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## The Exposure Effect to Some Air Pollutants as a Result of Specimens' Preservation for the Employees of Two Museums in Baghdad City

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### Abstract

The study aims to evaluate the health effects of exposure to air pollutants by applying hematological and biochemical analysis to (39) employees (15 male and 24 female) at the Iraqi National Museum (M1) and Natural History Museum (M2) in Baghdad City during the summer and winter seasons, who were exposed to air pollution, to determine the extent to which pollutants resulting from using of specific materials in cleaning, fogging, and preservation of museums' specimens, affect these employees' blood. A temtop device was used to measure the main indoor environmental parameters in these museums, particularly (total volatile organic compounds (TVOC), formaldehyde (HCHO), and particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>)). Basic hematological parameters: hematocrit (HCT), hemoglobin concentration (HGB), Red Blood Cell count (RBC), White Blood Cell count (WBC), Platelets count PLT, liver function, and renal function were measured. The test was performed after the volunteer employees completed a questionnaire about their age, sex, duration time of work, daily exposure, and other details. For the hematological test, although the average concentration of HGB level for M2 is less than in M1, the average concentration of it was within the normal range, and so for WBCs, RBCs, and PLT counts were within the normal range in the two museums for both seasons. Regarding the HCT level, the average concentration in winter was  $40.52 \pm 0.77$  for M1 and  $36.72 \pm 1.34$  for M2, meaning M2 results were below the normal range during the winter. As for biochemical analysis (liver function), the AST, ALT, and ALP levels were within the normal range in the two museums for both seasons, except that the ALP level in M2 was higher than in M1. In addition, renal function results showed that urea and uric acid levels in M2 were lower than in M1. In contrast, the creatinine level was higher in M2 than in M1, knowing that the levels of urea, creatinine, and uric acid were within the normal range in the two museums for both seasons.

**Keywords:** Air pollutants, Employees, Hematological test, Biochemical Analysis

تأثير التعرض لبعض ملوثات الهواء الناتجة من حفظ النماذج لدى العاملين في متحفي في مدينة  
بغداد

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## الخلاصة

تهدف الدراسة إلى تقييم الآثار الصحية للتعرض لملوثات الهواء من خلال تطبيق تحليل الدم والكيمياء الحيوية على (39) موظفا (15 ذكرا و 24 أنثى) في المتحف الوطني العراقي (M1) ومتحف التاريخ الطبيعي (M2) في مدينة بغداد ، خلال فصلي الصيف والشتاء ، الذين تعرضوا لتلوث الهواء ، لتحديد مدى تأثير الملوثات الناتجة عن استخدام مواد معينة في تنظيف وتعفير وحفظ عينات المتاحف على دم هؤلاء الموظفين . وتم استخدام جهاز Temtop لقياس المعلمات البيئية الداخلية الرئيسية في هذه المتاحف ، وخاصة (إجمالي المركبات العضوية المتطايرة (TVOC)، والفورمالديهايد (HCHO)، والجسيمات (PM<sub>2.5</sub> و PM<sub>10</sub>). تم قياس المعلمات الدموية الأساسية: الهيماتوكريت (HCT) ، وتركيز الهيموغلوبين (HGB) ، وعدد خلايا الدم الحمراء (RBC) ، وعدد خلايا الدم البيضاء (WBC)، عدد الصفائح الدموية (PLT) ، وظائف الكبد ، ووظائف الكلى . تم إجراء الاختبار بعد أن أكمل الموظفون المتطوعون استبياننا حول أعمارهم ، الجنس ، مدة الخدمة ، التعرض اليومي ، وتفاصيل أخرى . بالنسبة لاختبار أمراض الدم ، على الرغم من أن متوسط تركيز مستوى HGB ل M2 أقل منه في M1 ، إلا أن متوسط تركيزه كان ضمن المعدل الطبيعي ، وهكذا بالنسبة ل WBC ، RBCs ، و PLT كانت ضمن المعدل الطبيعي في المتحفين لكلا الموسمين . فيما يتعلق بمستوى HCT ، كان متوسط تركيزه في فصل الشتاء  $40.52 \pm 0.77$  ل M1 و  $36.72 \pm 1.34$  ل M2 ، مما يعني أن نتائج M2 كانت أقل من المعدل الطبيعي خلال فصل الشتاء . أما بالنسبة للتحليل الكيميائي الحيوي (وظائف الكبد) ، فقد كانت مستويات AST و ALT و ALP ضمن المعدل الطبيعي في المتحفين لكلا الموسمين ، باستثناء أن مستوى ALP في M2 كان أعلى منه في M1 . بالإضافة إلى ذلك ، أظهرت نتائج وظائف الكلى أن مستويات اليوريا وحمض اليوريك في M2 كانت أقل مما كانت عليه في M1 . في المقابل ، كان مستوى الكرياتينين أعلى في M2 منه في M1 ، مع العلم أن مستويات اليوريا والكرياتينين وحمض اليوريك كانت ضمن المعدل الطبيعي في المتحفين لكلا الموسمين .

## 1. Introduction

The environment and human health are seriously impacted by air pollution, which has become a major problem in recent decades [1]. One of every eight deaths in the world is associated with air pollution [2, 3]. Earlier studies have reported the association between air pollution and human morbidity and mortality [4-7]. The health effects of air pollution, observed from indoor and outdoor environments, have been of great concern due to the high exposure risk even at relatively low concentrations of air pollutants [8]. Air pollution is a "silent public health emergency" equated to "the new tobacco" [9]. Human diseases are mostly caused by a variety of pollutants [10]. The main source of indoor air pollutants is outdoor air [11]. These pollutants include construction materials, paints, combustion processes, and consumer goods, including mothballs, cleansers, and solvents. Additionally, particulate matter (PM), formaldehyde (HCHO), and volatile organic compounds (VOCs) are released from these sources. Their levels are noticeably higher in some indoor environments than outdoor ones [5]. The effects of indoor air pollution on human health depend on the concentration of the pollutant, duration of exposure, age, and gender of the individuals affected. Regarding workplaces, most of the main risks are evaluated in terms of exposure risk, local air conditioning, and personal protective equipment (PPE) use [12–16]. Research on using toxic substances in museums as preservatives has identified many toxic metals and pesticides in recent decades [17-19]. Due to the repeated use of pesticides, a poisonous cocktail was applied to the objects. As a result, restorers, conservators, curators, and scientists have been and still often are exposed to toxic substances in their daily work, most of the time without their knowledge [20]. Traditional or modern materials may act as a source of indoor pollutants, and this fact, with all related consequences, has been recognized for a while in the museum environment [21]. The main toxic effects of exposure to air pollutants are mainly on the respiratory, cardiovascular, ophthalmologic, dermatologic,

neuropsychiatric, hematologic, immunologic, and reproductive systems [1, 22]. The adverse effects linked to exposure to different chemical substances are likely to result from the interaction of the metabolites of the constituents of these substances with blood components or blood-forming tissues [23]. It should be mentioned that different environmental conditions and substances might affect hematological parameters significantly [24]. Blood or hematological are the more rapid and detectable variations under stress and fuel for assessing different health conditions [25]. People exposed to medium to high amounts of particulate matter 2.5 (PM<sub>2.5</sub>) for more than a year experienced changes in their hematological parameters [26]. Additionally, the inhaled pollutants cause epithelium injuries and activate the immune system to launch a cascading inflammation response [27]. Hematological studies are of ecological and physiological interest in helping to understand the relationship of blood characteristics to the environment [28]. The study evaluates the potential health effects of workers' exposure to indoor air pollutants due to various processes, including dust cleaning, fogging, and specimen preservation, carried out by employees at the Iraqi National Museum and the Natural History Museum in Baghdad. This study aims to determine the impact of these pollutants on blood by performing hematological and biochemical analyses such as hemoglobin levels, red blood cell counts, white blood cell counts, platelet counts, and liver and kidney function tests.

## 2. Materials and methods

### 2.1 Data and Samples Collection

To accurately determine indoor air quality at the two study sites (M1 and M2), a specific monitor/detector device called Temtop was used. This laser particle multi-functional detector, model LKC-1000S+ (US), with Display mode: TFT color LCD screen designed in California-Assembled in China. The laser particle sensor and high-precision electrochemical formaldehyde were adopted, which is capable of measuring several important air quality parameters and directly converting the concentration of pollutants in the air into visual data. The concentrations of (PM) are reported in ( $\mu\text{g}/\text{m}^3$ ), and gaseous contaminants in ( $\text{mg}/\text{m}^3$ ). To detect the complete blood count (CBC), Semi-Auto Biochemistry Analyzer NP 300C was used. In addition, Fully Automated Hematology analyzer G e n e x –count 60 was used to detect the biochemical test that included liver function (AST, ALT, ALP) and renal function (urea, creatinine, and uric acid). Table 1 describes the instruments used in the study, including their company and origin.

**Table 1:** Instruments and chemical materials used in the study

No.	Instruments	Company	Origin
1	Temtop LKC-1000S+ Air Quality Detector/IAQ monitor	Temtop	Designed by Temtop in California–Assembled in China
2	Semi-Auto Biochemistry Analyzer NP 300C	Nipigon	Canada
3	Fully Automated Hematology analyzer G e n e x –count 60	G e n e x	USA
4	Urea	Bio Systems	Spain
5	Creatinine	Bio Systems	Canada
6	Alkaline phosphatase (ALP)	Carolina Biological Supply Company	North–Carolina/ USA
7	Alanine aminotransferase (ALT) (GPT)	Bio Systems	Spain
8	Aspartate aminotransferase (AST) (GOT)	Bio Systems	Spain
9	Uric acid	SPINREACT	Spain
10	Hematology solutions	G e n e x	USA

## 2.2 The Field of Study

The current study utilized data from a questionnaire distributed to workers at two different museum sites in Baghdad. The first museum (The National Iraqi Museum) is located in AL-Karkh and is surrounded by transportation routes. It has Central Laboratories, which have different dimensions ranging between (8(length) x 6(width) x 4.3(high))m and (6(length) x 6(width) x 4.3(high))m with a volume of 206.4m<sup>3</sup> and 154.8 m<sup>3</sup> respectively with central ventilation conditions (moderate ventilation). The second museum (The Natural History Museum) was in AL-Rusafa, which is also surrounded by transportation routes. It includes several laboratories that have different dimensions ranging between (4(length) x 3(width) x 2.45(high))m and (8(length) x 10(width) x 3.8(high))m with a volume of 29.4 m<sup>3</sup> and 304 m<sup>3</sup> respectively. The source of ventilation is a turbine puller (moderate ventilation). The study involved 39 volunteer employees, 13 males and 10 females from the Iraqi National Museum and 2 males and 14 females from the Natural History Museum. Their ages range between 25 and 60 years, the service duration from one to more than 30 years, and they are exposed to pollutants such as PM2.5, PM10, TVOC, and HCHO for 4 to 6 or 8 hours daily in both museums. Museum workers use personal protective equipment such as gloves and masks to protect themselves from contaminants during cleaning, polishing, embalming, and preservation operations of animal and insect specimens. The data served as indicators of the workers' health status concerning their exposure to various pollutants inside the museums. Characteristics such as age, smoking status, number of years worked, and daily exposure hours were considered.

## 2.3 Blood sample collection and preparation

Five ml of venous blood samples were collected by venipuncture technique from 39 volunteer employees and placed in two types of tubes: the EDTA tube, which was used to place a small amount for accurate testing, and the gel tube, where the remaining sample was placed. These samples were taken to specialized laboratories to conduct laboratory tests. EDTA tubes measure the body's blood levels (hematological analysis). It includes EDTA, an anticoagulant that prevents blood clots. Gel tubes conduct the biochemical tests, which contain a gelatinous substance that accelerates the separation of blood serum (plasma). The studied parameters are listed in Table 2.

**Table 2:** Hematological and Biochemical parameters

Hematological analysis		Biochemical test	
CBC test		Liver function	Renal function
1	WBCs count	Aspartate aminotransferase (AST)	Urea
2	LYMs count	Alanine aminotransferase (ALT)	Creatinine
3	RBCs count	Alkaline phosphate (ALP)	Uric acid
4	HGB		
5	HCT		
6	PLT		

## 2.5 Hematological Parameters Analysis

Two ml of blood were put into an EDTA tube to determine the complete blood count (CBC) using a fully Automated Hematology analyzer (G e n e x—count 60) [29].

## 2.6 Biochemical test

Three ml of blood were put into a serum gel-separating tube for biochemical tests. A semi-autobiochemistry analyzer (NP 300C) automatically calculated the analytic

concentration of each sample [30]. The biochemical parameters are liver function, including AST, ALT, and ALP, and renal function, including Urea, Creatinine, and Uric acid.

### 3. Statistical analysis

In the current study, all data were expressed as mean value  $\pm$  SE by using the program IBM SPSS version 30.0 (2024), which was used to detect the effect of different factors in the studied parameters. A T-test is used to calculate the probability. It is significant when the probability is less than 0.05 [31].

## 4. Results and Discussion

### 4.1 Particulate Matter (PM<sub>2.5</sub>, PM<sub>10</sub>), Total Volatile Organic Compound (TVOC), and Formaldehyde (HCHO) in the Iraqi National Museum (M1) and the Natural History Museum (M2).

According to the results shown in Table 3, during winter, M1 exhibited a higher level of PM<sub>2.5</sub> at  $85.20 \pm 1.72 \mu\text{g}/\text{m}^3$  than in summer, which was  $57.23 \pm 2.64 \mu\text{g}/\text{m}^3$ . As well as, PM<sub>10</sub> was recorded as a higher value at  $125.55 \pm 2.53 \mu\text{g}/\text{m}^3$  during winter than in summer, which was  $85.11 \pm 3.93 \mu\text{g}/\text{m}^3$ . There were significant differences ( $P < 0.05$ ) between the means of PM<sub>2.5</sub> and PM<sub>10</sub> for both seasons of M1.

TVOC were recorded at  $1.05 \pm 0.09 \text{mg}/\text{m}^3$  in winter, while in summer, were  $0.93 \pm 0.09 \text{mg}/\text{m}^3$ . In addition, HCHO was recorded at  $0.37 \pm 0.05 \text{mg}/\text{m}^3$  during winter, while in summer was  $0.31 \pm 0.05 \text{mg}/\text{m}^3$ . When comparing the two seasons, the results showed no significant differences ( $P > 0.05$ ) between the means of TVOC and HCHO in M1. Similarly, M2 shows a higher level of PM<sub>2.5</sub> at  $86.22 \pm 0.82 \mu\text{g}/\text{m}^3$  during winter than in summer, which was  $52.33 \pm 0.92 \mu\text{g}/\text{m}^3$ . At the same time, PM<sub>10</sub> was higher level during winter at  $126.96 \pm 1.29 \mu\text{g}/\text{m}^3$  than in summer that was  $72.82 \pm 1.36 \mu\text{g}/\text{m}^3$ . There were significant differences ( $P < 0.05$ ) between the means of PM<sub>2.5</sub> and PM<sub>10</sub> for both seasons of M2.

As for TVOC values, M2 recorded  $0.71 \pm 0.15 \text{mg}/\text{m}^3$  through winter, while in summer was  $0.80 \pm 0.15 \text{mg}/\text{m}^3$ . In addition, HCHO was recorded at  $0.37 \pm 0.12 \text{mg}/\text{m}^3$  during winter, while in summer was  $0.28 \pm 0.07 \text{mg}/\text{m}^3$ . When comparing the two seasons, the results showed no significant differences ( $P > 0.05$ ) between the means of TVOC and HCHO in M2.

When observing the information in Table 3, it was found that the mean concentration values of PM<sub>2.5</sub> and PM<sub>10</sub> for both museums in winter were higher than in summer. These results are similar to other studies that suggested a significant increase in PM concentrations in winter is greater than in summer [32]. That means the two museums are less polluted in summer in Particulate Matter (PM<sub>2.5</sub> and PM<sub>10</sub>) than in winter. The possible reason for the rise in pollutants could be that the stable air conditions in winter inhibit pollutants from dispersing, which raises PM levels [33]. The higher concentrations of PM during winter are due to several factors, such as reduced ventilation and increased indoor activities, as people typically keep their windows closed to stay warm [34]. Industrial activities and indoor heating cause higher emissions of particles, especially in cities. Also, in cold temperatures, chemical reactions between pollutants lead to the formation of secondary aerosols, increasing PM<sub>2.5</sub> levels. As well as in winter, temperature inversion occurs when a layer of warm air traps cold air near the surface. This prevents pollutants from rising and dispersing [32, 35].

Furthermore, the values of PM<sub>2.5</sub> and PM<sub>10</sub> constantly exceeded the acceptable Threshold Limit Value (TLV) in both seasons, which is the PM<sub>2.5</sub> annual mean concentration of  $5 \mu\text{g}/\text{m}^3$  and  $15 \mu\text{g}/\text{m}^3$  for daily exposure [36, 37]. For PM<sub>10</sub>, the WHO recommends a yearly mean of  $15 \mu\text{g}/\text{m}^3$  and  $45 \mu\text{g}/\text{m}^3$  for daily PM<sub>10</sub> exposure [38].

In addition, the concentrations of TVOC and HCHO in each museum were nearly the same in winter and summer. This may be due to the two museums' use of acids, alcohols, and formaldehyde in cleaning, polishing, and maintaining archaeological models and fogging and preserving insects and animals. Moreover, reduced ventilation rates in winter result in the accumulation of pollutants, especially those released internally, such as formaldehyde [39].

**Table 3:** Comparison of the mean  $\pm$  SE of Particulate Matter (PM<sub>2.5</sub>, PM<sub>10</sub>), Total Volatile Organic Compound (TVOC), and Formaldehyde (HCHO) in The Iraqi National Museum (M1) and The Natural History Museum (M2) in winter and summer.

Museums	Means $\pm$ SE			
	P.M 2.5 $\mu\text{g}/\text{m}^3$	P.M 10 $\mu\text{g}/\text{m}^3$	TVOC	HCHO
M1 (Winter)	85.20 $\pm$ 1.72	125.55 $\pm$ 2.53	1.05 $\pm$ 0.09	0.37 $\pm$ 0.05
M1 (Summer)	57.23 $\pm$ 2.64	85.11 $\pm$ 3.93	0.93 $\pm$ 0.09	0.31 $\pm$ 0.05
P value	P < 0.05	P < 0.05	P > 0.05	P > 0.05
M2 (Winter)	86.22 $\pm$ 0.82	126.96 $\pm$ 1.29	0.71 $\pm$ 0.15	0.37 $\pm$ 0.12
M2 (Summer)	52.33 $\pm$ 0.92	72.82 $\pm$ 1.36	0.80 $\pm$ 0.15	0.28 $\pm$ 0.07
P value	P < 0.05	P < 0.05	P > 0.05	P > 0.05

#### 4.1 Data of Questionnaire of employees in the Iraqi National Museum (M1) and the Natural History Museum (M2)

The results shown in Table 4 revealed differences ( $p < 0.05$ ) between the means of time of daily exposure for the two museums, which may be due to the employees of M2 spending more time in the museum than the employees of M1. While there are no differences ( $p > 0.05$ ) between the means of duration time of work years, smoking status, chronic diseases, respiratory problems, sexes, and ages, it may be due to the similarity of the questionnaire results for both museums [40].

**Table 4:** The mean and SE  $\pm$  of the data Questionnaire in the Iraqi National Museum (M1) and the Natural History Museum (M2).

Demographical data		M1	M2	Probability
Duration time of work means $\pm$ SE in Years		16.78 $\pm$ 2.62	18.94 $\pm$ 2.62	P > 0.05
Time of daily exposure means $\pm$ SE in hours		4.96 $\pm$ 0.20	8.0 $\pm$ 0.0	P < 0.05
Place of work	Close	23 (100.0)	16 (100.0)	NA
	Open	0 (0.0)	0 (0.0)	
Place of living	Urban	23 (100.0)	16 (100.0)	NA
	Rural	0 (0.0)	0 (0.0)	
Smoking status	Smokers	3 (13.0)	2 (12.5)	P > 0.05
	Not smokers	20 (87.0)	14 (87.5)	
Chronic diseases	Yes	4 (17.4)	6 (37.5)	P > 0.05
	No	19 (82.6)	10 (62.5)	
Respiratory problems	Yes	3 (13.0)	2 (12.5)	P > 0.05
	No	20 (87.0)	13 (81.25)	
	Sometimes	0 (0.0)	1 (6.25)	
Age means $\pm$ SE (Years)	Sexes			
	Males	44.92 $\pm$ 1.52	43.0 $\pm$ 4.04	P > 0.05
	Females	46.10 $\pm$ 2.18	47.0 $\pm$ 1.83	P > 0.05
	Total	45.44 $\pm$ 1.26	46.50 $\pm$ 1.67	P > 0.05

## 4.2 Hematology Test

### 4.2.1 CBC test (WBC and RBC)

The unit of measurement for WBC is ( $10^9/L$ ), LYM is (%), RBC is ( $10^{12}/L$ ), HGB is (g/dl), HCT is (%), and PLT is ( $10^9/L$ ), these concentrations of the exposed employees were expressed as mean values  $\pm$  SE shown in the Tables 5, 6, and 7.

### 4.2.2 WBCs and LYMs count of employees and their percentage in (M1) and (M2).

White blood cells (WBCs), also known as leukocytes or leucocytes, are immune system cells that protect the body against infectious diseases and foreign intruders [41-46]. A typical white blood cell count ranges from 4,000 to 11,000 cells per microliter ( $\mu l$ ), which means  $(4-11) \times 10^9/L$  [47]. LYMs are agranulocytes, natural killer cells called lymphoid cells (also known as lymphocytes) [48]. Based on the results reported in Table (5), when comparing the two museums in terms of WBC results in summer and winter, it was noted that in summer, the mean count of WBCs in M1 was recorded as  $6.69 \pm 0.42$ , and in M2 was  $6.11 \pm 0.30$ . In winter, the mean count of WBCs in M1 was  $6.15 \pm 0.44$ , and in M2 was  $6.54 \pm 0.24$ . There are no significant differences ( $p > 0.05$ ) between the means of WBC count among the employees of the two museums. This is consistent with two previous studies that found no association between PM exposure and WBC counts or between air pollution and total white blood cell counts [49, 50]. As for the means of lymphocyte (LYMs) count (Table 5), in summer, the mean value of LYMs in M1 was  $39.44 \pm 1.30$  %, and in M2 was  $20.9 \pm 1.21$ %. Significant differences ( $P < 0.05$ ) exist between the means of LYMs of the exposed employees for both museums. This result is comparable with previous studies that found unchanged counts of total white blood cells (WBCs) and exposure to air pollution but found decreased counts of lymphocytes and other types of WBCs [50,51]. As shown in Table (5), workers exposed to formaldehyde showed a significant decrease in lymphocyte count [52]. In winter, the mean value of LYMs in M1 was  $25.49 \pm 1.69$ , and in M2 was  $22.13 \pm 1.15$ . It has no significant meaning ( $P > 0.05$ ) of LYMs between the mean values of LYMs.

### 4.2.3 RBC count, HGB, and HCT levels of employees and their percentage in (M1) and (M2).

According to the result in Table 5, in summer, the mean count of Red blood cells (RBCs) in M1 was  $4.65 \pm 0.09$ , and in M2, it was  $4.81 \pm 0.12$ . In winter, the mean count of RBCs in M1 was  $4.83 \pm 0.11$ , and in M2 was  $4.67 \pm 0.13$ . There are no significant differences ( $p > 0.05$ ) between the means of RBC count for the two museums. Furthermore, the results of the RBC count are within the normal range for the employees of the two museums, which is  $(3.5 \text{ to } 5) \times 10^{12}/L$ . This result is consistent with a previous study that found no significant association between air pollutants with hemoglobin, RBC, and platelet count [53].

### 4.2.4 Hemoglobin (HGB)

As for the Hemoglobin (HGB) level shown in Table 5, in summer, the mean level of HGB in M1 was  $13.57 \pm 0.28$ g/dl, and in M2, it was  $12.32 \pm 0.45$ g/dl. There are no significant differences ( $p > 0.05$ ) between the means of HCT for the two museums. In winter, the mean level of HGB in M1 was  $13.68 \pm 0.29$ g/dl, and in M2 was  $12.60 \pm 0.51$ g/dl. Significant differences ( $p < 0.05$ ) exist between the mean levels of HGB. Both museums are within the normal range for men (13-16.5) g/dl, and women (11.6-15) g/dl. The result of HGB in M2 is lower than in M1. This may be due to more women participating in the test in M2 than in M1, in which women have less hemoglobin than men do at all ages [54].

#### 4.2.5 Hematocrit Test (HCT)

Based on the results of the Hematocrit Test (HCT) in Table 5, the mean value of HCT in M1 was  $39.17 \pm 0.74\%$ , and in M2,  $38.06 \pm 1.24\%$  in summer. There are no significant differences ( $p > 0.05$ ) between the means of HCT for the two museums. While in winter, the mean value of HCT in M1 was  $40.52 \pm 0.77\%$ , and in M2 was  $36.72 \pm 1.34\%$ . There are significant differences ( $p < 0.05$ ) between the means of HCT for both museums. Since the normal range of the HCT is (37-47) %, M2 has a lower mean level of HCT than the normal range and M1 in winter. PM rises may have a greater effect on M2 than on M1, as shown in Table 2. This could be due to M2 having a smaller area and less ventilation than M1, which has a larger area and bigger windows. The higher concentrations of PM during winter are due to several factors, such as reduced ventilation and increased indoor activities, as people typically keep their windows closed to stay warm [55]. Industrial activities and indoor heating cause higher emissions of particles, especially in cities. Also, in cold temperatures, chemical reactions between pollutants lead to the formation of secondary aerosols, increasing PM<sub>2.5</sub> levels. As well as in winter, temperature inversion occurs when a layer of warm air traps cold air near the surface. This prevents pollutants from rising and dispersing [32, 56]. PM<sub>2.5</sub> (diameter  $\leq 2.5 \mu\text{m}$ ) is more hazardous to health as it penetrates deep into the lungs and bloodstream due to its smaller and finer size. PM<sub>10</sub> (diameter  $\leq 10 \mu\text{m}$ ) are larger particles and less likely to enter deep into the respiratory system and bloodstream. Both contribute to air pollution and harm health and the environment [57]. In addition to human occupation, the museum's furnishings, including carpet, paint, boards, and furniture made of pressed wood products, contribute to increased air pollution levels [58]. Air pollution exposures were significantly associated with an increased prevalence of anemia. People with anemia lived in areas with high annual mean PM<sub>2.5</sub> levels [59]. Long-term exposure to PM<sub>10</sub> is more likely to cause anemia, while short-term exposure may cause mild fluctuations in HGB levels [60, 61].

#### 4.2.6 Platelets count (PLTs)

As shown in Table 5, in summer, the mean count of platelets (PLTs) in M1 was  $247.04 \pm 10.63$ , and in M2, it was  $248.44 \pm 14.36$ . In winter, the mean count of PLTs was  $220.22 \pm 13.04$ , and M2 was  $250.88 \pm 16.63$ . There are no significant differences ( $p > 0.05$ ) between the means of PLTs among the employees of the two museums. Other studies found a positive association between air pollutants and platelet counts [53, 62]. Furthermore, the results of PLT for the two museums are within the normal range, which is  $(150-400) \times 10^9/\text{L}$ .

**Table 5:** The mean and SE  $\pm$  of blood parameters level for employees in the Iraqi National Museum (M1) and the Natural History Museum (M2) for two seasons.

Parameter	Summer		Probability	Winter		Probability
	M1	M2		M1	M2	
WBCs	$6.69 \pm 0.42$	$6.11 \pm 0.30$	$P > 0.05$	$6.15 \pm 0.44$	$6.54 \pm 0.2$	$P > 0.05$
LYMs	$39.44 \pm 1.30$	$20.93 \pm 1.21$	$P < 0.05$	$25.49 \pm 1.69$	$22.13 \pm 1.$	$P > 0.05$
RBCs	$4.65 \pm 0.09$	$4.81 \pm 0.12$	$P > 0.05$	$4.83 \pm 0.11$	$4.67 \pm 0.1$	$P > 0.05$
HGB	$13.57 \pm 0.28$	$12.32 \pm 0.45$	$P > 0.05$	$13.68 \pm 0.29$	$12.60 \pm 0.3$	$P < 0.05$
HCT	$39.17 \pm 0.74$	$38.06 \pm 1.24$	$P > 0.05$	$40.52 \pm 0.77$	$36.72 \pm 1.3$	$P < 0.05$
PLT	$247.04 \pm 10.63$	$248.44 \pm 14.36$	$p > 0.05$	$220.22 \pm 13.0$	$250.88 \pm 16.63$	$P > 0.05$

#### 4.3 Biochemical parameters in exposed employees of the two museums.

##### 4.3.1 Liver function: AST, ALT, and ALP

###### 4.3.1.1 Aspartate transaminase Test (AST) and Alanine transaminase Test (ALT)

Based on the results reported in Table 6, the statistical analysis showed that there were no significant differences ( $P > 0.05$ ) between the mean values of the Aspartate transaminase Test (AST) and Alanine transaminase Test (ALT) among the exposed employees of both museums in the two seasons. In summer, the mean values of AST were  $25.84 \pm 1.64$  for M1 and  $22.41 \pm 3.61$  for M2. During winter, the mean values of AST for M1 and M2 were  $27.45 \pm 1.69$  and  $27.39 \pm 1.55$ , respectively. Regarding the mean values of ALT (Table 11), the results were  $27.35 \pm 3.78$  in summer for M1 and  $25.70 \pm 2.05$  for M2. In winter, it was  $29.67 \pm 2.76$  for M1, and for M2 was  $32.27 \pm 2.59$ . In addition, the results of AST and ALT were within the normal range for the employees of both museums, which is (5-40) IU/L. Nonetheless, females displayed lower levels of liver disease biomarkers, namely ALT and AST, than males, which is consistent with previous findings [63]. These results disagree with another study, which indicated a positive association between exposure to PM<sub>2.5</sub> and levels of liver enzymes, such as AST and ALT [64].

###### 4.3.1.2 Alkaline Phosphatase Test (ALP)

For the Alkaline Phosphatase Test (ALP), the result in Table 6 showed that the mean level was, in summer,  $80.77 \pm 3.36$  and  $128.38 \pm 10.36$  for M1 and M2, respectively. In winter, the mean level of ALP was  $101.0 \pm 6.15$  for M1 and  $152.39 \pm 15.36$  for M2. The normal range of ALP is, for men: (80-306), and for women: (64-270). Although both museums are within the normal range level, there are significant differences ( $p < 0.05$ ) between the mean levels of ALP for both museums. The results for the employees of M2 are higher than M1. Exposure to air pollution may be the cause, as shown in Table 2. This corresponds with a previous study's key finding: serum ALP is positively associated with exposure to VOCs in the general population [63]. Furthermore, another study found no significant correlation between ALP level and PM<sub>2.5</sub> exposure concentration [64].

**Table 6:** The mean and SE  $\pm$  of liver function for employees in the Iraqi National Museum (M1) and the Natural History Museum (M2) for two seasons

Parameter	Summer		Probability	Winter		Probability
	M1	M2		M1	M2	
AST	$25.84 \pm 1.64$	$22.41 \pm 3.61$	$P > 0.05$	$27.45 \pm 1.69$	$27.39 \pm 1.55$	$P > 0.05$
ALT	$27.35 \pm 3.78$	$25.70 \pm 2.05$	$P > 0.05$	$29.67 \pm 2.76$	$32.27 \pm 2.59$	$P > 0.05$
ALP	$80.77 \pm 3.36$	$128.38 \pm 10.36$	$P < 0.05$	$101.0 \pm 6.15$	$152.39 \pm 15.36$	$P < 0.05$

##### 4.3.2 Renal function: Urea, Creatinine, and Uric acid

###### 4.3.2.1 Urea

Determination of serum creatinine and urea levels helps evaluate renal function in clinical settings [65]. The results in Table 7 showed that, in summer, the mean level of the urea test for M1 was  $35.72 \pm 1.81$ , and for M2, it was  $31.03 \pm 1.21$ . In winter, the mean level of the urea test was  $35.68 \pm 1.21$  for M1 and  $28.46 \pm 1.26$  for M2. Significant differences ( $p < 0.05$ ) exist between the mean urea levels for the two museums in both seasons. Although both museums were within the normal range (15–45 mg/dl), the level of urea in M2 was lower than in M1. This may be due to more men participating in the test in M1 than in M2, that urea levels are considerably greater in males than in females, regardless of age [66].

#### 4.3.2.2 Creatinine

Serum creatinine (a blood measurement) is an important indicator of renal health because it is an easily measured product of muscle metabolism excreted unchanged by the kidneys [67]. Based on the results in Table 7, the mean creatinine level in summer was  $0.81 \pm 0.03$  and  $0.98 \pm 0.02$  in M1 and M2, respectively. Significant differences ( $p < 0.05$ ) exist between the mean creatinine levels for the two museums. In winter, the mean creatinine level was  $0.95 \pm 0.03$  mg/dl in M1 and  $1.0 \pm 0.03$  mg/dl in M2. No significant differences ( $p > 0.05$ ) exist between the mean creatinine levels for the two museums. Average creatinine levels can vary depending on a person's age, sex, and muscle mass. However, average ranges are (0.7–1.2) mg/dl for males and (0.5–1.0) for females. As previously found, the rate of creatinine in women is lower than in men [68]. It has been noted from the results that the level of creatinine in M2 is equal to or very close to the upper limit of the normal range, although most of them are women. This may be due to the use of formaldehyde (FA) in M2 in fogging and preserving insects and animals more than in M1. Furthermore, the elevated levels of TVOC and HCHO in the laboratories of M2 may be returned to use acids in certain concentrations such as citric acid in tanning the skins of large animals, using formaldehyde, pesticides in the restoration and the conservation of insects, the use of some materials in the embalming of animals such as Borax salt ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ) for drying the skin of animals. The period of exposure to elevated levels at a rate of 8 hours a day, i.e. 56 hours a week, is sufficient to cause negative effects on employees and exhibits, according to the World Health Organization WHO [69]. Increased serum levels of creatinine strongly suggest a failure in kidney function due to exposure to formaldehyde [70, 71]. A previous study found that Short-term exposure did not affect the mean serum creatinine level [72].

#### 4.3.2.3 Uric acid

The results in Table 7 showed that, in summer, the mean uric acid level in M1 was  $5.17 \pm 0.20$ , and in M2 was  $4.63 \pm 0.12$ . In winter, the mean uric acid level in M1 was  $5.29 \pm 0.15$ , and in M2 was  $4.22 \pm 0.13$ . Significant differences ( $p < 0.05$ ) exist between the mean uric acid levels for the two museums in both seasons. Even though both museums are within the normal range of uric acid, which is for males (3.4-7 mg/dl) and females (2.4-6 mg/dl), M2 has lower levels than M1. This may be due to more women participating in the test in M2 than in M1. This is consistent with a previous study that found that men had higher serum concentrations of uric acid than women [73]. This is so because oestrogen protects women from gout because of its association with enhanced renal excretion of uric acid [67].

**Table 7:** The mean and SE  $\pm$  of renal function for employees in the Iraqi National Museum (M1) and the Natural History Museum (M2) for two seasons.

Parameter	Summer		Probability	Winter		Probability
	M1	M2		M1	M2	
Urea	$35.72 \pm 1.81$	$31.03 \pm 1.21$	$P < 0.05$	$35.68 \pm 1.2$	$28.46 \pm 1.26$	$P < 0.05$
Creatinin	$0.81 \pm 0.03$	$0.98 \pm 0.02$	$P < 0.05$	$0.95 \pm 0.03$	$1.0 \pm 0.03$	$P > 0.05$
Uric acid	$5.17 \pm 0.20$	$4.63 \pm 0.12$	$P < 0.05$	$5.29 \pm 0.15$	$4.22 \pm 0.13$	$P < 0.05$

## Conclusions

Museum workers are exposed to pollutants that alter blood, liver, and kidney parameters. This paper evaluates the health effects of exposure to air pollutants by applying hematological and biochemical analysis to a group of employees (male and female) at two museums in Baghdad City for two seasons. CBC test (WBC and RBC) count, liver function,

and renal function are measured. The tests were performed following a questionnaire given to the volunteer employees about age, sex, duration of work, period of daily exposure, and other details. As for the hematological test, the average concentration of WBCs, RBCs, PLT counts, HGB, and HCT levels are within the normal range in the two museums for both seasons, except that the HGB level in M2 is less than in M1. The HCT results were below the normal range during winter in M2. Since M2 is smaller and has less ventilation than M1, and the concentration of pollutants rises in winter more than in summer, M2 employees are more impacted by the contaminants than those in M1. Therefore, M2 results were lower than M1 during winter. As for liver function, AST, ALT, and ALP levels, they were within the normal range in the two museums for both seasons, except that the ALP level in M2 was higher than in M1. Renal function results showed that urea, creatinine, and uric acid levels were within the normal range in the two museums for both seasons, except that the levels of urea and uric acid in M2 were lower than in M1. In contrast, the creatinine level was higher in M2 than in M1.

### Conflict of interest

The authors declare that they have no conflict of interest.

### Ethical Approval

This study was conducted in accordance with the ethical guidelines, and approval was obtained from [University of Baghdad Ethics Committee]. The ethical approval reference number is [CSEC/1123/0092].

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