Levels of some trace metals and related enzymes in workers at storage-battery factories in Iraq

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مستويات بعض الفلزّات الزهيدة المقدار والإنزيمات المتصلة بها بين عمال مصانع بطاريات الخزن في البصرة، بالعراق

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خلاصة: تم قياس مستويات بعض الفلزّات الزهيدة المقدار (النحاس والحديد والرصاص والزنك)، وإنزيم أمينو لفيولينات ديهيدراتاز ALAD وسيرولوبلازمين CP والهيموغلوبين، وذلك في عينات دم من 37 عاملاً من العاملين الذكور في مصانع بطاريات الخزن بالقطاع الخاص. وتم تقسيم الرجال إلى ثلاث مجموعات بحسب وظائفهم على النحو التالي: 11 من عمال الشحن (المجموعة الأولى) و8 من عمال التصليح (المجموعة الثانية) و18 من عمال الصب (المجموعة الثالثة). وتم اختيار 60 رجلاً كمجموعة شاهدة. ووجد أن المستويات الوسطية كانت 14.63 و36.35 و58.00 و71.70 مكروغرام/100 مل بالنسبة للرصاص. وكانت 192.54 و133.90 و96.75 و45.37 ميكروغرام/مل بالنسبة للإنزيم ALAD. وكانت 14.02 و12.72 و12.20 و11.40 غرام/100 مل بالنسبة للهيموغلوبين، وذلك في المجموعة الشاهدة وفي المجموعات الأولى والثانية والثالثة على التوالي. ووجد ترابط سلبي يعتد به بين الرصاص وبين الإنزيم ALAD والهيموغلوبين على السواء. أما الترابط الإيجابي الوحيد الذي يعتد به فقد وجد بين مستويات الرصاص ومدة التعرض.

ABSTRACT Levels of some trace metals (copper, iron, lead and zinc), aminolevulinate dehydratase (ALAD), caeruloplasmin and haemoglobin were measured in the blood of 37 male workers from private-sector storage-battery factories. The men were divided into three groups depending on their jobs: 11 chargers (group I), 8 repair workers (group II) and 18 casting workers (group III); 60 men were selected as controls. Mean levels were 14.63, 36.35, 58.00 and 71.70 µg/100 mL for lead, 192.54, 133.90, 96.75 and 45.37 U/mL for ALAD, and 14.02, 12.72, 12.20 and 11.40 g/100 mL for haemoglobin for control and groups I, II and III respectively. Significant negative correlations were found between lead and both ALAD and haemoglobin. The only significant positive correlation was between lead levels and duration of exposure.

Taux de certains métaux-traces et enzymes qui y sont liées chez les ouvriers d'usines de fabrication d'accumulateurs à Bassora (Iraq)

RESUME Les taux de certains métaux-traces (cuivre, fer, plomb et zinc), de la déshydratase de l'acide δ-aminolévulinique (ALAD), la céruloplasmine et d'hémoglobine ont été mesurés dans le sang de 37 ouvriers d'usines de fabrication d'accumulateurs relevant du secteur privé. Ces ou-vriers ont été divisés en trois groupes selon leur travail: 11 étaient affectés à la charge des batteries (groupe I), 8 aux réparations (groupe II) et 18 à la coulée (groupe III); 60 hommes ont été choisis comme groupe témoin. On a trouvé des taux moyens de 14,63 µg/100 ml, 36,35 µg/100 ml, 58,00 et 71,70 µg/100 ml pour le plomb, de 192,54 UI/ml, 133,90 UI/ml, 96,75 et 45,37 UI/ml pour l'ALAD, et de 14,02 g/100 ml, 12,72 g/100 ml, 12,20 et 11,40 g/100 ml pour l'hémoglobine dans le groupe témoin et les groupes I, II et III respectivement. On a constaté des corrélations négatives significatives entre le plomb et l'ALAD d'une part et l'hémoglobine d'autre part. La seule corrélation significative était celle entre le taux de plomb et la durée d'exposition.

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Introduction

Certain trace metals are powerful inhibitors of enzymes containing the sulfydryl group. A number of these enzymes are concerned with haeme synthesis [*1*]. Trace metals are introduced into the human body by direct exposure to fumes and dust, or indirectly through the food chain. Their poisons can be detected by testing blood, urine or other organs, or the inhibition of certain enzymes such as aminolevulinate dehydratase (ALAD) by lead or the depletion of copper for the caeruloplasmin (CP) complex in iron reduction, or tests for iron in haemoglobin (Hb) [*2*].

Industry is the major source of lead pollution, particularly in battery factories [*3*]. An increase in blood lead levels has been detected in adults who either smoked and/or drank alcohol [*4*]. Toxicity has been studied through increased levels of lead in blood which is related to its level in the environment, and through the depletion of ALAD or Hb [*5,6*]. ALAD is the second enzyme in the haeme biosynthesis pathway and is one of the most sensitive indicators of blood lead accumulation due to exposure [*7,8*]. Anaemia in children is reported to be lead-induced, and is accompanied by iron deficiency [*9*]. Lead exposure is reported to increase blood lead levels in pregnant women and infants [*10*]. Levels of lead in bone serve as a dosimeter for cumulative exposure to lead and lead in bones acts as an internal source of circulating lead for many years after environmental exposure has ceased [*11*].

Lead pollution has been found in Baghdad because of the use of leaded petrol, battery manufacturing and the use of printing presses [*12,13*]. An increase in the absorption of lead among lead-exposed workers has been recorded [*3*]. Workers at a lead acid battery factory in Sudan had blood lead levels above 40 μg/100 mL [*14*]. High blood levels have also been reported among battery workers in Trinidad and Tobago [*15*] and at large factories in Korea, where the mean blood lead level among workers was found to be 54 μg/100 mL [*16*]. The recommended upper limit for lead levels in the body is 40 μg/100 mL [*17*].

In our study, a group of battery workers was chosen for health evaluation because of their exposure to lead, since there are no major industrial sources of lead emission in Basra.

Subjects and method

Selection of samples

The group selected for this study was private-sector storage battery workers who were unfamiliar with pollutants and their effects. As a result of workers limited knowledge, there is a complete lack of safety standards and practices in the workplace. The selection of this group was made after noting an increase in private-sector battery production because of the shortage of imported storage batteries.

The workers were divided into three groups depending on the nature of their job. Group 1 workers were responsible for charging batteries and casting their connection pools. Group II specialized in plate repair for damaged batteries and group III workers cast the plates and scratched the surfaces for covering with a film of zinc oxide. Information on workers' education level, occupation, and smoking and drinking habits was collected using a questionnaire during the collection of samples.

Blood sampling and analysis

Samples of blood were collected by authorized health staff during the period September to December 1996. They obtained the samples by venepuncture using disposable syringes. Samples were used for the determination of copper, iron, lead and zinc using a Pye Unicam SP9 atomic absorption spectrophotometer.

Lead was extracted by a 1:1 sulfuric acid:nitric acid mixture while other metals were measured by direct injection of 1:5 diluted plasma [*18*]. Erythrocyte ALAD activity was determined using a modified aerobic method [*19*]. The assay of ALAD in whole blood depends on direct colorimetric estimation of the amount of porphobilinogen produced from added ALAD after incubation for 1 hour. The results were corrected to constant haematocrit values as the enzyme only occurs in the erythrocytes.

CP was determined at pH 4–5 as CP catalyses the oxidation of paraphenylene diamine to yield coloured oxidation products at a rate of formation proportional to the concentration of plasma CP. The incubation time was 35 minutes at 35 °C and the colour was measured at 350 nm. The colour was stable for at least 6 hours. Hb concentration of blood was measured by the standard cyanomethaemoglobin method [*20*] and the haematocrit ratio (per cent) was also calculated.

Statistical analysis

Correlation measures were used to assess the relationship between lead and independent variables.

Results

Like almost all battery workers in the private sector, the participants in the study were uneducated, about 40% of all groups were smokers, and there was one worker who also drank alcohol. One of the group III workers showed a low Hb level (9.15 g/dL) indicating hypochromic anaemia.

Table 1 shows the distribution of the participating workers in groups according to their jobs. The table also shows mean values ± standard deviations of the trace metals copper, iron, lead and zinc, ALAD and CP activity and the levels of Hb.

Correlation coefficients (r) between blood levels and habits of workers and other related parameters are shown in Table 2. Only duration of exposure was significantly correlated with blood lead levels (P = 0.002); age, smoking and alcohol consumption were not. ALAD and Hb were significantly negatively correlated with blood lead levels.

In comparing the control group with the exposed workers using ANOVA, a significant increase in blood lead levels and a decrease in the unit activity of ALAD and Hb were found depending upon the nature of the worker's job. The blood lead levels increased from group I to III accompanied by a decrease in both ALAD and Hb. Values recorded for other trace metals and CP in the blood of the studied groups showed lower variations with nonsignificant relationships. Copper, iron and zinc levels were lower in the working groups than the control group. Mean CP values were of the same range.

Discussion

Blood lead concentration is currently regarded as the most reliable index of lead exposure. Proteins in the ALAD fraction of erythrocyte supernatant have the highest affinity for lead among erythrocyte constituents [*21*]. The factor most influencing blood lead levels is environmental exposure [*22*]. Absorbed lead due to exposure will inhibit the activity of erythrocyte ALAD [*23*].

Small shops that repair and/or rehaul car batteries in Basra are very common. In

Table 1 Concentrations of trace metals, enzyme activity and haemoglobin in blood from private-sector battery workers in Basra

Group	No.	Copper µg/100 mL	Iron µg/100 mL	Lead µg/100 mL	Zinc µg/100 mL	ALAD U/mL RBC	CP U/mL RBC	Hb g/100 mL
Control	60	99.95	105.00	14.63	88.00	192.54	30.63	14.02
		± 25.86	± 49.00	±5.86	± 17.00	± 24.91	± 5.90	± 1.60
I	11	92.63	93.82	36.35	87.09	133.90	35.04	12.72
		± 12.90	± 33.55	± 11.40	± 17.44	± 33.12	± 6.39	± 1.60
II	8	90.38	86.13	58.00	89.25	96.75	29.25	12.20
		±13.33	± 24.77	± 13.35	± 16.30	± 33.50	± 3.37	± 0.99
III	18	76.44	83.77	71.70	81.22	45.37	27.17	11.40
		± 8.81	± 33.95	± 24.80	± 11.42	± 20.53	± 4.14	± 1.05
Total	37	84.27	87.27	60.59	84.70	85.44	29.40	11.99
		± 13.33	± 26.87	± 23.73	± 14.50	± 26.00	± 7.50	± 1.30

Values are given as the mean ± standard deviation.
ALAD = aminolevulinate dehydratase CP = caeruloplasmin Hb = haemoglobin
RBC = red blood cells

these shops no precautionary measures are taken to ensure good ventilation, and suitability of workshops and cafeterias. Furthermore, the average work week is 48 hours and most men work for at least 4 years, there are no occupational health regulations governing permissible blood lead levels and no medical supervision of health and safety.

Table 1 indicates that levels of blood lead are dependent on lead exposure and reflects the decrease in ALAD and Hb. The higher blood lead levels of group III were due to higher lead exposure in their working environment. Battery workers neglect to use facemasks during work and this significantly increases blood lead levels due to inhalation. Levels of blood lead recorded for group I were close to the threshold limit value which is 40 µg/100 mL, while those for groups II and III were even higher [*17*].

Mean blood lead levels are generally found to be higher among smokers, those who drink alcohol and those who do not always wash their hands [*24*]. They are also greatly affected by air lead levels, especially among battery repair and casting workers where inhaled lead is the most important source of lead exposure [*25*].

For workers in our study who did not smoke or drink, the high blood lead levels recorded were due mostly to the level of lead in the air. Although air lead levels were not tested in our study, it is probable that the battery repair and casting workers were exposed to lead fumes arising from melting lead at high temperatures.

Workers with high blood lead levels (mean of 60 µg/100 mL) tended to have a higher prevalence of most of the symptoms of lead toxicity than did workers with lower blood lead levels. The other indicator is the low value of Hb. Among the casting workers (Group III), one worker had a blood lead level of 125 µg/100 mL which was confirmed by severe anaemia (Hb = 9.15 g/dL).

Table 2 **Correlation of various parameters in studied groups with blood lead levels**

Parameter	Correlation coefficient *r*	*P*-value
Lead/age	0.209	0.205
Lead/smoking	0.276	0.249
Lead/alcohol	0.056	0.644
Lead/duration of exposure	–0.515	0.002*
Lead/ALAD	–0.742	0.0001*
Lead/Hb	–0.508	0.0013*
ALAD/Hb	0.478	0.0027*

**Statistically significant*
ALAD = aminolevulinate dehydratase
Hb = haemoglobin

Blood lead levels showed no correlation to age, smoking and alcohol consumption ($r = 0.209$, 0.276 and 0.056 respectively) ($P > 0.05$). The only parameter which showed high correlation with blood lead levels was duration of exposure ($R^2 = 0.265$, $r = -0.515$, $P = 0.002$). Other parameters, which showed highly negative correlations with blood levels, were ALAD ($r = -0.742$, $P = 0.001$) and Hb ($r = -0.508$, $P = 0.0013$) as indicated in Table 2.

It has been shown that proteins in the ALAD fractions have the highest affinity for lead among erythrocyte constituents [*21*]. The results of our study illustrate this and show that as blood lead levels increased, the activity of ALAD decreased without limit. Blood lead levels had the same effect on Hb as shown in Table 1.

Lead stimulates urinary excretions of copper, iron and zinc since it interferes with their reabsorption or competes with other essential metals for metallothionein [*26*].

Conclusions

The results of our study reveal a high prevalence of elevated blood lead levels among private-sector battery workers in Basra. Exposure to lead fumes increased the absorption of lead. The decrease of ALAD activity and Hb levels were significantly related to the concentration of lead in blood. The mean value reported for blood lead levels among private-sector battery workers of 60 µg/100 mL was similar to those working in large battery factories, and it is higher than the limit of 40 µg/100 mL recommended by the World Health Organization [*17*].

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Note from the Editor

Since the years 2000/2001 are likely to witness the eradication of poliomyelitis from our Region, the fixed sections entitled *Regional data* and *Current topics* will be allocated to the follow-up of the progress of the WHO Special Programme for Poliomyelitis Eradication. This will continue throughout the six issues of volume 6 (2000) of the EMHJ.

Note from the Editor

In order to shorten the present delay in the production schedule of the EMHJ, we wish to announce that Vol. 6 No. 2 and No. 3 of the EMHJ will be published as a combined issue. It will include about 300 pages and is expected to cover the remaining articles accepted by the end of 1999.