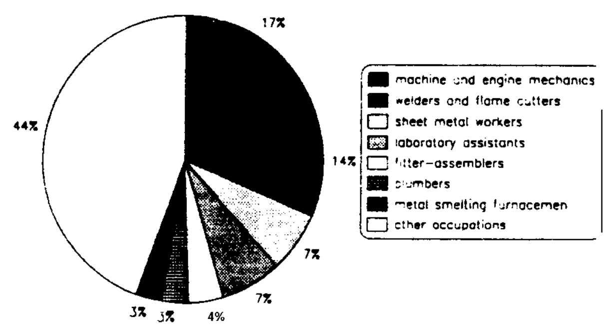

Fig. 1. The most commonly notified jobs in the Finnish ASA registry in 1989. The figure is based on 17,118 announcements in ASA. (Institute of Occupational Health, 1991).

those agents to which 1000 or more workers are exposed. Silica and wood dust, tobacco smoke, lead, hexavalent chromium and nickel compounds, mineral fibers and asbestos, polycyclic aromatic hydrocarbons and formaldehyde each affect 10 000 workers or more at concentrations indicated. In the project industrial hygienic measurements, mainly from the years 1980-1985 and biological monitoring data from 1987, were collected. The concentrations given in table 1 are estimates of time weighted averages. The estimates are usually based on several (10-300) industrial hygienic measurements collected at the project. Yet it must be admitted that the estimates are crude. For certain compounds, such as benzene, trichloroethylene, tetrachloroethylene and hydrazine, the exposures are periodic and it is particularly difficult to give any average exposure levels. In all, the exposure levels should be taken with due reservations.

In addition to the compounds listed in Table 1. close to 1000 workers are exposed to acrylonitrile, aniline, carbon tetrachloride, chlordane, cyclophosphamide, 1,2-dibromoethane, dimethyl sulphate, dioxane, epichlorohydrine, ethylene oxide, ethylene thiourea, 4,4-methylene-bis (2-chloroaniline) or MOCA. polychlorinated biphenyls and thiourea. Earlier chlorophenols were extensively used in the impregnation of wood and several thousand workers were involved.

It is difficult to estimate the total number of workers exposed to carcinogens because of mixed exposures. However, among the large groups, exposed to silica, wood dust, tobacco smoke and lead there are overlaps thus adding up the total over 100 000.

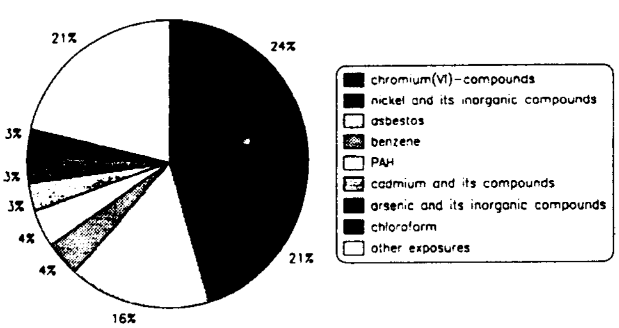

Fig. 2. The most commonly notified carcinogenic agents in the Finnish ASA-registry in 1989. The figure is based on 17,118 announcements in ASA. (Institute of Occupational Health, 1991).

Biological Monitoring of Exposure

Several exposures have been monitored from biological samples at the Finnish Institute of Occupational Health over the years. Styrene, tetrachloroethylene, trichloroethylene, methylene chloride, benzene, hexane, chlorophenols, PCB's, arsenic compounds, cadmium, chromium, lead, nickel and nicotine (tobacco smoke) are the most commonly monitored carcinogenic exposures. Usually the measurements are samples sent by the employers, and thus they do not constitute a random sample. Any conclusions from the files of biologically monitored workers should be drawn with due consideration.

Blood lead has been measured most extensively. In connection with a retrospective study, about 63 000 blood lead (B-Pb) measurements, conducted during 1973-1982 on approximately 22 000 workers from occupational lead exposure, have been transferred into a computer from the laboratory documents. In the same context, monitoring data on six organic solvents was also collected (nearly 22 000 measurements, 9 000 workers), including styrene (U-ManA), tetrachloroethylene (B-Per) and trichloroethylene (U-TCA) (Taskinen, 1990; Lindbohm, 1991). The number of measurements from other carcinogenic agents during the same time was considered too small for the study of reproductive hazards, and the data was not recorded.

Lead.
Fig. 3 shows blood lead concentrations for men and women between 1973-1982 in the monitoring data. According to the regulations, if the B-Pb of any worker in the workplace exceeds 2 µmol/l (= 40 µg/dl), all workers in similar tasks should be monitored. If very high B-Pb levels (>3 µmol/l) are found, the individuals should be monitored several times a year (Hernberg, 1984). To avoid overrepresentation of such repeated measurement, an individual is only entered once annually to Fig. 3 with the highest B-Pb result. The median values decreased from 1.3 to 0.7 µmol/l for men, which was a highly significant decrease ($p < 0.0001$, regression analysis). The highest values decreased from 6-8 µmol/l to 4.5 µmol/l among men and from 5-5.5 µmol/l to about 2.5 µmol/l among women.

The most clear-cut decrease took place during the first half of the 1970's in the industries where the levels were high in 1973. The industries where marked decreases took place are shown in Fig. 4, including lead smelting, founding, scrap metal and storage battery industries, and WC-plastics production. The estimation of B-Pb level is based on the annual mean of individual B-Pb results during each year when measured. A rapid decrease was also evident in glass and pottery manufacturing, graphics industry, paint manufacturing and motor vehicle inspection.

In some industries the decrease has been modest as shown in Fig. 5: chemicals and ammunition manufacture, and car repair works. In the chemical industry the highest exposures were related to the

Table 1.

Occupational exposure to suspected carcinogens in Finland

Exposure	No exposed	Branch (examples)	Concentration (µg/m³)
Silica	50000	Construction, founding, mining	100
Wood dust	20000	Sawmills, carpentry	1000
Tobacco smoke	20000	Bars, restaurants, airplanes	0.01 (as benzo(a)pyrene)
Lead comp.	20000	Engineering, founding, car repair, battery manufacturing	10
Mineral fibers	10000	Construction	0.1 F/cm³
Chromium 6 comp.	10000	Steel production, cutting, plating, welding, spray painting	50
Asbestos	10000	Construction, maintenance, brake repair	0.1 F/cm³
Nickel comp.	10000	Steel production, cutting, plating, welding	10
PAH	10000	Steel production, coking, founding, trucking	0.1 (as benzo(a)pyrene)
Formaldehyde	10000	Plywood, particle board production, laquering	500
Benzene	5000	Oil refining, gasoline distribution	500
Arsenic comp.	5000	Impregnation use of wood, glass industry, copper production	10
Styrene	3000	Lamination	100000
Radon	2000	Mining, underground work	1000 Bq/m³
Nitrosoamines	2000	Rubber, leather. metal industry	1
Cadmium comp.	2000	Hard soldering, founding, plastics production	1
Tetrachloroethylene	2000	Dry cleaning, degreasing	1000
Hydrazine	2000	Energy production	10
Methylene chloride.	2000	Pharmaceutical industry, paint removal	10000
Trichloroethylene	1000	Degreasing	1000
Chloroform	1000	Pharmaceutical industry	1000
Vinyl chloride	1000	PVC production, processing	500

manufacture and repair of storage tanks. In a small group of workers the B-Pb levels did not change during the study period. In car repair the exposure did typically not exceed the level 1.9 µmol/l. The measurements cover only a small part of the car repair industry.

In 1987, the highest B-Pb values were below 2 µmol/l in the PVC plastics manufacturing (Jaakkola & Anttila, 1992). In the storage battery industry no value exceeded 3 µmol/l. In foundries the highest values still exceeded 3 µmol/l, as well as in the railroad machine shops, miscellaneous metal and engineering industry, and various casting and torch-cutting works and in car radiator repair. Neither of the two large lead smelting enterprises were operating during that year. High B-Pb values were occasionally found also in stevedores and in the demolition of outdated explosives, but in these jobs there were, however, only few exposed workers.

styrene.

The number of workers monitored for styrene exposure increased rapidly from a few tens in 1973 and 1974 to 600-700 in the eighties. About one quarter of the measurements has been conducted on women.

Fig. 6 shows the percentiles of the yearly urine mandelic acid measurements from 1974-83 and 1987. "he overall exposure level of the workers monitored for styrene was high. Women were, on average, more exposed than men. About 60% of the measurements conducted on women, and about 35% conducted on men exceeded the present Finnish reference value of the exposed (3.2 mmol/l).

In 1987 the maximum mandelic acid concentrations were at the same level than in the early eighties. Upper quartiles and medians were somewhat lower in 1987 than in 1983. The overall decrease in exposure levels during seventies and eighties, as a consequence of technical improvement of ventilation systems, has been slow. The working methods have in large respects

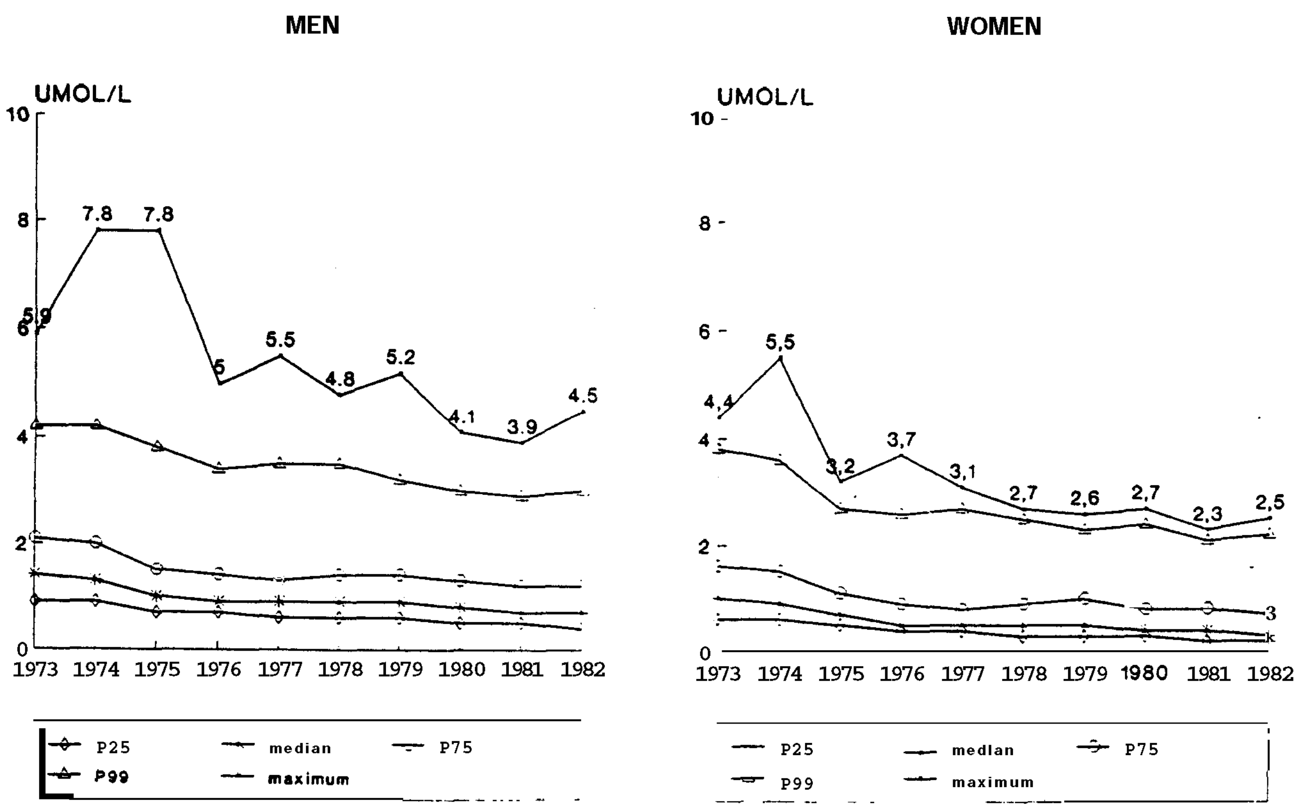

Fig. 3. Percentiles of the highest individual B-Pb results during the calendar years 1973-1982. Each year about 2,3004,900 men and 300-630 women were monitored for lead.

remained unchanged (Säämänen et al.,1991).

Because there is no information on the industry, occupation or work tasks in the data from 1974-83, the reason for the difference in exposure levels by sex is unknown. There may be more handlaminators among women than among men.

Tetrachloroethylene.

The number of monitored workers for tetrachloroethylene exposure has been around 150 per year during 1977-83 and in 1987, if only morning samples are included.

Only few workers had monitoring results higher than the Finnish reference value of exposed i.e 6.0 µmol/l (Fig. 7). There is no clear decrease in exposure levels during the period. The women were as exposed as the men although in the occupations there certainly is differences by sex. The washers are exclusively women and the men work as service-men in the laundries. The amount of workers in different industries is not available in the data before 1987, but the fur washers (1.2-7.5 µmol/l, geometric mean 2.7) and laundry workers **(0-14.0** µmol/l, geometric mean **0.8)** had the highest exposure levels in 1987 (Rantala et al.,1992). The industrial hygienic measurements in 1982-1985 indicated high short-term exposure in metal spray-washing work, **400*10^3** µg/m^3 on average.

Trichloroethylene.

Biological monitoring for trichloroethylene exposure has been conducted at the Institute since 1965. The amount of monitored workers was in its maximum in 1970. After that trichloroethylene has been replaced by tetrachloroethylene in dry cleaning work. In metal industry, on the other hand trichloroethylene has been replaced by 1,1,1-trichloroethane as degreasing agent. About 45% of the monitored workers were women.

The Finnish reference value of exposed (U-TCA 360 µmol/l) were exceeded by 10% of the workers. The yearly maximum exposure levels vary very much

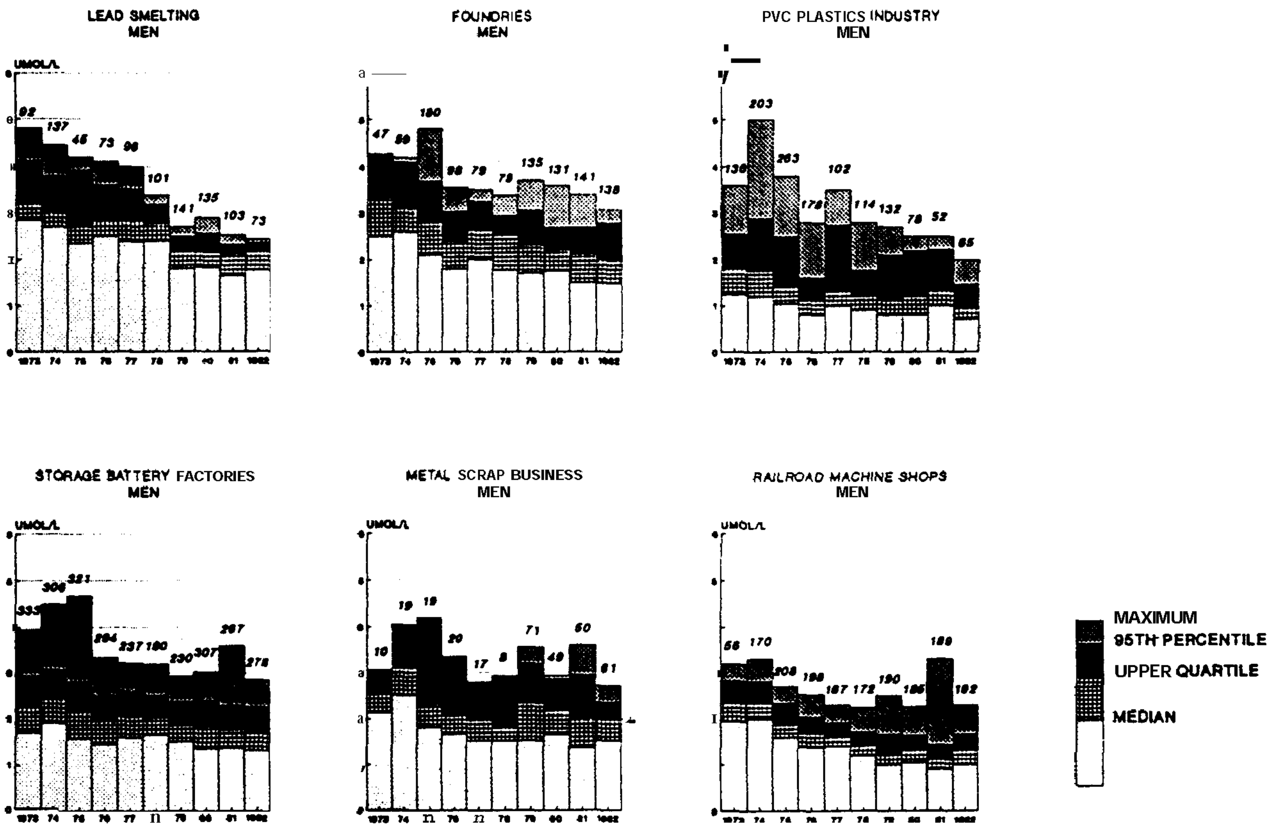

Fig. 4. The percentile of the individual yearly B-Pb mean values **during** 1973-1982 within selected industries. The number of workers measured each year shows on top of the bar

(Figure 8). The difference between the most exposed worker and the second can be many thousands pmols per liter. The upper quartiles and medians indicate that the typical exposure levels for trichloroethylene are decreasing during this period. The medians for both sexes were around 100 µmol/l in the middle sixties and about 40 to 50 µmol/l in the beginning of eighties.

The maximum urine trichloroacetic acid concentrations in 1987 was 860 µmol/l, suggesting a clear decrease compared to the earlier years. The highest exposure levels in 1986-1988 were found among metal degreasers (0-860 µmol/l, geometric mean 84) and painters (0-715µmol/l, geometric mean 70) (Rantala et al., 1992).

Conclusions

Based on the extensive survey of occupational carcinogens at the Institute of Occupational Health, Finland over 100 000 workers are estimated to be exposed to carcinogens, the most prevalent of which are silica, wood dust, tobacco smoke and lead compounds.

Some ideas about the trends in exposure can be obtained from historical data on biological monitoring, recorded at the Institute from occupational exposure to lead and some solvents. In the case of lead the register covers about 10% - 25% of all lead-exposed workers. The coverage is different in various industries. Workers in storage battery industries, lead smelting, metal foundries, railroad machine shop and the chemical industry were monitored most frequently.

As a whole a decreasing trend in B-Pb was seen between 1973-82. The periodic medical check-ups and compulsory lead-free periods of the high-exposed workers had an impact to lower B-Pb values in the plants with very high lead exposure. The decrease reflects technological development and hygienic improvements in the Finnish industry. Automation, closed and half-open emission sources, conveyors, improved ventilation, personal protective equipment

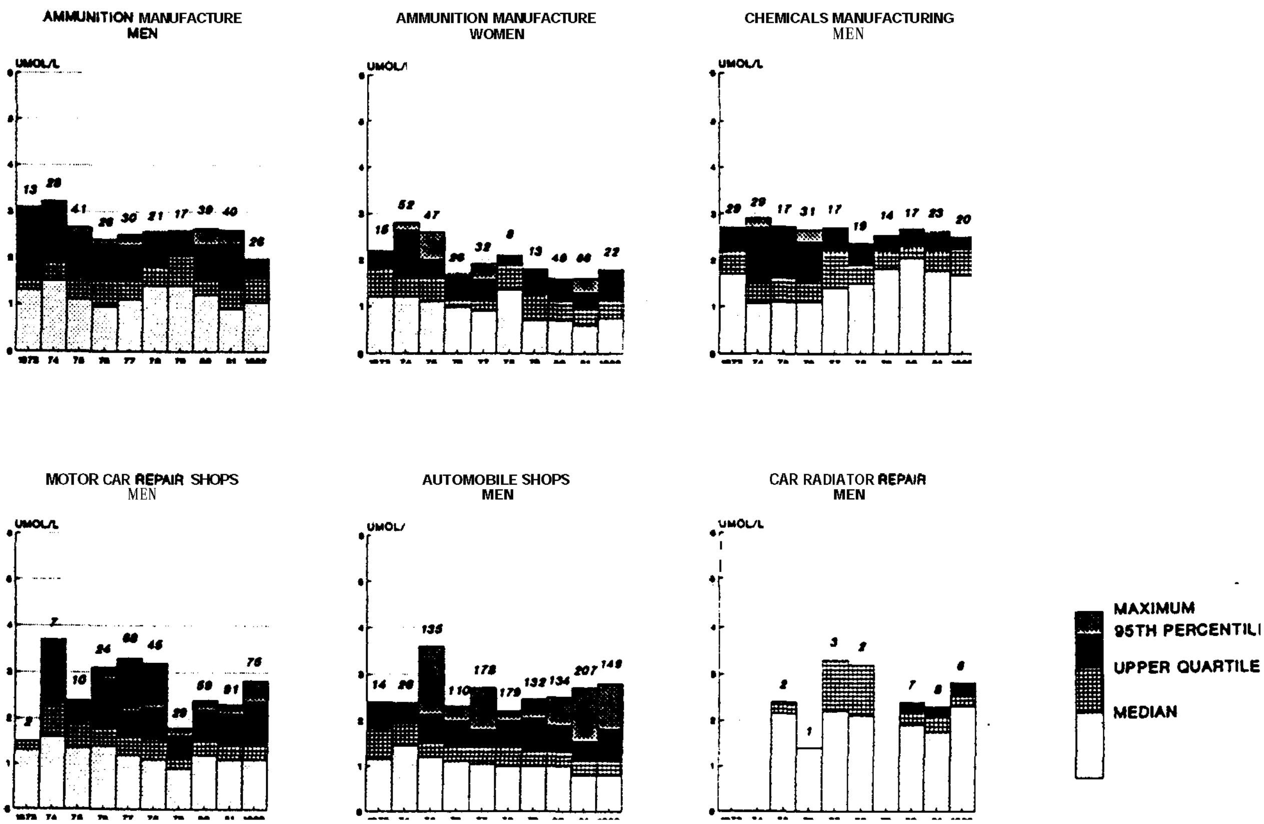

Fig. 5. The percentile of the individual yearly B-Pb mean values during 1973-1982 within selected industries. The number of workers measured each year shows on top of the bar.

Styrene

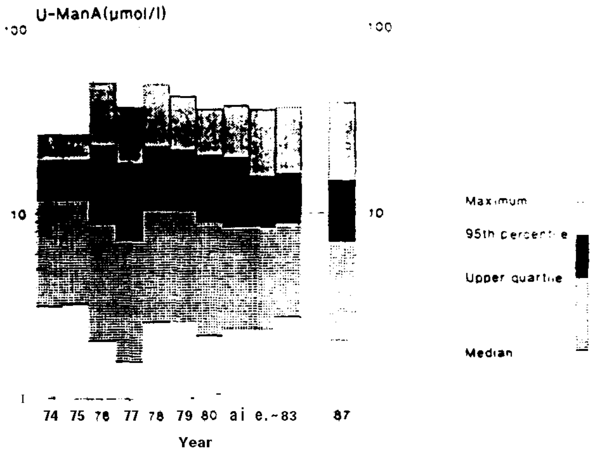

Fig. 6. The percentiles of urine mandelic acid (U-ManA) measurements in 1974-1983 and 1987 at the Finnish Institute of Occupational Health. Each year 100-700 workers were monitored.

and improved personal hygiene became common during 1970's. The plants were modernized. The materials were changed to safer ones. These are the common procedures for the reduction of exposure to occupational carcinogens, applicable to other exposures, and essential in the prevention of occupational cancer in general. Lead exposure diminished due to materials development especially in PVC plastics, paints, glass and pottery. In the graphics industry, the technology in type-setting changed.

In case of organic solvents the trends were not as clear-cut. For styrene and trichloroethylene a slight decrease while no change for tetrachloroethylene was observed. One has to be cautious in drawing conclusions from the relatively few and non-random measurements available. The data suggests, however, that as the work processes and other arrangements for these solvents

Tetrachloroethylene

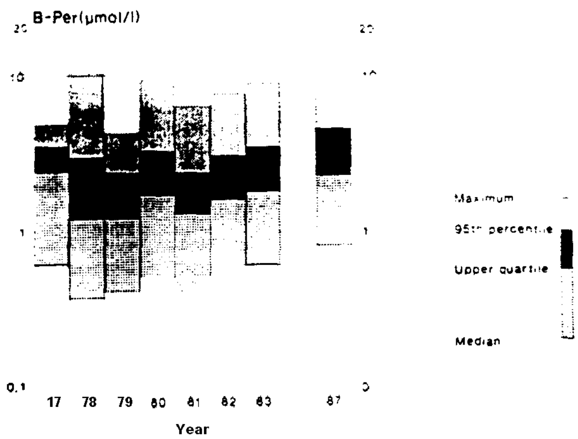

Fig. 7. The percentiles of blood tetrachloroethylene (B-Per) measurements in 1977-1983 and 1987, at the Finnish Institute of Occupational Health; only morning samples included. 100-200 workers were monitored each year.

Trichloroethylene

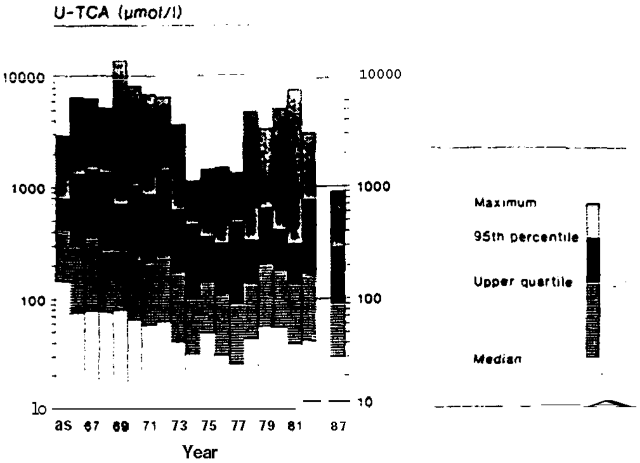

Fig. 8. The percentiles of urine trichloroacetic acid (U-TCA) measurements in 1965-1982 and 1987, at the Finnish Institute of Occupational Health. The median in 1987 <50 micromol/l, estimated value presented. 100-570 workers were monitored each year.

have not substantially changed, the exposures have remained fairly constant.

The occurrence of individual monitoring data and the large occupational survey give unique possibilities for future epidemiological studies on cancer among workers handling carcinogens in their occupational environment.

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