

ADVERSE HEALTH EFFECTS AMONG WORKERS IN AN EGYPTIAN LEAD CRYSTAL GLASS MANUFACTURING PLANT

By

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Abstract

Introduction: Glass production workers are exposed to several workplace factors that may affect their health. Lead encountered in the manufacture of crystal glass is known to cause harmful effects. It is necessary to highlight the health effects of lead among Egyptian crystal glass workers. **Aim of work:** The aim of the study was to identify some health disorders in relation to blood lead level (BLL) among Egyptian workers exposed to lead in a lead crystal glass factory and find the association between (BLL) and psychological morbidities and biochemical parameters. **Materials and methods:** A comparative cross-sectional study was carried out in the occupational health clinic at Faculty of Medicine, Ain Shams University. It included 50 workers from a lead crystal glass manufacturing plant (exposed group) and 50 non-exposed workers. Data collected included personal data, occupational and medical histories, clinical examination and body mass index (BMI). Blood lead level (BLL), serum calcium, serum uric acid, red blood cell (RBC) count, haemoglobin, serum creatinine, and blood urea nitrogen (BUN) were measured for both groups. A general health questionnaire was used to assess psychological morbidities. **Results:** Exposed workers and controls were matched for gender and age. Exposed workers had significantly more gastro-intestinal, neurological, heat-related, ear and nose symptoms. Regarding biochemical parameters, BLL, blood urea nitrogen (BUN) were significantly higher among exposed workers, while serum creatinine was higher among non-exposed workers. Psychological distress was statistically significantly more prevalent among exposed workers and the difference was statistically significant. Among the exposed workers, only 60%, 56%, 56% and 26% used gloves, masks, uniform and boots, respectively. **Conclusion:** Elevated BLL is associated with higher BUN and psychological morbidity among exposed workers.

Key words: Blood lead, Lead crystal glass factory, Gastro-intestinal, Neurological, Heat-related, Ear and nose symptoms.

Introduction

Glass is a transparent or translucent material that has no crystalline structure and behaves like a solid (Cambridge English Dictionary, 2005). There are five main sectors in the glass manufacturing industry: flat glass, containers and pressed ware, art glass, special glass (e.g. optical and electronic) and fibre glass (Werner, 1994). In the glass industry, the materials used are feldspar, dolomite, salt cake, soda, silica and others. In fact 96% of glass is made of silica. In the production of heavy crystal glass, the glass batch contains about 30% lead (Andersson, 1990). Crystal glass as a term is actually misleading as the structure of glass is non-crystalline. The term gained traction mostly for commercial purposes, to accentuate the beauty and special properties of lead glass, which is capable of amazing refraction and seems pseudo-crystal (Tait, 1991).

Occupational lead toxicity was first reported in 200 BC although it is believed it goes back to 2500 BC. Lancereaux was the first to report lead-related nephrotoxicity in 1862. There were many reports regarding the relation between occupational lead exposure and nephritis in the following decades, which made lead nephropathy as a common diagnosis (Muntner, 2003).

Because of the lately discovered health effects, many glass manufacturers have discontinued production of lead glass or have modified their production to so-called unleaded crystal glass, in which lead oxide is substituted by other oxides (barium oxide, potassium oxide, or zinc oxide) (Davison, 2003). However, in Egypt, the manufacture of leaded crystal glass is still prevalent. In fact, Egyptian lead crystal glass (made with 24%-30% lead oxide) is some of the finest refractive crystal glass. Though not as expensive as Strass or Swarovski crystal, this crystal glass is characterized by a prismatic brilliance, visual purity, sharp faceting and precise polishing (Shades of light, 2017).

Unfortunately, Egyptian workers in such factories are at risk of being exposed to different factors such as contact with toxic materials and harmful chemicals or harmful physical factors. During preparing materials, glass melting process and preparation of the final products, workers are exposed to inhaling free silica dust, lead dust and fumes, irritating alkaline gas or vapour due to combustion and melting materials, working in a hot weather, contact with infrared radiation and finally the danger of touching the

cutting pieces and glasses, etc... (Abdel-Rasoul et al., 2013).

The health hazards of glass manufacture have been listed in the International Labour Organization Encyclopaedia of Occupational Health and Safety. Morbid conditions in glass factory workers are injuries, heat exhaustion, respiratory morbidity, ophthalmic and renal morbidity (Lockey et al., 2011). Lead encountered in the manufacture of crystal glass is also known to cause harmful effects in the haematopoietic, nervous, digestive, renal, and other organ systems, inhibiting a number of enzymes in the biosynthesis of haem, as well as other enzymes with haematological significance (Bilban, 2015).

Anaemia caused by lead exposure is the result of the inhibition of haemosynthesis and aggravated failure of erythrocytes. In the case of minor build-up, changes in the kidneys are quite reversible, as early effects are mostly concentrated on the proximal tubules. A higher degree of exposure, however, leads to interstitial fibrosis and advanced renal failure (Patocka, 2008). It is postulated that lead affects the renin-angiotensin system, thus causing increased blood pressure (Hegazy et al., 2010).

Some previous studies dealt with morbidities of glass factory workers. An Indian study conducted in 2016 revealed that, among the glass workers, 33.04% had prick injuries, 14.91% musculoskeletal problems, 10.81% burns, 9.64% had hypertension, and 5.26% had ENT problems like noise-induced hearing defects and earache. Ocular injuries were reported by 4.09%, while 3.8% had chronic irritant cough, difficulty in breathing, and chest pain (Potdar, 2016). In Egypt, a study conducted in 2013 reported that glass workers had a significantly higher prevalence of chest, auditory and heat-related manifestations as well as deteriorated spirometric measurements and abnormal audiometric findings (Abdel-Rasoul et al., 2013).

This study is important as it will highlight the adverse health effects among Egyptian lead crystal glass workers and to provide effective recommendations to support their health.

Aim of work

To identify some health disorders in relation to blood lead level (BLL) among Egyptian workers exposed to lead in a lead crystal glass factory and find the association between BLL and psychological morbidities and biochemical parameters.

Materials and methods

Study design: This is a comparative cross-sectional study.

Place and duration of the study:

It was carried out in the occupational health clinic at Faculty of Medicine, Ain Shams University, from October to December, 2017.

Study sample: It included 50 males working at a lead crystal glass producing plant located in Greater Cairo Governorate who were scheduled to be subjected to periodic medical examination. Fifty workers from a public university with no history of job-related exposure to lead were matched by age and gender; were taken as controls.

Exclusion criteria: Workers who had any chest diseases, skin diseases, psychological disorders, cataract or any auditory diseases before employment in this factory were excluded from the study. A sample of 40 was calculated using morbidity prevalence among workers in a glass factory in India equals to $97 \pm 8\%$ and confidence interval of 95% (Brahmapurkar, 2013). The sample was calculated using Epi Info 2002 program. It was increased to include 50 exposed workers and 50 non-exposed ones.

Study Methods

1) A **pre-designed interview questionnaire** was used to record demographic data, occupational history (including years of working in the industry and use of protective devices), medical history of chest and auditory diseases, manifestations of heat stroke, heat exhaustion, heat cramps, sterility, cataract, skin rash and clinical manifestations of lead poisoning as well as past history of other diseases (mental, nervous diseases, hypertension, diabetes mellitus, liver and kidney diseases or use of antipsychotic drugs and skin, chest or eye allergies).

2) **Psychological distress was measured with the 12-item General Health Questionnaire (GHQ-12)**, using the original GHQ rating method (0-0-1-1) (Makowska et al., 2002). The questions ask about self-confidence, mood, sleep disorders, ability to concentrate and problem solving abilities. Points were summed up to a score ranging from 0–12, which was used as a continuous variable. Based on the optimal cut-off point of $\frac{3}{4}$, participants were categorized as non-distressed (GHQ-score: 0–3) and distressed (GHQ-score: 4–12).

3) General examination was done including: Weight, height and blood pressure measurement. The mean of 3 blood pressure measurements was used, all of which were taken by the researcher using a mercury sphygmomanometer. Patients were categorized as hypertensive if their systolic blood pressure was 140 mm Hg or higher, or diastolic blood pressure was 90 mm Hg or higher (WHO, 2005).

4) Laboratory investigation:

Venous blood samples were collected from all exposed and non-exposed workers (5 mL) in the morning between 7 a.m. and 8 a.m. to determine the levels of haemoglobin, hematocrit, red blood cell (RBC) count, and BLL, blood calcium level, blood urea nitrogen (BUN), serum creatinine and uric acid. The time schedule was adjusted, so that workers could participate in the study conveniently.

Analysis of blood lead was performed using Buck Model 210 VGP Atomic Absorption Spectrophotometer in the occupational unit laboratory at Faculty of Medicine, Ain Shams University. Other laboratory investigations were carried out in the central laboratory

of Ain Shams University hospital. Reference values of the laboratory were used. The upper limit for normal lead level was 20 $\mu\text{g/dL}$, and elevated levels more than 40 $\mu\text{g/dL}$ were considered cases with lead toxicity that necessitated restriction from work according to OSHA guidelines (CDC, 2018).

Consent

All subjects were informed about the study objectives and consent was given prior to the study.

Ethical approval

The study was approved by Faculty of Medicine, Ain Shams University, Committee for Medical Research Ethics.

Data management

Data were coded and presented to a personal computer. Data were analysed using SPSS statistical package version 20. Qualitative data were presented as frequency and percentages. Quantitative variables were presented as Mean \pm Standard deviation (SD). Chi squared test was used to compare qualitative variables, while student t test and ANOVA were used to compare quantitative variables. Significant difference was considered at a p value < 0.05 .

Results

Table 1: Socio-demographic and personal characteristics of the studied groups.

Characteristic	Exposed workers(No=50)	Non-exposed workers (No =50)	Total (No =100)	t	p
Age (Mean ± SD)	38.12 ± 4.87	40.22 ± 6.98	39.17 ± 6.08	-1.744	0.084
	No (%)	No (%)	No (%)	X²	p
Marital status					
Single	0	4 (8)	4	4.167	0.117
Married	50 (100)	46 (92)	96		
Education#					
Not educated	5 (10)	40 (80)	45	49.495	
Educated	45 (90)	10 (20)	55		
Smoking					
Smoker	17 (34)	25 (50)	42	2.627	0.105
Non-smoker	33 (66)	25 (50)	58		
BMI					
Normal	16 (32)	10 (20)	26	4.207	0.122
Overweight	23 (46)	20 (40)	43		
Obese	11 (22)	20 (40)	31		
Blood pressure					
Hypertensive	12 (24)	15 (30)	27	0.457	0.499
Normotensive	38 (76)	35 (70)	73		

#: Educated are those who completed primary education or higher.

** : Highly statistically significant

BMI: Body Mass Index

Table 1 showed that the exposed and the non-exposed workers were matched as regards age. There was no statistically significant difference between both groups regarding marital status, smoking habit, body mass index and blood pressure. As regards education, 80% of the non-exposed workers did not complete primary education. Regarding personal protective devices, only 60%, 56%, 56% and 26% of the glass factory workers used gloves, masks, uniforms and boots, respectively.

Total work duration of glass factory workers ranged from 2–35 years (11.18±6.2) and they worked 8 hours daily for 6 days/week (Untabulated data).

Table 2: Comparison between exposed and non-exposed workers regarding different symptoms.

Symptoms	Exposed workers (No =50)		Non-exposed (No =50)		X ²	p-value
	No	%	No	%		
Gastro-intestinal symptoms						
Abdominal colic	18	36	0	0	21.951	<0.001**
Constipation	15	30	5	10	6.25	0.012*
Anorexia	22	44	15	30	2.102	0.147
Heartburn	21	42	10	20	5.657	0.017*
Respiratory symptoms						
Chronic cough	12	24	10	20	0.233	0.629
Expectoration	15	30	15	30	0	1
Chest tightness	13	26	20	40	2.216	0.137
Wheezes	13	26	10	20	0.508	0.476
Bronchial asthma	7	14	10	20	0.638	0.424
Neurological symptoms						
General weakness	28	56	13	26	10.453	0.005*
Headache	24	48	10	20	8.734	0.003*
Nervousness	27	54	15	30	5.911	0.015*
Tremors	15	30	0	0	17.647	<0.001**
Muscle ache	21	42	5	10	13.306	<0.001**
Insomnia	19	38	5	10	10.746	0.001**
Lack of concentration	28	56	5	10	23.926	<0.001**
Ear and nose symptoms						
Irritated nasal mucosa	13	26	0	0	14.943	<0.001**
Hearing impairment	20	40	15	30	1.099	0.295

Tinnitus	14	28	0	0	16.279	<0.001**
Earache	13	26	0	0	14.943	<0.001**
related manifestations-Heat						
Heat rash	11	22	0	0	12.36	<0.001**
Muscle twitches	9	18	0	0	9.89	0.002*
Heat exhaustion	16	32	5	10	7.294	0.007*
Cataract	7	14	5	10	0.379	0.538
Infertility	11	22	0	0	12.360	<0.001**

*: Statistically significant

**: Highly statistically significant

Table 2 showed that there was highly statistically significant difference between exposed and non-exposed as regards abdominal colic, constipation, heartburn, all the neurological symptoms asked about, ear and nose symptoms except hearing impairment, heat-related symptoms except cataract, and none of the respiratory symptoms.

Table 3: Comparison between exposed and non-exposed workers regarding biochemical parameters.

Biochemical parameters	Exposed workers (No=50)	Non-exposed workers (No =50)	Total	t	p-value
	Mean \pm SD				
Blood lead level (BLL) ($\mu\text{g}/\text{dL}$)	28.24 \pm 8.64	14.2 \pm 4.78	21.22 \pm 9.9	10.05	<0.001**
Blood urea nitrogen (BUN) (mg/dL)	23.34 \pm 4.32	15.2 \pm 3.96	19.27 \pm 5.81	9.826	<0.001**
Creatinine (mg/dL)	0.68 \pm 0.122	0.96 \pm 0.12	0.82 \pm 0.19	-11.669	<0.001**
Serum uric acid (mg/dL)	4.7 \pm 0.8	5.07 \pm 1.91	4.88 \pm 1.47	-1.268	0.208
Blood haemoglobin (g/dL)	14.21 \pm 1.47	14.27 \pm 1.13	14.24 \pm 1.31	-0.244	0.808
Red blood cell (per μL)	4.97 \pm 0.45	5 \pm 0.38	4.98 \pm 0.41	-0.320	0.75
Total serum calcium (mg/ dL)	8.78 \pm 0.42	8.88 \pm 0.26	8.83 \pm 0.35	-1.463	0.147

**: Highly statistically significant

Regarding the biochemical parameters, Table 3 showed that BLL, and BUN were statistically significantly higher among exposed workers. However, serum creatinine level was higher among non-exposed group. The differences between exposed and non-exposed workers regarding serum uric acid, haemoglobin, RBC count and total serum calcium were not statistically significant.

Table 4: Comparison between exposed and non-exposed workers regarding GHQ-12

Variables	Exposed workers (No=50)	Non-exposed workers (No =50)	Total	t test/ X ²	p-value
Score of GHQ (group) Mean ± SD	3.2 ± 2.62	1.4 ± 1.58	2.3 ± 2.33	4.163	<0.001**
Distressed (GHQ>3) No (%)	18 (36)	5 (10)	23	9.543	0.002*

GHQ-12:General Health Questionnaire-12

*: Statistically significant

** : Highly statistically significant

Table 4 showed that among exposed workers, there were statistically significantly more distressed workers (18 vs 5).

No statistically significant correlation was detected between years of work in the glass industry and levels of biochemical parameters except creatinine (Pearson correlation coefficient 0.496, P value <0.001) (Untabulated data).

Discussion

Results of this work indicate that BLL is associated with many symptoms and diseases, affecting various body systems.

Regarding gastrointestinal tract (GIT) symptoms, abdominal colic was significantly more prevalent among exposed workers affecting 36% versus

none in non-exposed group (Table 2). This is similar to the results detected by Hwang et al. (1991) on his study on the relationship between blood lead and lead related symptoms among group of workers in Korea.

Constipation and heart burn were also significantly more prevalent among

the exposed workers compared with the non-exposed (Table 2). Case reports of some patients who were exposed to lead at work reported GIT symptoms including constipation (Shiri et al., 2007)

There was no significant increase of respiratory symptoms among workers in the lead crystal glass manufacturing plant in this study; being evaluated by history taking about chronic cough, expectoration, chest tightness, wheezes or asthma (Table 2). Abdel-Rasoul et al. (2013) reported that respiratory manifestations (rhinitis, cough, expectoration and dyspnoea) and deteriorated spirometric measurements were significantly more prevalent among exposed group of Egyptian workers in a glass industry. This controversy may be related to the type of exposure to irritants in different glass factories.

The relation between lead exposure and nervous system was obvious in this study, as there is highly statistically significant increase of reporting tremors (30 % in exposed and none in non-exposed group), muscle aches (42% in exposed vs 10% in non-exposed) and lack of concentration (56% in exposed vs 10% in non-exposed) (Table 2).

Other symptoms like general weakness, headache and nervousness; were significantly higher among the exposed group (Table 2). Those symptoms were reported by Papanikolaou et al. (2005) in their study on workers exposed to lead.

Regarding auditory manifestations due to lead exposure, there were highly statistically significant differences between exposed and non-exposed groups regarding tinnitus and earache. Twenty percent of the exposed group complained of tinnitus and the same percentage had earache in comparison to none in the non-exposed group (Table 2). Potdar et al. (2016) reported that earache and noise-induced hearing defects, at Puducherry glass manufacturing plant, were noticed in 5.26% of workers. Abdel-Rasoul et al. (2013) found that the exposed group experienced a significantly higher prevalence of all auditory manifestations (hearing loss, tinnitus and earache) and auditory findings (moderate to severe hearing impairment and V- dip) especially at the furnace sector. Nelson et al. (2005) also found that 16% of the disabling hearing loss in adults was attributed to occupational noise.

Regarding heat-related manifestations,

heat rash was highly significantly observed among exposed versus non-exposed workers (22% versus 0%). Heat exhaustion and muscle twitches were significantly related to exposed group too (32% and 18% respectively in exposed group versus 10% and 0% in non-exposed group) (Table 2). In a cross sectional study done by Sripaiboonkij et al., 2009 on respiratory and skin health among glass microfiber production workers; they reported heat exhaustion among 28.1%, heat cramps among 22.0%, heat hyperpyrexia among 2.6%, indicating significant occurrence of heat stress among glass factory workers. Abdel-Rasoul et al. (2013) reported that heat-related manifestations (exhaustion cramps and skin rash) were more frequent among exposed glass workers especially at batch and finishing departments with a highly significant relation when compared to non-exposed group. This is in agreement with the studies carried out by El-Safty et al. (2008) in Egypt and by Kishor et al. (2012) in India.

The current work showed that there was no significant difference between exposed and non-exposed groups in relation to cataract (Table 2). Lydhal (1984) studied infrared radiation and

cataract in age group of 70 years and older and found that statistically significant increase of all types of cataract, sub-capsular, cuneiform and nuclear compared to comparison group and he concluded that occupational infrared radiation exposure of glass workers accelerates the development of senile changes in the lens. This controversy may be due to different age range in our study than in their study.

It was found that 22% of the workers and none of the non-exposed group were infertile and the difference was highly significant (Table 2). Causes of reproductive dysfunction and infertility has been previously described in a review on males exposed to lead at the workplace, including oligozoospermia, decrease in sperm density and motility, abnormal sperm head morphology, decreased serum testosterone and hypogonadism (Queiroz and Waissmann, 2006).

In the current study, haemoglobin and RBC count showed slight non-significant decrease among exposed workers vs non-exposed ones (Table 3). In controversy, Hwang et al. (1991) in their study on the relationship between blood lead and lead-related

symptoms in low level lead exposure; found statistically significant difference between exposed and non-exposed regarding haemoglobin level. This may be explained by the small sample size of the current study.

BUN was significantly higher among the exposed versus non-exposed (Table 3). In the United States; hypertension, and exposure to lead, even at low levels were associated with chronic kidney disease as reported by Muntner et al. (2003). Blood lead concentrations were higher among adults with renal failure and had a history of childhood lead poisoning as reported by Emmerson (1991). Investigators from the Cadmibel Study Group on their study on impairment of renal function with increasing blood lead concentrations in the general population found an association between blood lead and impairment in renal function among the general population in Belgium (Staessen et al., 1992).

Regarding psychological distress among glass factory workers, our work showed highly significant association between distress (GHQ>3) and lead exposure (36% in exposed versus 10% in non-exposed) (Table 4). In line with this result, Jeyaratnam et al.

(1986) also reported significantly more complaints of anxiety and depression, poor concentration and forgetfulness, and some somatic complaints among lead-exposed workers in Singapore.

Conclusion: Lead crystal glass industry is significantly associated with high levels of BLL, BUN and psychological distress. Negligence of using personal protective devices is evident among the studied group of workers.

Conflict of interest

The authors report no conflict of interest.

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