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OCCUPATIONAL EXPOSURE TO INORGANIC LEAD IN MALAYSIAN BATTERY-MANUFACTURING FACTORIES

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SUMMARY

A study was carried out by the Factories and Machinery Department of Malaysia to assess the problem of occupational exposure to inorganic lead in Malaysian battery workers. The eight factories studied were divided into two categories: large, multinational subsidiaries with good industrial hygiene measures and small, locally-owned companies with poor hygiene features. A total of 251 workers (221 males and 30 females) were included in the study. Personal air sampling showed that 47% of the samples in the small factories had lead-in-air levels exceeding 150 ug/m^3, compared with 29% in the larger establishments. The highest air lead levels were found in the cutting, pasting/mixing and battery assembly sections. 86.7% of the female workers and 62.2% of the male workers in the smaller factories had blood lead concentrations above the proposed limits of 70 ug/100 ml (males) and 40 ug/100 ml (females). In contrast, only 7.6% of the male workers in the larger factories had blood lead levels exceeding the proposed limits. Three workers also had positive signs or symptoms on clinical examination. Legislation of specific regulations to protect the health of lead-exposed workers in Malaysia is currently being drafted by the government.

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INTRODUCTION

As a newly industrializing country, Malaysia is now facing the occupational health problems which inevitably accompany the process of development and industrialization. Exposure to inorganic lead at work is among the serious health hazards faced by workers in battery-manufacturing factories. The first such factory in Malaysia was set up in late 1960. Currently, there are about 10 battery-manufacturing factories employing over 500 workers in the country. Up to date, there has been no comprehensive survey done to determine the magnitude of the lead exposure problem in these workers although a few isolated studies has demonstrated excessive lead absorption in the subjects. [1,2] Consequently, a study was carried out by the Factories and Machinery Department of Malaysia in 1980-81 to assess the occupational exposure to inorganic lead of workers employed in lead-acid battery manufacturing factories in the country. The specific objectives were to determine lead-in-air exposure levels by personal monitoring and to assess the extent of lead absorption by determining blood lead concentrations and clinical examination of lead-exposed workers.

MATERIALS AND METHODS

Eight lead-acid battery manufacturing factories situated in the Klang Valley (which is the most highly industrialized region in the country) were included in the study. The factories were divided into two categories according to the criteria listed in Table I: Category 'A' consisted of two large subsidiaries of multinational corporations based in developed countries, while Category 'B' consisted of

TABLE I
CRITERIA FOR CATEGORIZATION OF LEAD-ACID BATTERY MANUFACTURING FACTORIES IN MALAYSIA

	Category 'A'	Category 'B'
1.	Number of workers employed $\geq$ 40	Number of workers employed $<$ 40
2.	Has local exhaust ventilation systems	Do not have local exhaust ventilation systems
3.	Regular blood lead monitoring of exposed workers	No regular blood lead monitoring of exposed workers
4.	Employers are aware of the toxic effects of lead	Employers are generally unaware of the toxic effects of lead
5.	Good housekeeping	Poor housekeeping
6.	Proper welfare facilities provided, e.g. washroom, shower-room, lockers, canteen, etc.	No proper welfare facilities provided

six small factories owned and managed by local businessmen. 131 workers (all males) were selected for study from Category 'B'. Those workers studied were all employed directly in the battery-making process for at least three months and were thus at high risk of being affected by inorganic lead exposure.

Although the details of the battery-making operations varied from one factory to another, the basic processes were similar. A lead matrix or grid was produced by the grid-casting machine. Paste composed primarily of lead, lead oxide, sulphuric acid, water and expanders, was pressed onto the grid at the pasting machine. The pasted grids or plates were then dried in the oven before they were "parted" and separated into two halves. The parted plates were then stacked to form elements with alternating positive and negative plates, and a separator inserted between each plate. These were then welded together to form groups and immersed in sulphuric acid for charging using a low tension direct current. The process was completed in the assembly section where the plates were assembled in moulded casings.

Due to the uniformity of the basic manufacturing process, the 131 workers in Category 'A' and 120 workers in Category 'B' could be classified into eight job-title groups based on their work, environmental and exposure similarities. [3] These groups are oxide milling, grid-casting, part-casting, cutting, pasting/mixing, negative drying, charging or formation and battery assembly.

Personal "breathing zone" sampling was carried out on the workers from all the job-title groups in the eight factories between June 1980 and September 1981. A total of 216 random eight-hour samples was collected using MSA Model G and S personal sampling pumps (calibrated to 1.7 litres/min) with three-piece open face cassettes. These contained 37 mm MCE membrane filters with 0.8 μm pore size (Millipore type AA). A three-piece open face technique was utilised instead of the two-piece open face method because the latter is size-selective against large particles, and may lead to underestimation of workers' total exposure. [4]

The filters were digested with nitric acid and analysed for lead by atomic absorption in accordance with NIOSH recommended methods S341. [5]

Blood samples were also collected from 251 workers by venepuncture in a lead-free environment. Analysis for blood lead was carried out using atomic absorption according to the NIOSH recommended method (P & CAM 262). [6]

Forty workers who had blood lead levels exceeding 70 μg/100 ml (for males) and 40 μg/100 ml (for females) were given a full clinical examination, including haemoglobin estimation. Urinary coproporphyrin and δ – amino laevulinic acid (ALA) were also determined in three workers who had positive clinical symptoms or signs, or a low haemoglobin level.

RESULTS

Table II shows the lead-in-air levels measured as breathing zone time-weighted averages over 8 hours for the workers in the two categories of factories. Since exposure to lead-in-air can be approximated by log normal distribution, [7,8] the distributions are described in terms of the median and geometric standard deviation (σg).

The median lead-in-air levels of all the job-title groups in Category 'A' factories were consistently lower than those in Category 'B' factories. The 52 personal air samples collected in Category 'A' had lead-in-air levels ranging from nondetectable ($<$ 10 $\mu g/m^3$) to 761 $\mu g/m^3$; 29% of these samples exceeded the American Conference of Governmental Industrial Hygienists (ACGIH)

TABLE II
LEAD-IN-AIR LEVELS MEASURED AS BREATHING ZONE TIME-WEIGHTED AVERAGES OVER EIGHT HOURS

Job-title groups	Category 'A' Median ($\mu g/m^3$)	σg	Range ($\mu g/m^3$)	No. of samples	Category 'B' Median ($\mu g/m^3$)	σg	Range ($\mu g/m^3$)	No. of samples
Oxide Milling	111	2.1	33-412	7(2)*	N.S.	N.S.	N.S.	N.S.
Grid casting	20	1.3	12-27	5(2)	33	1.9	10-112	23(6)
Part casting	21	1.8	10-41	3(2)	105	2.2	21-570	23(5)
Cutting	313	2.0	79-761	6(2)	1,057	2.0	180-2,780	8(2)
Pasting and mixing	122	1.5	48-195	9(2)	273	2.7	39-2,640	28(6)
Negative drying	37	1.9	11-80	3(2)	69	2.1	20-300	23(6)
Charging or formation	11	2.5	N.D.-28	3(2)	135	2.2	N.D-690	26(6)
Battery Assembly	85	2.5	N.D.-646	16(2)	256	2.5	35-2,023	33(5)

N.S. = Not sampled
N.S. = Non-detectable ($< 10 \mu g/m^3$)
* Number in parentheses ( ) indicates number of factories

Threshold Limit Value (TLV) of 150 $\mu g/m^3$. In Category 'B' factories, however, 47% of the 164 personal air samples collected exceeded the TLV; the range of lead-in-air values was from non-detectable to 2,780 $\mu g/m^3$.

An overall 43% of the personal air samples collected in both categories in the study exceeded the TLV.

Among the various job-title groups, the highest lead-in-air levels were found in the "cutting" section in both categories 'A' and 'B', followed by the pasting/mixing and battery assembly sections. The geometric standard deviations for all the job-title groups (except for pasting/mixing in Category 'B') were between 1.3 and 2.5, which is the common range for specific occupational groups experiencing similar exposure risks. [8]

Table III shows the distribution of blood lead

TABLE III
BLOOD LEAD LEVELS IN MALAYSIAN BATTERY WORKERS

Blood lead ($\mu g/100$ ml)	Category 'A' Male No.	%	Category 'A' Female No.	%	Category 'B' Male No.	%	Category 'B' Female No.	%
Less than 40	45	34.3	-	-	0	0.0	4	13.3
40 - 50	33	25.2	-	-	9	10.0	7	23.4
51 - 60	20	15.3	-	-	8	8.9	5	16.7
61 - 70	23	17.6	-	-	17	18.9	4	13.3
71 - 80	5	13.8	-	-	11	12.2	6	20.0
81 - 90	2	1.5	-	-	16	17.8	1	3.3
91 - 100	0	0.0	-	-	18	20.0	0	0.0
101-110	1	0.8	-	-	7	7.8	1	3.3
Above 110	2	1.5	-	-	4	4.4	2	6.7
Total	131	100.0			90	100.0	30	100.0
Mean ($\mu g/100$ ml)			47.0*			74.7*		
Standard deviation ($\mu g/100$ ml)			17.2			22.7*		

* Difference is statistically significant ($p < 0.01$)

levels in the 251 workers studied. There were no female workers in Category 'A' factories, while Category 'B' factories employed 30 females. 26 out of these 30 female workers (or 86.7%) had blood lead concentrations exceeding 40 μg/100 ml (which is the allowable level being adopted by the Malaysian government for occupationally exposed female lead workers). [9]

Among the male workers, 56 out of 90 (or 62.2%) in Category 'B' factories had blood lead concentrations above 70 μg/100 ml (which is the proposed allowable level for male lead workers in Malaysia). [9] In contrast, only 10 out of 131 workers (or 7.6%) in Category 'A' factories had blood lead levels exceeding 70 μg/100 ml.

An overall 36.6% of the 251 workers in the study population (92 males and females combined) had blood lead levels exceeding the proposed limits.

Since lead absorption is independent of sex group, both male and female workers in the two categories of factories were grouped together to compute their mean blood lead levels. The mean blood lead concentration of workers in Category 'B' (74.7 μg/100 ml) was significantly higher than that in Category 'A' workers (47.0 μg/100 ml), ($p < 0.01$) (Table III).

Out of the 92 workers with blood lead levels exceeding the proposed allowable limits, only 40 were given a full clinical examination because the remaining workers had either resigned from their companies or were retrenched when their factory closed down due to financial failure.

Three workers had positive clinical symptoms or signs, or a low haemoglobin level. One male worker was from a Category 'A' factory, while two (one male and one female) were from Category 'B' factories. The relevant findings are presented in Table IV.

TABLE IV
POSITIVE CLINICAL AND LABORATORY FINDINGS IN THREE LEAD-ACID BATTERY WORKERS IN MALAYSIA

	Case I (Category 'A')		Case 2 (Category 'B')		Case 3 (Category 'B')
	50 yrs male		28 yrs female		24 yrs male
c/o	General fatique and colicky abdominal pain	c/o	Tiredness and colicky abdominal pain	c/o	Tiredness
o/e	Gums-bluish discoloration Hb 14.1 gm/100ml PCV 42% Blood lead: 84μg/100 ml Urinary coproporphyrin: 204μg/1 litre Urinary δ-ALA: 13.95 mg/litre	o/e	Pallor + Hb 10.3 gm/ 100 ml PCV 30% Blood lead: 69μg/100 ml Urinary coproporphyrin: 220μg/litre Urinary δ-ALA: 14.47 mg/litre	o/e	Gums-bluish discoloration Hb 10.9 gm/ 100ml PCV 31% Blood lead: 107 μg/100 ml Urinary coproporphyrin: 1,207 μg/litre Urinary δ-ALA: 28.6 mg/litre

Note: c/o : complains of
o/e : on examination

DISCUSSION

Based on the criteria used for the categorization of factories in the study, the exposure levels of lead-in-air and the degree of lead absorption appear to be influenced by factors such as the size of industrial organization, management attitude and awareness, environmental control and housekeeping practices, regular biological monitoring and provision of proper welfare facilities. Not surprisingly, it is the larger, multinational companies which are able to afford the financial and technical support for provision of such positive measures. In contrast, the smaller companies are typical examples of "cottage" industries owned and managed by local entrepreneurs, who are usually ex-employees of the larger establishments from where they had initially learnt the trade. Due to constraints of limited capital, control measures and welfare amenities are thus commonly omitted from the factory set-up. The consequences of failure to implement such measures is strikingly demonstrated in the study findings among workers in the small factories.

An alarming 47% of the personal air samples collected exceeded the TLV of 150 $\mu g/m^3$, while 86.7% of the female workers and 62.2% of the male workers had blood lead levels exceeding the proposed Governmental allowable limits. Two workers also had clinical and biochemical features strongly suggestive of excessive lead absorpiton.

However, even among the larger, multinational battery companies, 29% of the personal air samples were found to exceed the TLV, and a small but still notable 7.6% of the workers (all males) had blood lead concentrations above the proposed limits. One worker also had clinical features suggestive of excessive lead absorption.

This underlines the urgent need for education of management and workers on the health hazards in the lead industry, as well as legislation and enforcement of specific regulations for the protection of lead workers in Malaysia. Although the current study covers only battery-manufacturing factories, occupational exposure to lead is also found in other industries in Malaysia such as metal smelting, painting processess, automobile assembly, pottery and printing. An estimated 17,000 workers occupationally exposed to lead [1] will stand to benefit from the proposed lead regulations currently being drafted by the Government of Malaysia. These contain specific guidelines on industrial hygiene and biological monitoring requirments, as well as provisos for statutory medical examinations of lead-exposed workers. As noted earlier, the allowable limits set for blood lead are 70 μg/100 ml for males and 40 μg/100 ml for females, which are in line with most other national requirements. These regulations should thus contributre significantly towards the protection and promotion of the health of lead workers in the country.

CONCLUSIONS

The study has shown that there is an acute problem of environment lead exposure and excessive lead absorption in Malaysian battery workers, particularly those employed in the smaller locally-owned factories. There is thus an urgent need for education and legislative control to safeguard the health of workers in the lead industry in the country.

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