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PREDICTING BLOOD LEAD LEVELS USING AIR LEAD LEVELS IN ACID BATTERY MANUFACTURING PLANT

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ABSTRACT

Uncontrolled activities of battery plants cause high emissions of lead (Pb). These emissions are considered a cause of significant threat not only to the workers of battery plants, but also to individuals living within the neighborhood. Twelve air samples were collected from a battery plant during different working days, and four air samples were collected from the vicinity of the battery plant. The air samples were analyzed for Pb levels using Flame Atomic Absorption Spectrophotometry (FAAS). Blood lead (BPb) levels were predicted from the obtained results of air samples following application of Richter *et al.* 1979 model. The arithmetic means for both air Pb levels and predicted BPb levels were 1369 ± 929 µg/m^3 and 85.56 ± 11.22 µg/100 mL respectively. The regression factor between air Pb levels and predicted BPb levels was (R = 0.955). The arithmetic mean of both air Pb and BPb levels were above the internationally reported acceptable levels (50 µg/m^3 and 40 µg/100 mL). BPb levels in individuals living in the vicinity of the acid battery plant were also predicted using Richter *et al.* (1979) model. The arithmetic means for both air Pb levels and predicted BPb levels were 61.2 ± 35.0 µg/m^3 and 52.23 ± 4.76 µg/100 mL respectively. Air Pb level of samples collected from inside battery plant was considered as a good specimen for predicting BPb level. It could be concluded that workers of battery plant and individuals who live within its vicinity are at high risk for Pb pollution.

KEY WORDS : Blood lead level, Prediction, Air, Acid battery plant, Vicinity

INTRODUCTION

Lead poisoning is considered a significant environmental threat (Wani *et al.*, 2015). Its deleterious effects on human body appears as harming cardiovascular system, hematopoietic system, nervous system, kidneys, and reproductive system (Needleman *et al.*, 1996).

Occupational exposure is believed to be the major cause of Pb poisoning in adults, as appeared in workers of battery plants (Qasim and Baloch, 2014). Approximately 85% of total global consumption of Pb is for Pb-acid batteries production (Basit *et al.*, 2015). In many countries, acid battery manufacture exposure is almost unregulated and monitoring of exposure are rarely exist (Manhart *et al.*, 2016). Therefore, Pb fumes and dust that are generated from such operations pose an exceptional health risk, not only to workers inside the factories, but also to individuals living within the neighborhood of these industries (Rodney and Lee, 1985).

BPb Level is considered as the dominant biological marker used in workplace monitoring, and clinical assessment regarding removal from exposure (Qasim and Baloch, 2014).

In Jordan, there are many Pb acid battery manufacturing plants which are considered as a potential major sources of Pb emissions and pollution (Nsheiwat *et al.*, 2010). The main goal of this study was to measure air Pb level in acid battery manufacturing plant located in Marka, Jordan. The obtained results were applied to evaluate the validity of using air Pb levels in predicting BPb levels in workers of the same Pb acid battery plant.

MATERIALS AND METHODS

Chemicals

Nitric acid (HNO_3, 69-71%) of spectroscopic grade was obtained from Gainland chemical factory, UK. Acetone (99.6%) of spectroscopic grade was purchased from Fisher scientific. Deionized water of analytical reagent grade water purification system (Millipore) was used. Lead standard solution of 1000 ppm was purchased from BDH laboratory supplies, UK.

Sample collection and preparation

Twelve air samples were collected during different working days from the Pb acid battery plant. Specimens were collected once daily by a portable constant air flow sampler at a flow of 2 L/min through a bubbler filled with 45 mL of diluted HNO_3 (0.798 M). Sampling time was the daily working period which lasted 8 hours. Also, four air samples were collected from the vicinity of the Pb acid battery plant in the same manner as those samples that were collected from inside the plant.

All laboratory equipment used for the sampling and sample treatment were soaked in 10% HNO_3 for 24 hours, followed by rinsing with deionized water, then dried with acetone.

Sample preparation was carried out directly following collection. The collected air samples were transferred into separate labeled 50 mL volumetric flask, diluted with deionized water to the mark and kept for further analysis.

Instrumental analysis of air samples

Lead levels in air samples were determined using FAAS (model spectr AA. 250 plus, Varian). The analysis was performed at the department of Chemistry, the University of Jordan, Jordan.

Quality Assurance and Control

Reagent blank samples were used to correct instrument readings. Accuracy and precision of the method were validated by six replicate measurements at concentrations of 5 ppm and 20 ppm as shown in Table 1 (Al-Subeihi, 2002).

Table 1. Accuracy and precision results (Al-Subeihi, 2002)

Spiked Pb (µg/mL)	*No. of samples	Measured Pb (µg/mL)	Accuracy (Relative error)	Precision (STD)
5	6	4.35	13	0.124
20	6	19.14	4.3	0.886

Prediction of BPb levels in the workers of Pb acid battery plant

Prediction of BPb levels for both workers and individuals in the vicinity of the battery plant of the current study was performed using air Pb levels, by applying the model developed by Richter *et al.*, 1979 (Richter *et al.*, 1979).

Data analysis

Normality of the data had been assessed using Shapiro-Wilk test included in the statistical SPSS software (Mishra *et al.*, 2019). Data are considered normally distributed when $p > 0.05$ (Mishra *et al.*, 2019). For normally distributed populations, t-test was used to investigate the difference between sample means of two groups. Results were considered significantly different when $p < 0.05$ (Daniel and Cross, 2013).

RESULTS

Determination Pb in air samples

Mean level of Pb in air samples of the acid battery plant was 1369 ± 929 (µg/m³), and ranged from 274 to 3453 (µg/m³) (Table 2). The Shapiro-Wilk test

Table 2. Predicted BPb Levels Using air Pb Levels

Sampling day	Air Pb (µg/m³)	Predicted BPb levels (µg/100 mL)
Day 1	294	68.75
Day 2	274	67.96
Day 3	517	75.46
Day 4	586	77.04
Day 5	785	80.85
Day 6	1549	90.44
Day 7	1580	90.74
Day 8	1654	91.42
Day 9	1737	92.17
Day 10	1894	93.49
Day 11	2110	95.17
Day 12	3453	103.23
Mean	1369	85.56
STD	929	11.22

result (p = 0.277) indicated that the sample came from a normal population. On the other hand, the mean of Pb in air samples collected from the vicinity of battery factory was 61.2 ± 35.0 (µg/m³). The Shapiro-Wilk test result (p = 0.392) indicated that the sample selected from a normally distributed population.

A one tailed t-test between the mean level of air Pb inside the acid battery plant of this study and the 50 µg/m³ OSHA's permissible exposure limit inside battery plants (OSHA, 2018a) indicated a significant difference (p = 0.000).

Prediction of BPb levels in acid battery workers and in individuals in the vicinity of the acid battery plant

Richter *et al.* (1979) measured air Pb levels in different days and BPb levels in 62 male workers in a battery plant in Jerusalem (Richter *et al.*, 1979). The correlation between BPb and air Pb levels in their study was significant (r = 0.69). It is represented in the following equation:

Table 3. Air Pb levels in the vicinity of the acid battery plant

Sampling day	Air Pb (µg/m³)	Predicted BPb levels (µg/100 mL)
Day 1	32.2	47.73
Day 2	62.8	53.29
Day 3	110.0	58.46
Day 4	39.9	49.45
Mean	61.2	52.23
STD	35.0	4.76

$$\text{Log BPb} = 1.430 + 0.165 \text{ X } \log \text{PbA}$$

where the BPb level is expressed as µg/100 mL and the air Pb (Pb A) level is expressed as µg/m³.

BPb levels in acid battery plant workers of this study were predicted by extrapolation, using Richter *et al.* (1979) model (Richter *et al.*, 1979). Results ranged from 67.96 to 103.23 µg/100 mL (mean of 85.56 ± 11.22 µg/100 mL). Result of Shapiro-Wilk test (p = 0.292) suggested that sample selected from a normal population. According to the Occupational Safety and Health Administration (OSHA, 2018b), BPb levels of 40 µg/100 mL or more suggests possible Pb toxicity. One sample t-test (one tailed) indicated a significant difference between the reference value of OSHA and the mean value of workers of the acid battery plant (p = 0.000).

Furthermore, BPb levels in individuals living in the vicinity of the acid battery plant were predicted by extrapolation using the same model. The results ranged from 47.73 to 58.46 µg/100 mL (mean of 52.23 ± 4.76 µg/100 mL). Shapiro-Wilk test (p = 0.688) suggested that the sample came from a normally distributed population. A one sample t-test (one tailed) indicated a significant difference between the mean value of individuals residing near the acid battery plant and the reference value of OSHA (p = 0.007).

Table 4. Correlation between predicted BPb levels using air Pb levels and predicted BPb levels using endogenous hair Pb levels

Sampling day	Predicted BPb levels using air samples (µg/100 mL)	*Predicted BPb levels using scalp hair samples (µg/100 mL)
Day 1	68.75	57.16
Day 2	67.96	109.04
Day 3	75.46	95.8
Day 4	77.04	77.36
Day 5	80.85	94.53
Day 6	90.44	85.42
Day 7	90.74	42.38
Day 8	91.42	53.83
Day 9	92.17	101.14
Day 10	93.49	108.09
Day 11	95.17	100.3
Day 12	103.23	98.03
mean	85.56	85.26
STD	11.22	22.57

*Obtained from a study performed by Al-Subeihi and Battah (2020)

Quality Assurance and Control

Analysis of blank samples revealed no detection for any trace of Pb. Accuracy and precision of the method using spiked hair samples at concentrations of 5 ppm and 20 ppm have been described in table 1. Results of the observed Pb concentration were in excellent agreement with the certified values and the method recoveries were 87 ± 2.9 % and 95.7 ± 4.6 %, respectively (Al-Subeihi, 2002).

DISCUSSION

The main objective of this study was to measure air Pb level as a marker of Pb exposure in workers of Pb acid battery manufacturing plant located in Marka, Jordan. The obtained results were applied to evaluate the validity of using air Pb levels in predicting BPb levels in workers of the same battery plant.

Since Pb concentration inside the battery plant is expected to increase through the working period, sampling time was chosen to be long enough in order to ensure collecting representative specimen to the working hours. So sampling time was through the whole work period (8 hour).

The experimental method, which was adopted for collecting air sample, where air Pb was directly digested by passing through a bubbler containing diluted HNO_3 (0.798 M), showed acceptable validated results. Other reported methods revealed collection of lead sample on a proper polycarbonate membrane before being subjected to digestion on hot plate (Bruno *et al.*, 2000).

The mean level of Pb in air samples of the acid battery plant was 1369 ± 929 (µg/m³), and ranged from 274 to 3453 (µg/m³) (Table 2). These findings were around 27-fold greater than the 50 µg/m³ allowable exposure limit (OSHA, 2018a). Air Pb level of 1260 µg/m³ was recorded in a battery plant in china (Chen *et al.*, 2006). It was noticeable that the current results were comparable with that reported by Chen *et al.* (2006). In another study, mean Pb level in air samples collected from battery manufacturing plants was 88.6 ± 0.1763 µg/m³. It was obvious that the present findings were around 25-fold more than that reported by Ho *et al.* (1998). Elevation of air Pb levels demonstrated high emissions of Pb in the acid battery plant. On the other hand, the average of Pb in air samples collected from the vicinity of battery factory was 61.2 ± 35.0 µg/m³ which was greater than OSHA's permissible exposure limit inside the battery plants. Based on these findings, it is clear that the high emissions of Pb had not only affected inside battery plant environment but also its vicinity.

BPb levels in acid battery plant workers were predicted by extrapolation, using Richter *et al.* 1979 model. The results ranged from 67.96 to 103.23 µg/100 mL (mean of 85.56 ± 11.22 µg/100 mL). Strong correlation is expected between Pb levels in air and the predicted BPb levels with correlation (r) = 0.955. This correlation supported using air Pb level to predict BPb level in exposed workers. These predicted results were comparable with the results of workers involved in Pb acid battery plant in Bangladesh (78.70 µg/100 mL) (Ahmad *et al.*, 2014).

Moreover, Table 4 shows that the mean of predicted BPb levels using air Pb samples matched the mean of predicted BPb levels using endogenous hair Pb samples obtained from the same battery plant (Al-Subeihi and Battah, 2020). A two sample t-test (two tailed) indicated almost no difference between the means of the two sample (p = 0.967). This result strongly supported using air Pb in predicting BPb levels of exposed humans in polluted areas.

BPb levels of individuals in the vicinity of acid battery plant of this study were also predicted by extrapolation using Richter *et al.* (1979) model. The results ranged from 47.73 to 58.46 µg/100 mL (mean of 52.23 ± 4.76 5 µg/100 mL). Strong correlation is expected between Pb levels in air and the predicted BPb levels and the correlation is r = 0.99. It was concluded that occupational exposure to Pb not only affected the workers inside the battery plant but also might affect the individuals in the vicinity.

In a case study of occupational Pb toxicity in battery workers, a BPb level of 60.45 ± 14.54 µg/100 mL was reported (Basit *et al.*, 2015), the workers had been suffering from headache, abdominal pain, anemia, nausea, tremors, etc. and had higher mean BPb level than those who did not had such illnesses. In another study, Qasim and Baloch (2014) had reported 2 cases of occupational Pb poisoning in adult battery workers where BPb levels in case 1 and case 2 were 98.83 and 120.20 µg/100 mL, respectively. Both male patients had initially suffered from intermittent abdominal pain, headache, and fatigue for 6 - 8 years. At a later stage, they developed slurred speech, psychosis, and tremors of hands. Therefore, it could be concluded that the workers of the acid battery plant were chronically exposed to Pb and were at the risk of developing Pb toxicity.

According to OSHA, BPb level should be below 40 µg/dL where levels more than 40 µg/100 mL, worker should be notified in writing and provided with medical examination. Moreover, workers have BPb level of 60 µg/100 mL for a single time must be removed from their job and could be placed to a job of lower exposure (OSHA, 2018b). All predicted BPb levels in the workers of the current study are greater than 60 µg/dL (Figure 1). Therefore, it could be concluded that the workers of the acid battery plant

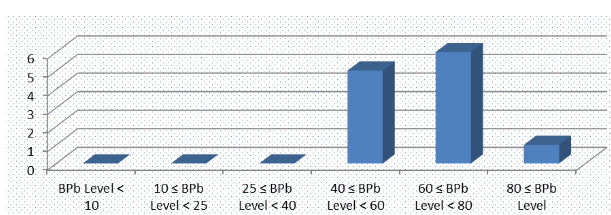

Fig. 1. Frequency of predicted BPb levels

were chronically exposed to Pb and were at the risk of developing Pb toxicity.

CONCLUSION

This study revealed that air Pb levels in a local acid battery plant were relatively high compared to the permissible exposure limit of OSHA. Moreover, the vicinity of the battery plant had been affected by the high Pb emissions which expected to be emitted from the activities of the battery plant. It could be concluded that workers of the battery plant and individuals who live in the vicinity are at high risk for Pb pollution.

Recommendation

Based on these results and conclusions, means to reduce exposure to Pb are highly recommended to reduce its air levels, closely monitor BPb levels among workers and to conduct regular educational programs to various workers about the health risk of Pb. Also, residence are advised to be cautious by residing in the neighborhood of battery plants.

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