INVESTIGATION OF ALUMINUM TOXICITY AMONG WORKERS IN ALUMINUM INDUSTRY SECTOR

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Abstract

The study was conducted to evaluate urine aluminum concentration among a total of 150 participants (80 aluminum technicians and 70 non-aluminum technicians as a control). Data were collected through a previously prepared questionnaire which consists of two parts. The first part concerned with demographic data such as age and nationality. The second part concerned with occupational data such as working hours, working years, smoking, and diseases. The mean concentration of aluminum is 51.62$\pm$ 29.59 µg/l and the mean concentration of group control 16.32 $\pm$ 12.49 µg/l. The following variables were associated significantly with aluminum concentration: age, weekly working hours, smoking and daily smoking packets.

According to our study, aluminum workers have high concentrations of urine aluminum compared with other studies, in addition to that the incidence of diseases in relation to exposure is low, simply because: 1-Self reported questionnaires may be not a proper way to collect data about diseases. 2-Traditional surveillance approaches used in public health practice are difficult to apply to metals poisoning because adverse health effects related to metal exposure may not be clinically diagnosed, except at very high exposure levels, and are not usually listed as reportable diseases.

Finally Special safety precautions and educational programs are also needed to limit the aluminum exposure in this industrial group.

Keywords: Aluminum, heavy metal toxicity

Introduction

Aluminum and its compounds are major constituents of the Earth's crust, comprising up to about 7- 8% of the Earth's crust (Emmanuel and Ryan, 1995). It has been reported to be the third most abundant element (after oxygen and silicon) and the most abundant metallic element, and is found in combination with oxygen, fluorine, silicon, sulphur and other species; it does not occur naturally in the elemental state (ATSDR, 1999; Wagner, 1999).

No known useful biological function was identified for aluminum (Greger JL, 1992). It has been noted that toxic effect of aluminum on living organisms has become clear only recently even though the element is present in small amounts in mammalian tissues. Aluminum is now being implicated as interfering with a variety of cellular and metabolic processes in the nervous system and in other tissues (Greger JL, 1992).

According to the requirements of the U.S. Occupational Safety and Health Administration (OSHA), employers have to reduce exposures to aluminum to or below an 8-hr time-weighted average (TWA) of 15 mg/m3 for total aluminum dust or 5 mg/m3 for the respirable fractions (NIOSH, 2005).

Humans are exposed to aluminum from a variety of environmental sources. Due to the fact that aluminum sulfate (alum) is used as a flocculating agent in the purification of municipal water supplies, drinking water may contain high levels of aluminum. Other important sources of exposure include aluminum cans, containers, and cooking utensils, as well as medications that contain aluminum (Greger, 1992). Aluminum inhaled from dust has been found to be retained in pulmonary tissue and peribronchial lymph nodes but is largely excluded from other tissues. The average dietary intake of aluminum by adults is probably 3 to 5 mg/d (Alfrey, 1984). It has been found that most of the aluminum absorbed from the intestinal tract is excreted in urine, leaving total body aluminum stores of less than 30 to 40 mg. Individuals with normal glomerular filtration rates who increase their aluminum intake by ingesting aluminum-containing antacids increase their absorption and urinary excretion of the metal (Kaehny et al., 1977).

Environmental Aluminum Exposure

The Joint Food and Agriculture Organization (FAO) / World Health Organization (WHO) Expert Committee on Food Additives and Food Contaminants recommended a provisional tolerable weekly intake (PTWI) of 7.0 mg/kg b.w.; this value includes the intake of aluminum from its use as a food additive (FAO/WHO, 1989; IPCS, 1997). In 2006, the PTWI was further lowered to 1.0 mg/kg b.w. citing that aluminum compounds may exert effects on reproductive and developing nervous systems at lower doses than were used in setting the previous guideline (FAO/WHO, 2006).

Toxicity of Aluminum in Humans

Toxicity of Al in humans has been investigated and found to occur in at least two specific situations. Dementia in dialysis patients is related to Al exposure (Mazzaferrso, 1997; Suarez-Fernandez et al., 1999).

Chronic renal failure is thought to decrease Al excretion and enhances Al toxicity (Flaten et al., 1996). The pathogenesis of Al toxicity is complex because it may depend on other factors such as impaired parathyroid function which affects Al absorption and/or distribution (National Library of Medicine, 2000). Osteomalacia or metabolic bone disease is another important aspect in relation with aluminum toxicity (Ogborn et al, 1991).

Al inhalation, especially in workers, may be associated with increased incidence of asthma (Sorgdrager et al., 1998; Vandenplas et al, 1998; Kausz et al, 1999).

Study Hypothesis

The main hypothesis for the present study implies that workers in aluminum industry are exposed to aluminum during their work. This exposure is occupational in nature and is being associated with health risk factors.

It is postulated that duration of exposure expressed in terms of exposure years is associated significantly with aluminum level. Furthermore, aluminum level is associated significantly with the practice attitudes, perception and knowledge of occupational risks.

Study Objectives

1. To study elevated urine aluminum levels and its association to work place exposure in Jordan.
2. Develop and provide information and educational materials to persons at risk and aluminum industries.

Methods and Subjects

Study Design: experimental cross-sectional design.

Study Setting

The present study was conducted in Arabic company for aluminum manufacturing in Albaqua.

Sampling Frame

One hundred and fifty participants were chosen to participate in the present study among them 80 aluminum technicians and 70 non-aluminum technicians.

Sampling Technique:

Occupational Data

Occupational and demographic data for participants were obtained through prepared questionnaire.

The first set of questions in the questionnaire determine the demographic data of the participants under this study includes age, gender, smoking habits, type and place of occupation, and duration of employment. The second set the questions include working type, job type, use of personal protective equipment such as mask, gloves and lab-coat, diseases such as sensitivity, urinary tract infection and the perception of participants for occupational dangers associated with their job.

Aluminum Measurement

The concentration of Aluminum was analyzed by atomic absorption spectrophotometer (AAS) which allow for the measurement of a wide range of concentrations of metals in biological samples. The atomic absorption spectrophotometer consist of a Flam Atomic Absorption Spectrometry (F-AAS) (Shimadzu, AA-6300, Tokyo, JAPAN) fully equipped for flame (air acetylene), and a Graphite furnace atomization (GFA-AAS) (Shimadzu, EX7, Tokyo, JAPAN).

The samples were analyzed using the spectrophotometer placed at the Princess Haya Center for Biotechnology.

Statistical Analysis

The data obtained from analysis of the urine of the subject investigated in this study regarding the concentration of the heavy metals and the associated factors demographically and environment of work were presented as: frequency, percentage and T test using statistical package for the social sciences SPSS (version 16, SPSS, an IBM Company, Chicago, USA). P value of ≤ 0.05 was considered statistically significant in the results presented of the study.

Results

Demographic Results

As shown in table 1, about 96% of participants in study and control groups are Jordanians. All study participants are aluminum technicians and all control group participants are non- aluminum technicians.

About 66% of participants in study group are married and about 54% in control group are also married.

Table 1: Demographic data of participants

VARIABLE	STUDY GROUP		CONTROL GROUP	
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)
Nationality Jordanian Non-Jordanian	 77 3	 96.25 3.75	 67 3	 95.71 4.29

Job **Technicians** **Non technicians**	**80** **0**	**100** **0**	**0** **70**	**0** **100**
Social Status **-Married** **- Single**	**53** **27**	**66.25** **33.75**	**38** **32**	**54.28** **45.72**

Using of Protective Tools

Hearing protective tools was reported by about 83% in study group and about 24% in control group. Protective coat was used by all participants in study group and about 3% in control group. Gloves were shown to be reported by all study group participants and 90% in control group participants. Eye glasses using was reported by about 94% of participants in study group versus 66% in control group. Protective Shoes were used by all study group participants and about 91% of control group participants. About 98% of study groups used head cap while it is used by about 77% of control group participants. Welding glasses were reported by about 83% of aluminum technicians while its use was reported by about 44% in control group participants. About 84% of study group participants used face mask versus about 36% of control group participants (table 2).

Table 2: Using protective tools and their statistical significance

VARIABLE	STUDY GROUP		CONTROL GROUP		P VALUE
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Hearing tools: -Yes -No	66 14	82.5 17.5	17 53	24.29 75.71	0.052
Protective coat: **-Yes** **-No**	80 0	100 0	2 68	2.86 97.14	-
Gloves: **-Yes** **-NO**	**80** **0**	**100** **0**	**63** **7**	**90** **10**	**-**
Glasses: **-Yes** **-No**	**75** **5**	**93.75** **6.25**	**46** **24**	65.71 34.29	**0.730**

Shoes (protective): **-Yes** **-No**	**80** **0**	**100** **0**	**64** **6**	91.43 8.57	**-**
Head cap: **-Yes** **-No**	**78** **2**	**97.5** **2.5**	**54** **16**	**77.15** **22.85**	**0.646**
Welding glass: **-Yes** **-No**	**66** **14**	**82.5** 17.5	**31** **39**	**44.29** **55.71**	**0.05**
Face mask: **-Yes** **-NO**	**67** **13**	**83.75** **16.25**	**25** **45**	**35.71** **64.29**	**0.441**

Exposure to Work Risk Factors among Study and Control Groups

In this part of the study, we investigated work related risk factors between study and control groups. Exposure to gases was reported by all study group participants and by about 96 % of control group participants. welding gases were exposed by about 98% of aluminum technicians and about 91% of control group participants. Cold/heat stress was reported by 99% of participants who are involved in aluminum and 90% of control groups. About one third of aluminum technicians reported their living closed to factories versus 10% of participants in control group. Smoking was reported by 60% in control group and this was more than that reported by study group (about 49%) (table 3).

Table 3: Exposure to work risk factors among study and control groups

Variable	STUDY GROUP		CONTROL GROUP		p value
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Gases and vapors: **-Yes** **-No**	**80** **0**	**100** **0**	**67** **3**	**95.71** **4.29**	**-**
Metal gases: **-Yes** **-No**	**78** **2**	**97.5** **2.5**	**64** **6**	**91.43** **8.57**	**0.694**
Cold/ heat: **-Yes** **-No**	**79** **1**	**98.75** **1.25**	**63** **7**	**90** **10**	**0.826**
Living closed to factory:					**0.074**

-Yes -No	**25 55**	**31.25 69.75**	**7 63**	**10 90**	
Smoking: -Yes -No	**39 41**	**48.75 51.25**	**42 28**	**60 40**	**1.00**

Diseases Shared among Study and Control Groups

About 3% of study and control group participants reported suffering from epilepsy. About 1% of participants in both groups reported being diabetics and having contact sensitivity. Asthma was reported by about 3% of control group participants and about 1% of study group participants. Bronchitis was reported by about 6% of study group participants and this is the double of control group participants (about 3%). Tuberculosis was about 3% in control group and about 1% in study group (table 4).

Table 4: Diseases shared among study and control groups

Disease	STUDY GROUP		CONTROL GROUP		p value
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Epilepsy: -Yes -No	2 78	2.5 97.5	2 68	2.86 97.14	-
Diabetes : -Yes -No	1 79	1.27 98.73	1 69	1.43 98.57	-
Sensitivity (contact): -Yes -NO	1 79	1.27 98.73	1 69	1.43 98.57	-
Asthma: -Yes -No	1 79	1.27 98.73	2 68	2.86 97.14	0.902
Bronchitis Yes - No -	5 75	6.25 93.75	2 68	2.86 97.14	0.720

Aluminum Concentrations in Study and Control Groups

The mean of aluminum concentration in study group is 51.62$\pm$ 29.59 µg/l and this was higher than the mean concentration of group control 16.32 $\pm$ 12.49 µg/l. The variations between study and control groups are statistically significant (p value 0.000) (table 5).

Table 5: Aluminum concentrations in study and control groups

Heavy metal	Mean (µg/dl)	Standard deviation	P value
Aluminum-Study group	51.62	29.59	0.00
Aluminum-Control-group	16.32	12.49	

The Relationship between Aluminum Concentration And Other Variables

The results did not show statistical difference between age among study and control groups (p value 0.065). the results showed significance correlation between aluminum concentration and age (p value 0.000). smoking years and aluminum concentrations are correlated significantly (p value 0.000). Weekly working hours and aluminum concentration are also correlated significantly (p value 0.042) (table 6).

Table 6: The relationship between aluminum concentration and other variables

Paired variables	Mean (µg/dl)	Standard deviation	P value
Age Urine Aluminum concentration	32.6 51.47	9.70 29.68	0.000
Smoking years Urine Aluminum concentration	11.99 57.15	8.09 29.87	0.000
Weekly working hours Urine Aluminum concentration	44 51.63	10.89 29.46	0.042

Discussion

The present study is concerned with the occupational approach to investigate the harmful effects of aluminum on workers in aluminum industry. Naturally, people are exposed to aluminum because of its high availability in nature.

The present study was conducted to achieve the following objectives: to determine the prevalence of aluminum toxicity among workers in aluminum industry and to correlate the occupational exposure for aluminum with diseases such as respiratory diseases and hypersensitivity.

The data of the present study showed that the mean concentration of aluminum among aluminum workers is 7.0 ug/l with standard deviation 5.2 ug/l. Compared with other studies, the aluminum workers are considered at lower exposure level. Rollin et al. (1996) reported in his study that prior to employment in the potroom, workers' mean urine aluminium level before employment was 24.2 µg/L; after 36 months of employment it was 49.1 µg/L. In another study conducted by Drabløs et al. (1992), the mean urine aluminum level of 15 workers in an aluminum fluoride plant exposed to a mean of 0.12 mg Al/m3 was 12 µg/L, of 12 potroom workers in an aluminum smelter exposed to a mean of 0.49 mg Al/m3 was 54 µg/L and of

7 foundry workers in the aluminum smelter exposed to a mean of 0.06 mg Al/m3 was 32 μg/L; that for the 230 controls was 5 μg/L.

The data showed that using the following protective tools hearing tools, eye glasses, head cap, welding glass and face mask, was shown to retain the aluminum concentration below the average (p value <0.05 for all). It is required to reduce the exposure to aluminum. According to the requirements of the U.S. Occupational Safety and Health Administration (OSHA), employers have to reduce exposures to aluminum (NIOSH, 2005).

The data of the present study showed that exposure to gases has similar distribution among participants with various aluminum concentrations and this is not statistically significant (p value 0.439). Other studies across the literature showed that the pot emissions contained various chemicals among which are aluminum oxide, carbon dusts, particulate polycyclic organics, gaseous and particulate fluorides, carbon monoxide, carbon dioxide, sulphur dioxide and nitrogen oxides. These chemicals reflects increased exposure to aluminum (Söyseth et al., 1994).

The other variables in this section such as welding gases, organic solvents, metals, metals, noise contamination, cold/heat stress and hobbies follow the same pattern of discussion. In these cases, we think that participants are still having high exposure even below the average and that is why no significant differences have been observed. In the opposite side, two variables were associated significantly with aluminum concentration. These variables are stress at work environment and waste management, they showed significant correlation with aluminum (p value 0.000). The previous two variables were shown to lead to relatively less exposure to aluminum. These findings do not agree with other studies conducted in animals in which it has been suggested that maternal stress during pregnancy could enhance aluminum induced developmental toxicity in mouse and rat offspring (Colomina et al., 1998; 1999; 2005; Roig et al., 2006).

The study data showed that there is a trend that more aluminum concentration is shown among 55.6% of smokers which is more than that for less aluminum exposure (44.4%). These findings are consistent with findings reported by Chan-Yeung et al. (1983) who reported that participants with groups exposed to aluminum are more likely to be smokers.

The data of the present study showed low incidence of diseases among participants. Furthermore, they were not correlated with aluminum concentration.

The data showed that aluminum concentration is positively correlated with age (p value 0.000). The data of the present study agree with other reported studies in literature in which a greater increase in blood aluminum was seen in subjects aged > 77 than in those aged < 77 (serum aluminum 101 vs. 38 μg/L at 1 hr), who consumed ~ 4.5 mg/kg aluminum hydroxide and

3.3 to 6.5 g citrate (citrate: aluminum, 1.6:1 to 3.2:1) after an overnight fast (Taylor et al., 1992). Comparing oral aluminum bioavailability in the subjects < 59 with those >59 years of age failed to reveal a difference (Stauber et al., 1999). The results of the present study showed that aluminum concentration to be correlated significantly with weekly working hours (p value 0.000). It has been realized by the U.S. Occupational Safety and Health Administration (OSHA) that employers have to reduce exposures to aluminum to or below an 8-hr time-weighted average (TWA) of 15 mg/m3 for total aluminum dust or 5 mg/m3 for the respirable fractions (NIOSH, 2005).

Finally, aluminum concentration was shown to correlate significantly with daily smoking packets. The relation between aluminum and smoking was discussed previously and it was reported that smokers have more aluminum concentrations in their blood compared with other population Rollin et al., 1996.

Conclusions

1- The mean concentration of aluminum in study group is 51.62+ 29.59 ug/lit and this is higher than the mean concentration of group control 16.32 + 12.49 ug/lit.
2- Using protective tools during work reduces the exposure to aluminum.
3- Aluminum concentration is correlated significantly with age, weekly working hours and smoking years.

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