BIOLOGICAL MONITORING OF WORKERS EXPOSED TO INORGANIC LEAD IN SINGAPORE

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ABSTRACT

Medical surveillance of workers exposed to a lead hazard is a common practice in many countries. In Singapore, legislation on periodic medical examinations for lead exposed workers in factories was introduced in 1985. This paper discusses the results of the laboratory tests in workers exposed to inorganic lead in 1987.

The WHO recommended that the health-based limit for lead absorption be 40 μg/dL for adult male workers. Taking this level, we could divide the factories into a "higher risk" category and a "lower risk" one, the latter not having a single result of blood lead of 40 μg/dL or above. The former category included factories manufacturing PVC and lead storage batteries, with the highest level of 79.6 μg/dL found in PVC manufacture.

Of the 3 main races in Singapore, the Chinese have the lowest blood lead levels after adjusting for the type of industry, age and duration of exposure to lead. Age was correlated with the duration of lead exposure. The higher blood lead levels in Malays and Indians may have been contributed to by eating habits (eating with hands). The higher prevalence of smoking among Malays may also be contributory.

The results in this study, while reassuring that no worker was found with blood lead above 80 μg/dL, also indicated that workers in some factories were still exposed to a health risk.

Keywords: Lead exposure, blood lead, race

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The adverse health effects of lead are well known. The early symptoms of excessive lead absorption in workers are quite non-specific and include headache, fatigue and constipation. Anaemia of varying degrees is not uncommon. Other manifestations may include "colic" and weakness. Serious overabsorption of lead can cause paralysis and encephalopathy, although this would be uncommon now (1, 2). Renal damage may also occur (3).

Medical surveillance of workers exposed to a lead hazard is a common practice in many countries. In Singapore, legislation on periodic medical examinations for lead exposed workers in factories was introduced in 1985 (4). Such workers are to be provided pre-employment and six monthly examinations which include a clinical examination and, for inorganic lead exposure, an estimation of the haemoglobin and blood lead levels.

The examinations are carried out by designated factory doctors, and the results are monitored by the Department of Industrial Health of the Ministry of Labour.

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This paper discusses the results of the laboratory tests in lead-exposed workers in Singapore in 1987.

MATERIALS AND METHODS

Factories have to submit summary reports of the results of examinations to the Department of Industrial Health. In addition, they have to keep records of each examination for 5 years. From the summary reports received for one round of examinations in 1987, we contacted the companies for the detailed results. Clarifications were sought from the companies concerned where these were required. It was found that the various doctors who had conducted the examinations had sent the blood samples to 4 different laboratories.

A total of 53 companies was involved, and the examinations covered 771 workers. However, this study included only 658 workers after excluding:

a) all female workers, who numbered only 48 (6.2%)
b) persons of races other than the 3 major races – Chinese, Malay and Indian; these numbered 38 (4.9%)
c) 27 persons (in addition to the above) who had their blood tests in one laboratory which did not receive blood samples from any other company.

The study group therefore comprised only males of the 3 major races in Singapore.

For the analysis of blood lead, 2 laboratories used the graphite method and the third the flame method of atomic absorption spectrophotometry.

The data were analysed using the Chi-square test, analysis of variance and analysis of covariance. Analysis of covariance was used to adjust for age, duration of exposure to lead and industry group when comparing mean blood lead levels between the 3 races, with the

general linear modelling procedure in the statistical analysis system (SAS) software package.

RESULTS

The statutory medical examinations covered 771 workers in 53 factories (Table I). After excluding the groups mentioned above, the study group of 658 males comprised 297 Chinese (45.1%), 299 Malays (45.4%) and 62 Indians (9.4%). Their mean age was 34.1 years with a standard deviation of 8.1 years.

Table II shows the blood lead results according to the different industries and types of occupations. These seem to fall neatly into 2 groups, one where there were results equal to or exceeding 40 µg lead/dL (high risk industries) and the other where all the blood lead levels were below this value (low risk industries). The highest level was 79.6 µg/dL in PVC manufacture. The second highest level of 66.9 µg/dL was found in the manufacture of storage batteries.

Age, duration of exposure to lead, distribution by industry group and blood lead levels between the 3 races are compared in Table III. The Chinese workers were significantly older. There was no significant difference in the mean duration of exposure to lead among the 3 races. Age was correlated with duration of exposure to lead ($r = 0.53$, $p < 0.001$). The distribution of the 3 races was significantly different in the 2 industry groups. Malays were over-represented in the low risk industries.

After adjustment for age, duration of exposure and industry group, the Chinese had a significantly lower mean blood lead compared to the other races. (Chinese vs Malays : $p < 0.001$, Chinese vs Indians: $p < 0.001$, Indians vs Malays: $p > 0.05$).

Table I
Industries providing statutory medical examinations for lead-exposed workers, 1987

Type of industry/ Occupation	No. Factories	No. Workers
1 Manufacture of paints and pigments	11	88
2 Painters	10	92
3 Electronics	8	64
4 PVC manufacture	6	83
5 Shipbreaking	3	29
6 Manufacture of storage batteries	2	52
7 Manufacture of solder	2	16
8 Telecommunications	1	218
9 Manufacture of TV tubes	1	34
10 Welders in shipyards	1	28
11 Soldering of car radiators	1	20
12 Others	7	47
Total	53	771

DISCUSSION

In the biological monitoring of workers exposed to a lead hazard, the main indicator of overexposure is the blood lead level (1). A number of countries have adopted various blood lead levels, ranging from 40 to 70 µg/dL, at which affected workers are to be removed from further exposure (5). However, the WHO recommended 40 µg/dL (1.9 umol/L) for adult male workers as the health-based limit (6) which, if exceeded, would indicate the necessity for technical and personal preventive measures to be taken at the workplace. At 40µg of lead per 100 mls of blood, the effects of lead on haem synthesis become measurable as an accumulation of protoporphyrin in the erythocytes and an increased excretion of d-ALA

Table II
Blood lead levels in different industries

Type of Factory/Work	No. Fty	No. Workers	Blood Pb in µg/dL Mean	SD	Max	%>40
1 PVC manufacture	6	81	30.0	15.5	79.6	22.2
2 Storage battery manufacture	2	47	32.4	11.4	66.9	23.4
3 Shipbreakers	4	38	36.8	9.7	62.0	31.6
4 Firing range instructors	1	12	40.8	6.2	49.6	38.5
5 Manufacture of TV tubes	1	33	21.1	11.3	49.0	12.1
6 Solder manufacture	2	13	26.1	11.0	44.0	23.1
7 Manufacture of paints and pigments	17	87	14.3	6.8	38.6	–
8 Telecommunications	1	215	15.4	5.7	38.2	–
9 Metal bearing manufacture	1	3	29.0	8.2	36.0	–
10 Painters	10	81	18.1	6.9	35.0	–
11 Extraction of tin and tungsten from ore	1	6	26.2	4.2	32.0	–
12 Electronics	5	26	15.8	7.1	31.0	–
13 Printing	1	2	19.0	1.4	20.0	–
14 Manufacture of ammunition	1	10	10.4	3.8	19.0	–
15 Manufacture of silverware	1	4	15.0	2.9	18.0	–
Total	48	658				

Table III
Duration of Exposure to Lead,
Age, Type of Industry and Blood Lead By Race

	Chinese n = 297	Malay n = 299	Indians n = 62	Significance
Age (years) mean ± SD	35.1 ± 8.5	33.4 ± 7.4	32.8 ± 8.5	$p < 0.05$
Exposure duration (months) mean ± SD	109.4 ± 84.9	116.6 ± 81.9	97.9 ± 90.0	NS
No. in high risk industries (%)	134 (59.8)	60 (26.8)	30 (13.4)	$p < 0.001$
No. in low risk industries (%)	163 (37.6)	239 (55.1)	32 (7.3)	
Blood lead (µg/dL)				
Unadjusted mean ± SD	20.1 ± 11.5	20.9 ± 12.2	25.0 ± 11.0	$p < 0.05$
Adjusted* mean	18.0	23.4	22.8	$p < 0.001$

* for age, exposure duration and industry group
NS Not significant ($p > 0.05$)

and coproporphyrin III in the urine (7).

Taking this level of 40 µg of lead per 100 mls blood, we can divide the factories with lead exposure into 2 categories: a "higher risk" category and a "lower risk" one, the latter not having a single result of blood lead of 40 µg/dL or above. The former category included factories manufacturing PVC (where lead salt stabilisers were used) and lead storage batteries. The highest 2 blood lead levels were found in these two industries. This corroborates the findings of Phoon and Ong (8) who also found "high level exposure situations" in these industries. Our "higher risk" category also included firing range instructors, shipbreakers, solder manufacture and the manufacture of television tubes. In the report by Tola et al (7), levels exceeding 70 µg/dL were found among workers in PVC manufacture, lead scrap smelting, shipbreaking and storage battery manufacture, among others. Thus, the findings in the 3 studies broadly concur on the higher risk types of industries.

Our results show that of the 3 main races in Singapore, the Chinese have the lowest blood lead levels after adjusting for age, duration of exposure and type of industry. In our visits to lead factories, we have observed that it is common practice for Malays and Indians to eat with their hands. Ingestion is recognised to be an important route of entry for lead to be absorbed into the body (9). This habit of eating with hands probably contributes to the higher blood lead levels among the Malays and Indians.

We do not have information on the smoking status of our subjects. But smokers have been reported to have higher blood lead levels (10), although another study did not find this to be so (11). Malays in Singapore have been found to have a higher prevalence of smokers, 46.3% among males, compared with 32.9% and 31.8% respectively among Chinese and Indians (12). Smoking with contaminated fingers could also give risk to an ingestion hazard. The higher prevalence of smoking among Malays may also be a contributory factor to the higher blood lead levels.

In addition to emphasizing good personal hygiene (washing hands before meals, bathing and change of work clothes at the end of a shift), workers handling lead should also be discouraged from eating with their hands and smoking, especially in the workplace.

In conclusion, the results in this study while reassuring on one hand in that no worker was found with blood lead level above 70 µg/dL, on the other hand also indicated that conditions in some factories could be improved. The higher risk factories have been identified, and while the hazard is not serious, these factories should be more closely monitored to ensure reduction of risk to workers.

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