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Variations in human exposure in car battery industry

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Abstract. Human protection at the workplace aims at knowing and remove all the situations that can occur in the work, which could lead to accidents and occupational diseases. This study assess the occupational exposure to lead and dust for workers from different workplaces in a company producing car batteries. Workplace lead (Pb) concentration (39 measurements) was performed by X-ray fluorescence spectrometry. Biomarkers of exposure and effects have been performed for 278 workers, represented by blood lead level (GF-AAS) urinary delta-amino levulinic acid (ΔALA) (standard regular method). The results of workplace air measurements pointed out high lead concentrations in some working areas, while the mean concentration of total dust did not exceed the maximum allowable concentration. The blood lead level (BPb) varied between 5.84 ug dL^{-1} and 65 ug dL^{-1}, with an average of 33.7 ug dL^{-1} (below workplace acceptable limit – 40 ug dL^{-1}. Urinary ΔALA ranged from 1.83 mg L^{-1} to 50.32 mg L^{-1} with an average value of 8.7 mg L^{-1}. The results of this study showed that for about 2/3 of the investigated workers, the occupational exposure to inorganic lead and total dust, in car battery industry, is within normal biological tolerable limit for lead. There is still possibility of toxic effects upon susceptible individuals, especially in case of failure to comply good workplace practices or technical and organizational measures which would decrease exposure and associated health risks.
Key Words: lead, exposure, health, workers, workplace.

Introduction. In our days, humans are exposed to multiple aggressions from the social environment, from the natural environment or from the working environment. Humans demands increasingly more for society and organizations to create conditions for them to work and live in safety.

Lead poisoning has been identified as an occupational hazard first time by Hippocrates (Dounias et al 2010). Unlike other metals, lead has no physiological role in the body and there is no minimum level that would be considered non toxic. Among adults exposure occurs mainly in the occupational environment. Exposure to lead can occur in more than 100 types of industry where it is used. Lead affects multiple body systems causing permanent effects.

Occupational risk depends on the amount of dust in the air, the size of lead particles in the air, solubility compounds, exposure, and hygiene conditions. The most dangerous operations are accompanied by heating the metal to near boiling point when vapor releasing is maximum. The risk of lead exposure is low when it is used at temperatures below 500°C (IPCS 1995). Lead effects on organs and body systems have been extensively studied along time. So there are recognized its effects on the nervous system, cardiovascular system, renal system, reproductive system, alongside more recent discoveries regarding carcinogenic effects in animals (Laiguo et al 2012). In industry the main way of lead entering the body is the respiratory route. However, in some cases, the actual risk of exposure is not given only by the amount of lead in the air but also by the lead ingested as a result of poor hygiene conditions (contaminated food and clothing, smoking in the workplace and other). The time of exposure is also playing a major roll (Paoliello & De Capitani 2007). Of secondary etiological factors, there should be mentioned gender and age (women and adolescents are more sensitive to lead than seniors who show a certain resistance), alcoholism, unbalanced diet, low in phosphorus and calcium, malnutrition, infectious disease posed by viruses (by creating a state of acidosis); habits, bad habits at work and individual hygiene failure (IPCS 1995). Car battery industry is an industry where employees are exposed to hazardous chemicals (lead being the most toxic of them), so it is binding to implement a program for safety and health at work in this industry. Such a program should be aimed on eliminating/limiting and controlling these risk factors for workers, also taking into account specific regulations.

Methods. Lead (Pb) and total dust (TD) concentration were measured for 39 workplace sites. Sampling was performed in four sections of the car battery factory in 2009, according to technological process and equipment requirements for exposure controls, as follows: 2 sections where lead and lead oxide are processed for producing the battery metal elements (section capacity I with greater technological wear and station capacity II - characterized by modern technology), one section where the battery carcasses are produced and where the Pb is not used as a raw material (department of injection) and station maintenance. In capacity I section were performed 28 measurements, 8 measurements in capacity II section, and 3 measurement in injection section. PB and TD at the workplace were measured in fixed points over a sampling period of 15 minutes along the installation and the results were expressed in mg/m^3. Sampling in fixed points is a method used to determine the background pollution at the workplace using a set consisting of pump-filter. Lead was analyzed by X-ray fluorescence spectrometry using an analyzer type NITON XL 700 series U 3362 using CD 109 with 6424LY series. TD at the workplace was analyzed by gravimetric method.

Biological sampling and analyses were performed in 278 workers. For 240 out of 278 workers we performed blood lead level (BPb) by Graphite Furnace–Atomic Absorbtion Spectoscropy (GF-AAS), and ΔALA from urine by standard regular method for 243 out of 278 workers. The age distribution was between 18 and 58 years and workplace exposure in terms of duration pointed out a high heterogeneity varying form months to more than 20 years.

Data entry, cleaning and analyses (statistical tests and graphs) has been carried out in Microsoft Excel Version 5.0. Descriptive statistical tests consists of: measure of central tendency (arithmetic mean, median) and variability measurements (minimum and maximum range value, standard deviation). Advanced statistical analysis was performed on data based on descriptive analyze results using linear regression test, to test a dependent variable based on several quantitative independent variables. The results were tested and interpreted by the value of P ("P value"), considering the statistical significance level of P less than 0.05.

Results and Discussion

Air measurement at the workplace. The average concentrations of Pb and TD determined in sections of the plant are shown in the Table 1.

Pb concentration at workplace ranged from 0.14 mg/m^3 to 9.10 mg/m^3 in the capacity I, from 0.78 mg/m^3 to 1.71 mg/m^3 in capacity II and from 0 mg/m^3 to 1.33 mg/m^3 in injection section, respectively.

TD concentration at workplace ranged from 0.01 mg/m^3 to 15.35 mg/m^3 in the capacity I, from 3.00 mg/m^3 to 4.25 mg/m^3 in capacity II and from 0.17 mg/m^3 to 7.33 mg/m^3 in injection section, respectively.

The distribution of Pb concentration as against as the investigated workplaces showed major differences from one workplace to another as fallows: Pb bellow 0.1 mg/m^3 from 14.29 to 66.67%, and above 0.1 from 33.33 to 85.71%, while TD below 10 mg/m^3 from 87.50 to 100%, and above 10 mg/m^3 from 0 to 12.50% (Figure 1).

Table 1

Results of the Pb and TD measurements

Sections	Sampling areas	Lead Average(mg/m^3)	Total dust Average mg/m^3)
Capacity I	Oxides	0.33	<0,01
	Foundry	0.46	1.91
	Mill	0.14	0.67
	Sovema	5.54	15.35
	MAC	0.32	2.28
	Assembly line 1	2.01	5.67
	Assembly line 2	0.27	1.14
	Assembly line 4	1.23	3.50
	Traction assembly	9.10	11.50
	Repairs	2.54	5.67
Capacity II	Oxide mill	1.37	3.17
	Sovema	0.78	3.00
	Assembly line 1	1.71	4.25
Injection	Injection workshop PPCo mill recovery	1.33	7.33
	Injection Machine	0.00	0.17

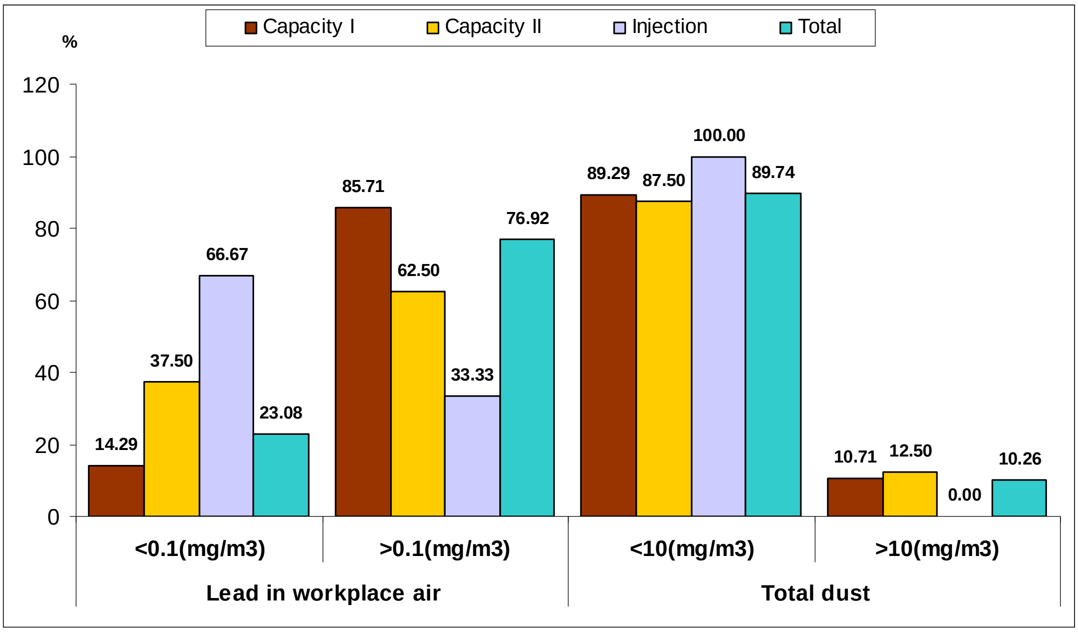

Figure 1. Lead and total dust in all four section of the plant.

Health results (biomarkers of exposure and effects). Aged distribution is characterized by heterogenity, therefore the 278 workers enroled in the study 44.96% are aged between 41 and 50 years, 19.42% are aged between 31 and 40, 15.11% are over 50 years old, and the rest of them are younger than 30 years (Figure 2).

A major component of exposure assessment is the time of exposure. It is very important to know the period of time worker is spending in the plant, but also the period of time he/she is working at the same workplace.

Thus, over 50% of workers in the study were working in the factory for more than 20 years, and of these 27% are doing the same job since they have been hired. A percentage of 20% are exposed for more than 10 years in the same workplace (Figure 3).

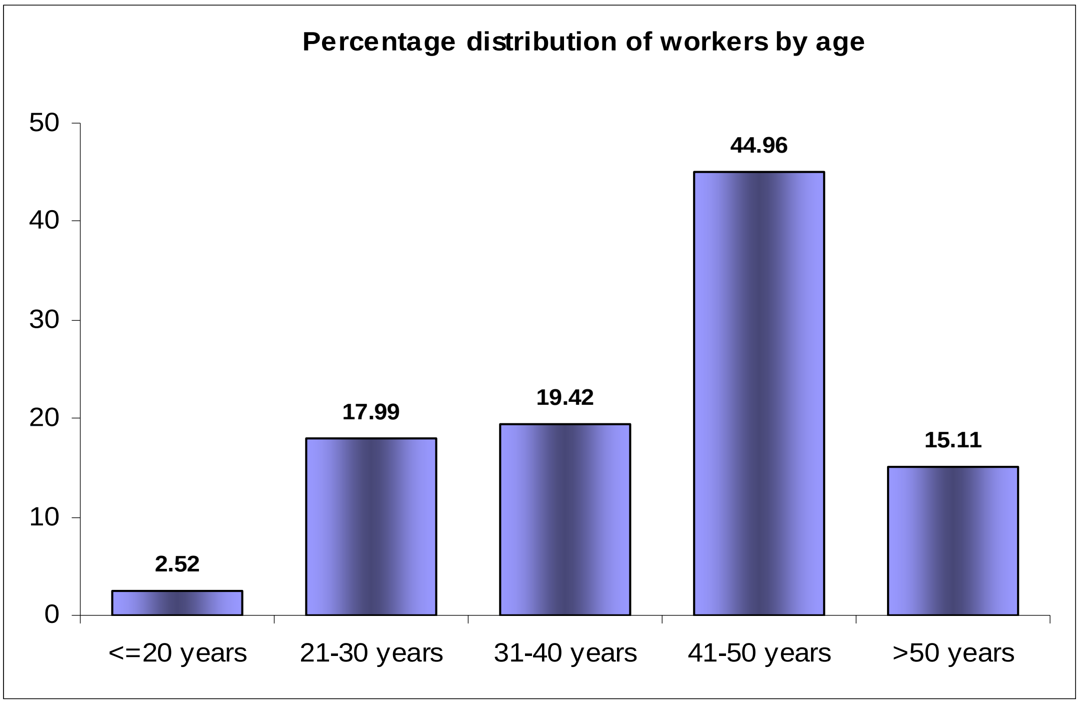

Figure 2. Percentage distribution of workers by age.

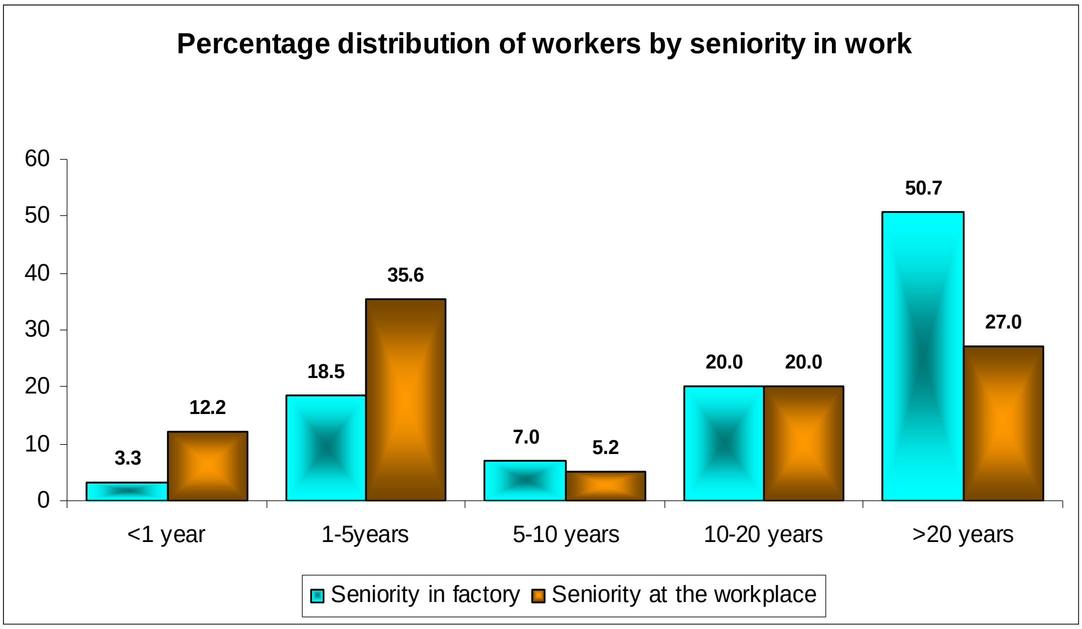

Figure 3. Percentage distribution of workers by seniority in work.

Biomarkers of exposure (BPb) and effects (ΔALA) has been carried out in 240 workers and 243 workers, respectively. The enrolled workers were divided into 4 categories depending on Pb concentration at workplace: lower than 0.1 mg/m^3, from 0.1 to 1 mg/m^3, from 1 to 2 mg/m^3 and higher than 2 mg/m^3. BPb level average and the correlation between BPb and Pb concentration at workplace were calculated for each working place.

The coefficient of determination for our data (R^2 = 0.67) showed a correlation between averaged BPb and Pb concentration at workplace (Figure 4).

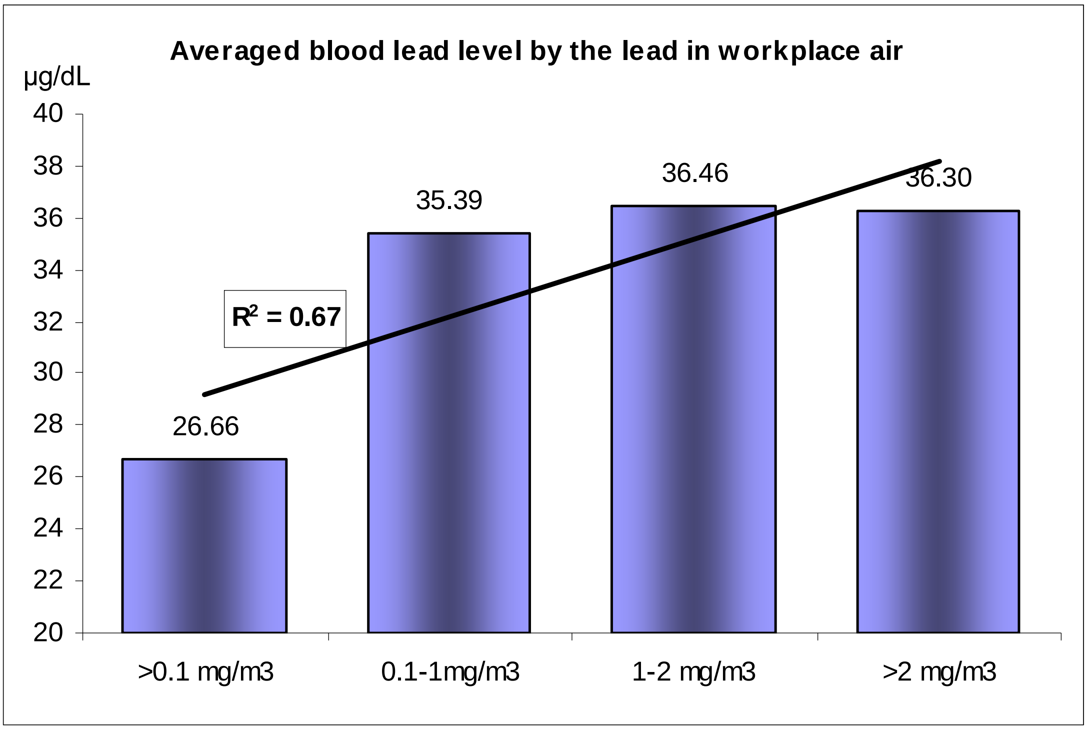

Figure 4. Averaged BPb by the Pb in workplace.

Statistical analysis includes the four investigated groups of workers and the group, with the lowest exposure (group 1 - workplace air lead concentration <0.1 mg/m^3) was used as the reference group for the other three (Table 2).

Table 2

Statistical analysis for BPb results

BPb						*Statistical indices*			
Pb	*N*	*Mean*	*Standard deviation*	*n>40*	*%>40*	*t*	*p*	χ^2	*p*
<0.1 mg/m^3	39	26.66	13.16	5	12.82	*Reference group*			
0.1-1mg/m^3	62	35.39	10.99	16	25.81	-3.45	0.001	2.45	0.12
1-2 mg/m^3	89	36.46	9.60	24	26.97	-4.19	<0.001	3.10	0.08
>2 mg/m^3	34	36.30	9.59	10	29.41	-3.61	0.001	3.06	0.08
>0.1mg/m^3	185	36.07	10.04	50	27.03	-4.22	<0.001	3.51	0.06

N = the number of workers in each investigated group.

Student t ("t" in the above table) test makes comparisons between averaged BPb for reference group and the other three groups. In all cases the p value was less than 0.05, so we can conclude that there is statistical significance between the mean BPb and average workplace concentration of Pb.

The chi square ("χ^2" in the above table) test is a consistent test, nonparametric used to test the degree of "closeness" between an empirical and a theoretical distribution and it was applied for the same groups as the t test. The chi square test was used for testing the significance of difference between two frequencies (between frequencies of the reference group and the frequencies of the other three groups with BPb higher than 40 µg dL^{-1}, "*%>40*").

The p value ("p" in the above table) for the chi square test was higher than 0.05 so there is no statistical significance between the frequency of workplace Pb and the frequency of subjects with BPb higher than 40 µg dL^{-1}.

The association between the risk factor and the disease was estimated by relative risk (RR), resulting from the report between the risk of deasease in the group exposed and the risk of disease in less/un exposed group. For workers in the study the relative risk was 2.11 (Table 3). This mean that workers from higher contaminated workplace are likely to have higher BPb than the maximum allowable concentration (MAC). Odds ratio (OR) can be defined as a probability distribution of a phenomenon in an experimental group and a control group. OR for the exposed group was 2.52, while the RA was 52.56%, meaning that 52.56% of the exposed workers (more than 0.1 mg/m^3 Pb at workplace) have BPb higher than the MAC (40 µg dL^{-1}) (Table 3).

Table 3

Risk calculation for BPb

Risk BPb >40µg dL^{-1} (<0.1 - >0.1 mg/m^3)		
RR	OR	RA %
2.11	2.52	52.56

The correlation between ΔALA and Pb at workplace, and the correlation between frequency values of ΔALA exceeding the MAC and Pb at workplace have been analyzed for the four working places.

There is an association between the average of ΔALA and Pb concentration at workplace (R^2=0.57).

There is no correlation between individual exposure (Pb at workplace) and individual BPb and ΔALA (Figure 5) because lead exposure depends on a number of factors, such as personal hygiene (smoking at the workplace, eating with dirty hands, others) and workplace practices.

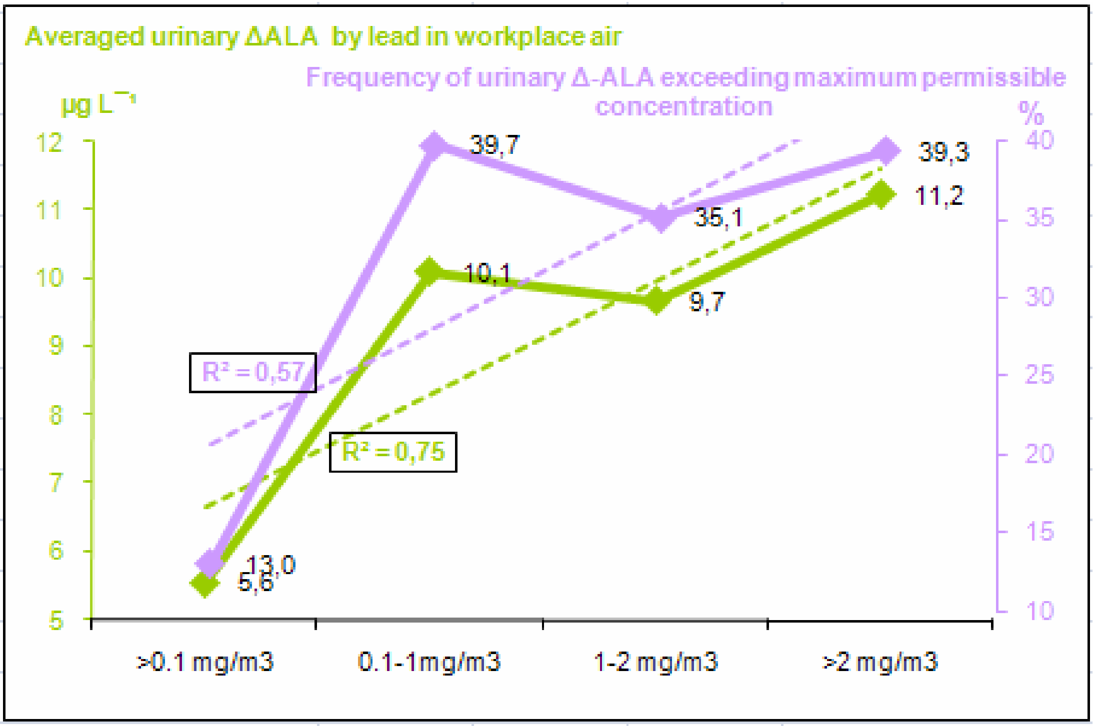

Figure 5. Correlations between ΔALA and Pb concentration from workplace

In Figure 6 are presented the values of BPb and ΔALA for the smokers and non-smokers workers in the study. For both BPb and ΔALA the mean values were higher for smokers than for non-smokers.

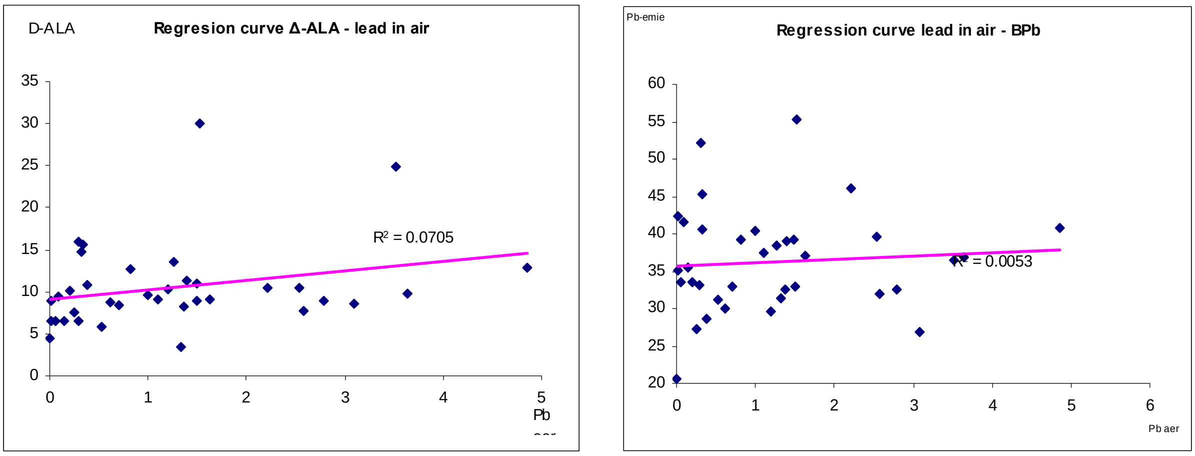

Figure 6. Individual correlation for BPb and ΔALA.

As regarding the concentration exceeding the MAC, 53.8% of the workers having the BPb higher than 40 µg dL^{-1} and urinary ΔALA higher than 10 mg L^{-1} were smokers (Figure 7).

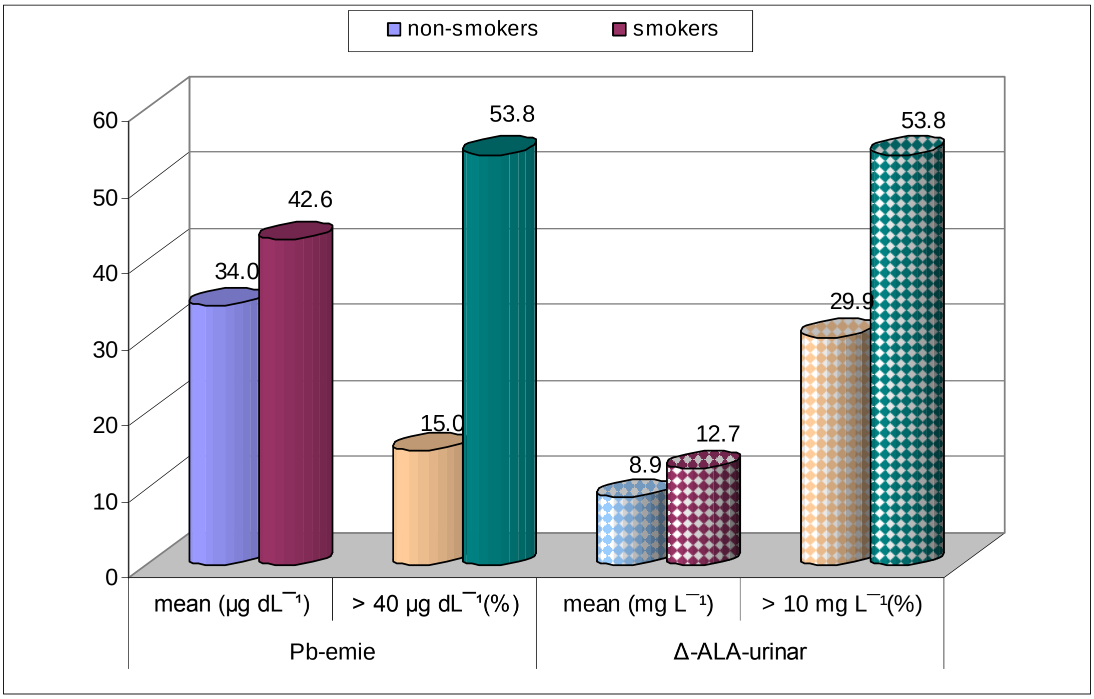

Figure 7. Values of BPb and ΔALA for the smokers and non-smokers workers.

Conclusions. Pb concentration at the workplace showed high heterogeneity both, between and within the four investigated working places. BPb was between 5.84 and 65 ug dL^{-1}, with an average of 33.7 ug dL^{-1}. BPb values above the limit of 40 ug dL^{-1} were found in 36% of investigated subjects. Urinary ΔALA ranged from 1.83 to 50.32 mg L^{-1} with an average value of 8.7 mg L^{-1}.

The results of this study showed that for about 2/3 of the investigated workers, the occupational exposure to inorganic Pb and TD, in car battery industry, is within normal biological tolerable limit for lead. There is still the possibility of toxic effects of susceptible individuals, especially in case of failure to comply good workplace practices or technical and organizational measures which would decrease exposure and associated health risks.

Exposure and health risk assessment at a workplace contaminated by Pb need to address very specific issues mostly because of individual susceptibilities and confounding factors, as well. Occupational risks depends on the amount of dust in the air, the size of lead particles in the air, solubility compounds, exposure, and hygiene conditions. Of secondary etiological factors, gender and age can be mentioned, alcoholism, unbalanced diet, malnutrition, infectious disease; habits, bad habits at work and individual hygiene failure.

Occupational exposure risks in a plant producing batteries are heterogeneous. This heterogeneity derives not only from the existence of several operations in the manufacturing process (each with a specific risk exposure to lead in air), but also from and the differences in susceptibility of employees in the development of diseases associated with lead exposure, susceptibility ranging especially by gender and age.

According to the data above, the security and safety measures at workplace, in a plant producing batteries should be taken according to each category of exposure.

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