Original Article

Lead and Cadmium Toxicity in Tile Manufacturing Workers in Assiut, Egypt

Ragaa M Abd Elmaaboud[1*], Zaghloul T. Mohamed[1]

Safaa M. George[1], Azaa M. Ez El-dine [2], Doaa M. El Shehaby[1].

[1] *Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Assiut University, Egypt.*

[2] *Clinical Pathology Department, Faculty of Medicine, Assiut University, Egypt.*

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Abstract

Occupational lead and cadmium exposure are important health issues in developing countries. This study aimed to detect toxic metal contents in raw materials used to make tiles and to assess exposure health impacts on workers. The study sample consisted of 74 tile workers, having a mean age of 35.2 years, in the Industrial City of Arab El Awamer, Assiut (Egypt). Elemental analysis of the raw materials was performed by using scanning electron microscopy. The data collection questionnaire was divided into two parts; the first included demographic data, symptoms attributed to toxic elements and possible sources of exposure to metals. The second part was designated to assess heavy metal exposure health impacts through clinical examination and biological investigations. Many toxic elements were identified in the raw materials used to make tiles, and the most abundant were lead and cadmium. Analysis of the clinical data revealed that 66% of the workers suffered from headache, constipation (8%), abdominal colic (33.8%) and 30% suffered from a variety of respiratory problems such as dyspnea (60%), cough (13%) and chest tightness (27%). Fifty percent of the workers complained of weak grip, 33.8% of foot drop, and 54% had tremors. Burton's line in gums was present in 28% of workers and 28.2% were diagnosed with constrictive lung diseases. Of the 74 workers, 90.5 % showed toxic lead levels and 80% had toxic cadmium levels. 10.8% had abnormal alpha glutathione levels with a positive strong linear correlation between lead and cadmium levels and years of work. It is mandatory to develop and implement measures to prevent these hazardous exposure effects among tile industry workers.

Keywords: Lead, Cadmium, Occupational hazard, Toxicity, Tiles Manufacturing, Assiut.

* Corresponding Author: Ragaa M. Abd Elmaaboud
Email: ragaamohabd@yahoo.com

التسمم بالرصاص والكادميوم لدى عمال صناعة الأُجرَ (البلاط) بمدينة أسيوط في مصر

المستخلص

يُعد التعرض المهني للرصاص والكادميوم قضية صحية هامة وخاصة في البلدان النامية. وحيث تعد صناعة الآجُرَ إحدى مصادر التعرض لهذه العناصر، فقد هدفت هذه الدراسة إلى تحديد ما

تحتويه المواد المستخدمة في صناعة الآجُرَ (البلاط) من العناصر السامة ومدى تأثيرها على صحة العاملين. شملت الدراسة أربعة وسبعين عاملاً في ستة أماكن لتصنيع الآجُرَ بالمدينة الصناعية بعرب العوامر بأسيوط، حيث أجريت التحاليل لتحديد العناصر في عينات المواد الخام المستخدمة في التصنيع بواسطة مجهر المسح الإلكتروني، وتم دراسة استبيان تضمّن أسئلة حول المعلومات الديموغرافية للعمال وأسئلة عن الأعراض التي يمكن أن تُعزى إلى التعرض للعناصر السامة، كما أجريت بعض الفحوص السريرية وأشعة سينية على الصدر وبعض التحاليل على عينات دم وبول مأخوذة من العاملين. وقد أثبتت نتائج تحليل المواد الخام المستخدمة في صناعة الآجُرَ أنها تحتوي على العديد من العناصر الثقيلة السامة و أن النسبة الأكبر كانت لعنصري الرصاص والكادميوم. وأظهرت الفحوص السريرية للعمال أن (66%) منهم يشكون من الصداع، و(8%) يعانون من الإمساك مع تغير في لون البراز، و حوالي ثلثهم (33.8%) يعانون من أعراض المغص المتكرر. وحوالي (30%) من العاملين لديهم مشاكل في الجهاز التنفسي؛ عانى (60%) منهم من ضيق تنفس. كما بيّن الاستبيان أن (50%) من العاملين يشتكون من ضعف في قبضة اليد، وثلثهم (33%) كانوا يشكون من هبوط القدم. وأن (60%) من العاملين لديهم ظلال داكنة تحت العينين، كما وجد الخط الأزرق في اللثة لدي (28%) من العمال، وظهرت أعراض التليف الرئوي لدى (27.8%) من الذين أجروا اختبار وظائف التنفس. وأنه من أصل (39) حالة وافقت على فحص الصدر بالأشعة السينية (11) حالة ما يمثل (28.2%) كان لديهم علامات التليف الرئوي. و أن (90.5%) من العاملين لديهم مستوى رصاص سام ومرتفع بالدم، و (80%) من العمال كانوا يعانون من مستوى سام ومرتفع للكادميوم. و (10.8%) كان لديهم مستوى غير طبيعي من ألفا-جلوتاثيون-اس-ترانسفيريز (alphaGST) في البول، وأن مستوى الرصاص السام في الدم يزيد بزيادة عدد سنوات التعرض، ووجود علاقة ذات دلالة إحصائية بين مستوى الرصاص في الدم والأعراض العصبية عند العاملين. وإن نتائج هذا البحث تستوجب وضع وتفعيل ضوابط لحماية العاملين بصناعة الآجُرَ لمنع ما يتعرضون له من مخاطر صحية.

الكلمات المفتاحية: الرصاص، الكادميوم، السموم المهنية، صناعة الآجر (البلاط)، أسيوط.

1. Introduction

Tile are one of the most widely used materials in construction [1]. Toxic products of the tile production process are mixtures of predominantly clays, dust, vapor and other natural occurring minerals that have been mixed with water and fired in a high temperature [2]. In the tile industry, a certain amount of coloring agents are added to the clay and mixed in a ball mill. Exposure to these heavy metals in the tile production process occurs mainly during mixing, storing, handling and other activities where large amounts of respirable dust particles are generated [3].

Occupational lead exposure in many developing countries is entirely unregulated, often with no monitoring of exposure. Although there are numerous small-scale industries which use lead-based raw materials that may pose health risks to workers, there are no workplace regulations for monitoring lead exposure among these workers [4] and no such data are available with the labour departments or any other related authority.

Cadmium is a naturally occurring heavy metal and is an occupational hazard within a variety of industrial settings. The workplace is the most common source of cadmium exposure, occurring mainly through inhalation of dust and fumes [5]. Cadmium principally affects the lung, kidney, liver, and testes following acute intoxication, which leads to nephrotoxicity due to prolonged exposure [6]. Cadmium is a potent cell poison and which causes oxidative stress by increasing lipid peroxidation and/or by changing intracellular glutathione levels. Inhalation exposure can result in acute hepatic and renal injury, while intake of cadmium-contaminated food causes acute gastrointestinal effects, such as nausea, vomiting and diarrhea [7].

This study aimed to do an elemental analysis of raw materials used in the manufacturing of tiles, detect different heavy metals present in their raw materials and to determine the toxicological health hazards among tile manufacturing workers that may have resulted from heavy metal exposure during the tile manufacturing process.

2. Subjects and Methods

This is a community based, cross sectional study including all workers (total coverage technique, 74 workers

Figure 1- *Direct contact with raw materials used in tile manufacture process*

Figure 2- *Direct contact during cutting and glazing in tile manufacture process*

Figure 3- *Glazing waste*

working in about 6 tile manufacturing factories) fulfilling the predetermined inclusion criteria. A written informed consent was obtained from each participating worker.

2.1 Inclusion criteria

- Adult male (more than 18 years old).
- Working in direct contact with raw materials used in the tile manufacture process (cutting, glazing as shown in Figure 1-3).
- Working at least 8 hours daily for not less than one year in this industry.
- Not known to be diseased at the time of joining the tile factory.

A structured questionnaire was used for data collection and was divided into two parts. The first part included questions about demographic data of workers, all possible symptoms that may be attributed to exposure to the previously mentioned toxic elements, general health status and all possible sources of exposure to heavy metals. The second part of the questionnaire consisted of a clinical data sheet which includes signs of poor health and a clinical examination for suspected toxicological health hazards such as pallor, blue line in the gums, chest findings, abdominal signs, and peripheral neuropathy.

Blood samples were collected from all workers (5 mL) and tested for complete blood count, blood lead and cadmium levels, blood urea, serum creatinine, and urine Alpha Glutathione S- transferase level by Glory Science Co. ELISA kits (2400 Veterans Blvd. Suite 16-101, Del Rio, TX, United

Table 1- *Elemental analysis of raw materials used in tile manufacture*

Element	Material 1(%)	Material 2 (%)
Mn	0.42	0.46
Fe	1.44	5.95
Ni	10.75	12.35
Cu	16.86	20.28
Zn	2.73	0.62
Cd	34.39	25.09
Pb	36.58	35.24

Table 2- *Neurological complaints among tile manufacturing workers*

Complaints		No. (%)
Weak grip strength		37 (50.0)
Degree of grip weakness:	Mild	14 (37.8)
	Moderate	20 (54.1)
	Severe	3 (8.1)
Trend of grip weakness:	Increase with time	35 (94.6)
	Fixed	2 (5.4)
Foot drop		25 (33.8)
Tremors		40(54.0)
Numbness		17 (23.1)
Headache		49 (66.2)

State). Chest X-rays and pulmonary function tests were also performed.

2.2 Method of detection of lead and cadmium

1 mL of whole blood was collected in a vacutainer pro-thrombin tube and then acid digested using nitric acid (5 mL of HNO_3 to 1 mL blood) then put on a hot plate for approximately 30 min until the volume of the sample reduced to 1 mL [8]. Analysis of blood lead and cadmium levels was performed using Buck Model 210 VGP Atomic Absorption Spectrophotometer in the Central Laboratory of the Faculty of Science, Assiut University.

Samples of two different raw materials consisting of waste product resulting from glazing process (Material 1) and raw material (Material 2) were collected in 500 g quantities and subjected to elemental analysis by Dual JSM-5400 Scanning Electron Microscopy equipped with Oxford Link ISIS 300 EDX system at Assiut University, Egypt.

2.3 Statistical analysis

SPSS software package version 16 was used to analyse the data. Descriptive statistics were done in the form of frequencies, mean and SD. Analytic statistics were done as chi-square, independent sample t-test and pearson correlation. ANOVA Test was used and values were considered significant when p value was <0.05.

3. Results

Samples of different raw materials were analyzed by scanning electron microscopy (Table-1). The SEM analysis showed that there were many toxic elements in these

Table 3- *Clinical signs among tile manufacturing workers*

Clinical Signs	No.	%
Pallor of face and hands	27	36.5
Darkness under the eyes	45	60.8
Blue line on the gums	46	62.2
Chest wheezes and rhonchi	19	25.7
Abdominal tenderness	4	5.4

Table 4- *Blood and urine analysis of the studied cases*

Parameter	No.	%	(Mean ± SD)
Blood lead level (μg/dL)			
Accepted (up to 20)	7	9.5	75.1 ± 46.1
Toxic (more than 20)	67	90.5	
Blood cadmium level (μg/dL)			
Accepted (less than 5)	15	20.3	18.2 ± 24.4
Toxic (5 or more)	59	79.7	
Hb(mg/dL)			
Normal (14 and more)	12	25.5	14.8 ± 2.1
Anaemic (less than 14)	35	74.5	
Urinary alpha-glutathione S-Transferase(IU/L)			
Normal (22-50)	66	89.2	57.3 ± 3.3
Abnormal (more than 50)	8	10.8	
Blood urea (mg/dL)			
Normal (20 – 40)	47	100.0	26.2 ± 3.7
Elevated (more than 40)	0	00.0	
Serum creatinine (mg/dL)			
Normal (0.6 - 1.2)	47	100.0	0.78 ± 0.2
Elevated (more than 1.2)	0	00.0	

materials such as cadmium, lead, copper, arsenic, iron, zinc and traces of other elements. The most abundant toxic elements were lead and cadmium; lead represented more than one third of the raw material (36.58% and 35.24%, respectively) followed by cadmium (34.39% and 25.09%, respectivelly), while other elements (Mn, Cu, Ni, and Zn) collectivelly represented less than one third of these raw materials.

Toxic effects of lead on workers' CNS are shown in Table-2. Our results revealed that 66.2% of workers complained of headache and 50% of workers complained of weak grip that was moderate in 54.1%, mild in 37.8% and severe in 8.1%. More than half of workers (54%) had tremors and about one quarter of them (23.1%) had numbness in upper and lower extremities.

Table-3 shows clinical signs observed among tile man-ufacturing workers. A majority of the workers (62.2%) reported blue line on the gums (Burton line) followed by darkness under the eyes (60.8%), pallor on face and hands (36.5%), chest wheezes and rhonchi (25.7%) and abdominal tenderness (5.4%) respectively.

Results of laboratory investigations are shown in Table-4 which indicates that 90.5% of the workers had toxic blood lead levels (BLL) with a mean ± SD concentration of 75.1 μg/dL. Regarding urine alpha-glutathione S-transferase levels, it was found that 8 cases (10.8%) had abnormal levels while the majority of workers (89.2%) had normal levels. Blood urea and serum creatinine levels were determined in 47/74 workers and all of them were within the normal reference range of 20-40 mg/dL and 0.6-1.2 mg/dL, respectively. After testing the urine Alpha glutathione in workers, it was found that 8 cases (10.8%) had abnormal

Table 5- *Relationship between blood lead level and systolic/diastolic blood pressure in studied cases*

Grade of blood pressure (mmHg)	No.	Mean blood Lead level (μg/dL)	*p* value
Systolic blood pressure			
• Low	3	69.1	
• Normal	47	73.9	0.007**
• High	24	78.1	
Diastolic blood pressure			
• Normal	27	70.6	
• High	47	82.8	0.034*

*Statistically significant, **statistically highly significant

levels while a great majority of workers (89.2%) had normal levels.

Table-5 shows the relationship between blood pressure and blood lead levels (BLL) among 74 workers. Our results revealed a statistically significant relation between BLL and both systolic and diastolic blood pressure as there is a linear trend of increase in BLL from low to normal to higher grade of blood pressure (Low 90/60 or lower, normal between 90/60 and 139/89, and high 140/90 or higher) with a statistically significant difference between the three grades ($p = 0.007$). The same findings were observed in diastolic blood pressure ($p = 0.034$), as those suffering from high blood pressure reported higher blood lead levels than normotensive workers.

Results show a positive, highly statistically significant moderate correlation between BLL and years of work ($p = 0.002$, r = 0.33) (Table-6). There was a negative, moderately significant correlation between weight ($p = 0.001$, r = - 0.53) and BLL. Hemoglobin levels showed a negative, moderate statistically significant correlation with blood lead level (r = - 0.41 and $p = 0.023$). No statistically significant correlation was seen between blood cadmium level and years of work, blood urea, serum creatinine and alpha-glutathione S-transferase level.

The relation between BLL and cadmium levels and years of work is shown in Table-7, which indicates a linear

Table 6- *Correlation between blood lead and cadmium with some clinical parameters*

Parameters		r	*p* value	Sig.
	Years of work	0.33	0.002	**
	Weight	- 0.53	0.001	**
	Body mass index	- 0.66	0.008	**
Lead (μg/dL) *	Hemoglobin	- 0.41	0.023	*
	Blood urea	0.12	0.28	NS
	Serum creatinine	0.07	0.63	NS
	Alpha-glutathione S-transferees (IU/L)	0.07	0.583	NS
	Years of work	0.16	0.91	NS
	Lead (μg/dL)	0.63	0.003	**
Cadmium (μg/dL)	Blood urea	0.04	0.78	NS
	Serum creatinine	0.05	0.54	NS
	Alpha-glutathione S-transferase (IU/L)	0.08	0.16	NS

* Statistically significant   ** Statistically highly significant, NS: Statistically not significant

Table 7- *Relationship between blood lead and cadmium levels with years of work among tile manufacture workers*

Years of Work	No. of workers	Mean ± SD Blood lead (µg/dL)	Mean ± SD Blood cadmium (µg/dL)
1 to 5 years	14	51.1 ± 6.3	9.2 ± 1.3
6 to 10 years	13	52.9 ±7.2	16.7 ± 4.2
11 to 15 years	17	68.7 ± 4.4	18.5 ± 3.4
16 to 20 years	23	86.3 ± 5.4	20.6 ± 2.4
21 to 25 years	7	91.1 ± 8.6	38.1 ± 4.6
F value		6.3	3.8
p value		0.009**	0.029*

*Statistically significant, **statistically highly significant*

Table 8- *Relationship between blood cadmium level and chest X- ray findings in our studied cases*

Chest X- rays	Toxic cadmium level ≥ 5 µg/dL		Normal cadmium level < 5 µg/dL		Total	
	No.	%	No.	%	No.	%
Normal	4	33.3	24	88.9	28	71.8
Abnormal Findings	8	66.7	3	11.1	11	28.2
Total	12	30.8	27	69.2	39	100.0
p value			0.02*			
Chi-square			5.12			

Statistically significant

association between intoxication and years of work in the tile manufacture industry. The highest mean±SD concentration of blood lead and cadmium levels were present in the workers who had worked from 16 to 20 years.

Regarding the toxic effects of heavy metal (cadmium) exposure on the respiratory system, a respiratory function test was performed. Table-8 shows a statistically significant relationship between blood cadmium level and chest x-rays in the studied workers ($p = 0.02$). It was found that 12 out of 39 workers who underwent chest x rays were suffering from toxic blood cadmium levels (equal to or more than 5 µg/dL). Among these workers, two thirds had abnormal findings in their x-rays compared to one third who showed normal x-ray findings.

Table-9 shows logistic mutivariate regression analysis model that was highly predictive of major symptoms that may have resulted from exposure to high blood lead levels in the studied sample. The symptoms in order were: tremors (odds ratio = 14.03), Weak grip (odds ratio = 11.1), presence of foot drop (odds ratio = 10.4), occurance of numbness (odds ratio = 9.68), presence of pallor (odds ratio = 7.52), presence of blue line in the gums (odds ratio = 5.42), high systolic blood pressure (odds ratio = 3.07), high diastolic blood pressure (odds ratio = 2.2) and occurance

Table 9- *Mutivariate regression analysis for the most important risk factors of high blood lead levels among tile manufacturing workers*

Variables	B	S.E	Wald	df	Sig.	Odds ratio
Tremors	3.334	1.120	8.854	1	0.003	14.03
Weak grip strength	7.79	60.45	0.017	1	0.002	11.132
Foot drop	2.56	0.989	6.89	1	0.009	10.43
Numbness	2.04	0.97	4.423	1	0.003	9.684
Presence of pallor in face and hands	1.709	0.984	3.12	1	0.008	7.522
Blue line on the gums	1.69	1.43	1.39	1	0.023	5.421
High systolic blood pressure	1.62	0.894	3.304	1	0.06	3.07
High diastolic blood pressure	0.79	0.95	0.69	1	0.04	2.20
Headache	0.79	0.95	0.69	1	0.08	1.20
Constant	-3.17	1.943	2.66	1	0.01	0.042

of headache (odds ratio = 1.2). Foot drop reflects the affection of lead toxicity on the motor function of the workers and may interfere with the performance and productivity of such workers as well as the psychological disturbance that may have resulted from this complaint.

4. Discussion

Occupational heavy metal toxicity is still a health problem in many countries such as Egypt and Turkey [9]. Although there are numerous industries which use lead-based raw materials that may pose health risks to workers, there are no standardized workplace regulations to avoid lead and cadmium exposure. Moreover, there are no sufficient studies carried out on blood lead and cadmium levels in workers or on the contribution of common workplace practices to lead poisoning [10]. Occupational lead and cadmium exposure with or without symptoms has not been sufficiently investigated in Egyptian workers, in particular, workers who are involved in glazing traditional tiles [11].

In the present study, samples of different raw materials used in tile manufacturing were analyzed. As shown in Table-1, there were many toxic elements in these materials

such as cadmium, lead, copper, arsenic, iron zinc and traces of other elements. The two most abundant toxic elements were lead and cadmium. This study revelaed the same low standard work conditions as described by Hisham et al. Tile workers did not wear any kind of protective clothes or any protective respiratory devices during their job [12]. Regarding toxic effects of lead on CNS, results in Table-2 revealed that 66% of workers complained from headache. This may be explained by the fact that lead increases the permeability of the blood-brain barrier and causes disruption, allowing large molecules such as albumin to enter the brain which increase osmotic pressure and causes ions and water to follow, resulting in edema of the brain and an increase in intracranial pressure [13].

Neurological complaints of workers that may be related to lead exposure are described in Table-2. Once lead enters the body, it interferes with normal cell function and physiological processes. The nervous system seems to be the most sensitive system to lead poisoning [13].

Weak grip strength increased with time in about 95% of the workers, which may point to the cumulative effect of lead toxicity in those workers; with an increase in work-

ing time there is a concomitant increase in their complaint of weakness. Regarding other neurological complaints, our results showed that about one third of workers (33.8%) suffered from foot drop. In addition, more than half of workers (54%) suffered from tremors and about one quarter of them (23%) had numbness. These findings are consistent with many other studies that documented the effects of lead on the peripheral nervous system, especially motor nerves [14].

Bellinger (2004) investigated the behavioral and neurobiological mechanisms of the functional deficits observed in lead-exposed humans [15]. He stated that lead causes the axons of nerve cells to degenerate and lose their myelin coats. It was found that in adults, manifestations of lead toxicity may appear at blood lead levels greater than 80 μg/dL [16]. Signs that occur in adults at blood lead levels exceeding 100 μg/dL include wrist and foot drop, signs of encephalopathy, such as delirium, coma, seizures, and headache. It is rare to be asymptomatic if blood lead levels exceed 100 μg/dL [17].

Pallor on face and hands, a clinical sign that may reflect lead and cadmium exposure, was reported in approximately one third of cases (Table-3). This may point to anemia and peripheral vasoconstriction. Blue line in the gum was found in 62.2% of workers. This bluish to black edging of the teeth, known as Burton line, is an indication of chronic lead poisoning [18]. This line is caused by a reaction between circulating lead with sulphur ions released by oral bacterial activity, which deposits lead sulphide at the junction of the teeth and gums [19]. This symptom is an important sign in the detection and diagnosis of chronic lead toxicity; however, it is not always present in all cases and usually related to chronic oral lead exposure. Our results are in agreement with Mood et al. who studied lead toxicity in traditional tile workers in Mashhad in Iran, 2010, and reported that blue line was present in 64.8% of the studied cases [20].

Table-3 also shows that one quarter of the workers (25%) had chest related complaints in the form of chest wheezes and ronchi. Only 4 workers (5%) showed abdominal symptoms in the form of abdominal tenderness. This was lower than reported by Mood et al. who documented abdominal tenderness in 15.1% of their studied sample [20]. Five of our workers (27.8%) showed symptoms that suggested obstructive lung disease while the remaining workers were normal. The table also shows that out of 39 cases that agreed to undergo chest X-rays, 11 cases showed symptoms suggestive of obstructive lung disease, which may be attributed to occupational exposure to cadmium and partially to occupational silicosis. These findings are constant with Sorahan et al. who studied 624 workers employed in a cadmium alloy factory and reported that exposure to cadmium oxide fumes increases risks of chronic non-malignant diseases of the respiratory system [21].

Lead poisoning may be acute (from intense exposure of short duration) or chronic (from repetitive low-level exposure over a prolonged period), but the latter is much more common [22]. Classically, "adult lead poisoning" or "lead intoxication" has been defined as exposure to high levels of lead typically associated with severe health effects when BLL is more than 20 μg/dL [14]. Our results showed that 90.5% of the workers had toxic BLL, exceeding 20 μg/dL with a mean of 75.10 μg/dL (Table-4). This value is greater than reported in the study by Mood et al. in which workers had a mean toxic BLL of 57.80 μg/dL, while only 7 cases (9.5%) showed acceptable BLL levels [9]. Our results are partially consistent with Rashid et al. who studied the effect of lead on hematological parameters in 51 occupationally exposed individuals comprising 27 lead furnace workers, 24 lead pellet handlers and 20 healthy and service-matched controls [18]. The lead workers had the highest blood lead levels (71.20 μg/dL) compared to healthy subjects (29.80 μg/dL), while workers handling pellets had moderately increased blood lead levels (45.50 μg/dL). The furnace exposed workers had higher blood lead levels compared to the lead pellet handlers [21-22].

Table-4 also shows that more than three quarters of the workers suffered from anemia (74.5%), which is in accordance with the findings of Rashid et al who concluded that chronic lead exposure causes normocytic normochromic (NC/NC) anemia and demonstrated a dose-response relationship between lead levels and severity of anemia [22]. Anemia may appear at blood lead levels higher than 50 μg/ dL. This depends upon the amount of lead in blood and tis-

sues, as well as the time course of exposure.

After testing the urine Alpha glutathione of workers, it was found that 8 cases (10.8%) had abnormal levels, while a great majority of workers (89.2%) had normal levels (Table- 4). Our results are consistent with a cross-sectional study done by Garcon et al. (2007) that aimed to evaluate the usefulness of a set of early biological markers of oxidative stress of nephrotoxicity for the bio-monitoring of workers occupationally exposed to lead [25]. They found that mean levels of Pb in blood and urine were also 387.10 ± 99.10 μg /L and 217.7 ± 117.7 μg /g creatinine, respectively. The mean levels of Cd in blood and urine were 3.26 ± 2.11 μg/L and 2.51 ± 1.89 μg/g creatinine, respectively, suggesting relatively low occupational exposure levels [25]. Alpha-glutathione S-transferase and urinary protein levels were reported between the two groups and were closely correlated with Pb and/or Cd exposure levels. These results suggest the use of alpha-glutathione S-transferase excretion in urine as a hallmark of early changes in the proximal tubular integrity. Hence, successful prevention of renal diseases induced by occupational exposure to lead and/or cadmium largely relies on the capability to detect nephrotoxic effects at a stage when they are still reversible or at least not yet compromising renal function.

Table-4 also shows that out of the 74 workers, blood urea & serum creatinine tests were done in 47 cases and levels were normal in all workers. This is explained by the fact that kidney damage occurs with exposure to high levels of lead, which were not reported in the study (40-60 μg/dL). Long-term exposure to toxic levels of lead cause nephropathy that may lead to Fanconi syndrome, in which the proximal tubular function of the kidney is impaired [24]. Long-term exposure to lead levels lower than those which cause lead nephropathy have also been reported as nephrotoxic in patients from developed countries that had chronic kidney disease or were at risk because of hypertension [25].

Numerous studies have indicated a relationship between moderate or heavy lead exposure and high blood pressure [26-27]. The present results have shown that low-levels of lead exposure are related to changes in blood pressure (Table-5). The same findings were also noted in dia-stolic blood pressure ($p = 0.034$), as those suffering from high blood pressure reported higher blood lead levels than normotensive workers. These results are in agreement with Pocock et al. (1988) who studied the relationship between blood lead concentration and blood pressure in a survey of 7371 men from 24 British towns and found a statistically significant positive association [29].

The present results also support findings of an earlier report by Harlan (1988), who studied the American population and analyzed data from the National Health and Nutrition Examination Survey and revealed significant correlations between blood lead levels and blood pressure [27]. He also stated that blood lead levels were significantly higher in groups with high diastolic blood pressure (greater than 90 mm Hg). These findings and those from other studies [28] confirm the relationship between blood lead levels and blood pressure at relatively low levels that are commonly observed in the general population; however, the strength and importance of this relationship require further studies through epidemiologic and metabolic investigations.

Regarding cadmium levels, about 80% of the workers reported toxic levels of cadmium compared to one fifth of workers who showed normal levels. As shown in table - 4, the mean level of Cd was 18.2 ± 24.4 μg/dL, which was higher than that reported by Garcon et al (2007) [25].

The correlation studies in table-6 showed a positive, highly significant moderate correlation between blood lead level and years of work (p - 0.002, r = 0.33). This important finding explains the cumulative toxicity of occupational lead exposure in workers that may have a negative impact on their health status and a bad impact on their work performance. The weight of workers is usually an indication of their health status, and malnutrition and being underweight is usually associated with many health problems. Table-6 shows a negative, statistically moderate, significant correlation between workers weight and blood lead levels (p = 0.001, r = - 0.53). This negative correlation may be attributed to the toxic effects of lead on the gastro-intestinal tract in the form of nausea and loss of appetite, together with reduction in the protein content in workers' meals. In the same table, hemoglobin level shows a negative, moderate, statistically significant correlation with blood lead level (r

= - 0.41 and p = 0.023). Also, there was a strong positive, highly significant linear correlation between blood lead level and blood cadmium (r = 0.63 & p = 0.003) in our studied workers. This finding was expected in our study because both lead and cadmium were the most abundant elements in the raw materials that the workers were exposed to (Table-1). Also, these are the elements which are usually associated with many health hazards among workers in the tile industry.

In the present study, no statistically significant correlations were found between blood cadmium and years of work, blood urea, serum creatinine and alpha-glutathione levels. These findings may be related to the fact that kidney function tests that were used in the present study are usually elevated in late phases of kidney infection and are usually normal in early renal diseases [29]. Despite this, alpha-glutathione was more sensitive than serum creatinine and blood urea to detect early kidney problems [30]. Alpha-glutathione was elevated in about 11% of workers as shown in table 4. It is, therefore, highly recommended to do screening for nephrotoxic effects of cadmium by alpha-glutathione routinely and regularly rather than to perform tests for usual kidney functions (blood urea and serum creatinine) [31].

Table-8 shows a statistically significant relationship between blood cadmium level and chest x-rays in the studied workers (p = 0.02). It was found that 12 out of 39 workers who underwent chest x rays were suffering from toxic blood cadmium levels (equal to or more than 5 μg/dL). Among these workers, two thirds had abnormal findings in their x-rays compared to one third who showed normal x-ray findings. The present results agree with other reports which showed that glazing and enameling of tiles can lead to metal poisoning and lung diseases, which can lower workers' productivity [31-32].

Table-9 shows logistic multivariate regression analysis model that was highly predictive of major symptoms that may have resulted from exposure to high blood lead levels in the studied sample. The symptoms in order were: tremors (odds ratio = 14.03), weak grip (odds ratio = 11.1), presence of foot drop (odds ratio = 10.4), occurrence of numbness (odds ratio = 9.68), presence of pallor (odds ra-

tio = 7.52), presence of blue line in the gums (odds ratio = 5.42), high systolic blood pressure (odds ratio = 3.07), high diastolic blood pressure (odds ratio = 2.2) and occurrence of headache (odds ratio = 1.2). Foot drop reflects the affection of lead toxicity on the motor function of the workers and may interfere with the performance and productivity of such workers beside the psychological upset that may have resulted from this complaint [33].

5. Conclusion

Occupational exposure to heavy metals, especially lead and cadmium, should be viewed as a very serious health risk to the workers engaged in tile manufacturing. Workers should be informed about the multiple health hazards and complications that may occur from their persistent exposure to toxic raw materials used in the manufacturing of tiles. In order to reduce the exposure to lead, cadmium and other toxic substances, simple protective gear should be adopted and strictly observed to safeguard the health of workers.

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