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Use of Scalp Hair as a Biomarker to Determine Airborne Heavy Metal Concentrations for the Academic Laboratory Employees

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Abstract

Academic chemical laboratories (ACL) are considered public places the employees come in contact with a variety of pollutants. The aim of the current study was to detect heavy metals levels in the indoor air of ACL in two universities in Baghdad city and assess their levels in the academic employees' scalp hair as biomarkers. Air samples inside ACL were collected to detect Fe, Cd, Zn, Pb and Cu. Scalp hair samples were collected from 40 adult chemical laboratory employees aged 30-60 years, who worked 5 days/week for 6 hours a day. Personal information relating to employees such as age, duration of exposure, smoking habit and sex, was collected as a questionnaire. The results of this study concluded that academic laboratory employees were exposed to high levels of heavy metals which was proven through the use of scalp hair; old ages, prolonged working periods, smoking habit have significant effects in increasing the levels of heavy metals in scalp hair, while the employees' gender variation did not have a significant effect.

Keywords: Airborne heavy metals, Scalp hair, Academic laboratory, Indoor air pollution.

استخدام شعر فروة الرأس كمؤشر حيوي لتحديد تراكيز المعادن الثقيلة المحمولة جوا لدى عاملي المختبرات الاكاديمية

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الخلاصة

تعدالمختبرات الكيميائية الأكاديمية (ACL) من الأماكن العامة التي يتعرض موظفوها لمجموعة متنوعة من الملوثات. كان الهدف من الدراسة الحالية هوالكشف عن مستويات المعادن الثقيلة في الهواءالداخلي لـ (ACL)في جامعتين من الجامعات التابعة لمدينة بغداد وتقييم مستوياتها في شعرفروة رأس الموظفين الأكاديميين كمؤشرحيوي. تم جمع عينات الهواءداخل (ACL) للكشف عن الحديد، الكادميوم، الزنك، الرصاص، والنحاس. تم جمع عينات شعرفروة الرأس من 40 من العاملين البالغين في المختبرات الكيميائية وممن قد عملوا لمدة 5 أيام / أسابيع لمدة 6 ساعات / يوم. تم جمع المعلومات الشخصية المتعلقة بالموظفين مثل العمر، مدة التعرض، عادةالتدخين والجنس من خلال عمل استبيان.اشارت نتائج هذه الدراسة إلى أن موظفي المختبرات الكيميائية الأكاديمية يتعرضون لمستويات عالية من المعادن الثقيلة،وقدثبت ذلك من خلال عينات شعر فروة الرأس العائدة لهم، وان الاعمار الكبيرة، فترات العمل الطويلة، عادةالتدخين ذات تأثيركبيرفي

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زيادة مستويات المعادن الثقيلة في شعرفروةالرأس، في حين أن جنس الموظفين لم يكن له تأثيرمعنوي ضمن المجاميع المدروسة.

1. Introduction

Academic chemical laboratories (ACL) are considered as occupational environments where students and employees such as teachers, chemists, specialists and technicians conduct their practical experiments, scientific research and experimental teaching. They are continuously exposed to different types of toxicants and pollutants [1].Chemical laboratories are microenvironments where a wide variety of contaminants may be identified because of the large spectrum and number of chemicals available. These chemicals increase due to the source strength which depends on type and the number of chemical experiments achieved and the number of persons employed in the laboratory. These chemicals may pollute laboratory's indoor air and cause the potential acute, chronic, toxically and cancer threats to health of the staff [2].People spending about 80% -90% of their lives living indoors (houses, offices, labs, libraries and other) where the indoor air has direct effects on their health. Consequently, the WHO considers that the poor indoor air quality in workplace represents a hazard to general health for example nervous system disorders, skin lesions, vascular damage, immune system dysfunction and even cancer [3]. Most of these places have been shown to be hazardous for study and research. In several academic labs, the use of small amounts of chemicals may cause health issues for employees [4]. Three major routes exist for exposure to chemical substances, i.e., inhalation, dermal and ingestion routes, dose of absorbed chemical substances through inhalation and skin absorption can estimate the magnitude of chemical exposure. Chemical absorption exposures to the skin or eyes are caused not only by close contact with solvents, but also by ambient gas, vapors or particulate matter (PM) with heavy metals [5].

The possible sources of heavy metals with PM in the laboratories that determine their concentrations are combustion sources such as Bunsen burners used, produced powders in the experiments and chipped pieces from walls, as well as other construction materials that are generally the main source that are found in the outdoor air. Ventilation plays a major role as it may act as a highway for their transport from outdoors to indoors. Additionally, occupant behavior in the laboratories can cause suspension of the settled particles affecting indoor air PM concentrations considerably, along with type of cleaning and its frequency, similar to reports from other indoor microenvironments [6].

Many researchers proposed that human hair should be used to monitor heavy metals. It is regarded, according to the environmental protection agency (EPA), as one of the most significant biomarkers due to its fat content compared to other tissues [7]. Heavy metals in human hair are an important indicator for evaluating human exposure to metal residues in the indoor air [8] [9]. Rashed and Hossam mentioned in their study that during the growth process hair absorbs heavy metals as metabolic and end products in its composition [10]. The long-term human exposure is beneficial in hair tests to detect changes in hair composition over time. It would also include relevant insights on health and medical matters [11]. It is an excellent source of information and provides strong markers of past metabolism and environmental susceptibility [12] and can be collected without harming the donor and retained for longer periods than other materials. Hair heavy metal concentrations will thus represent the average level of the human body which indicates if the population is exposed to heavy metals [10].

The aim of the current study was to detect the levels of some heavy metals in the ACL ambient air and assess toxic elements in employees scalp hair. Qualitative variables affecting mineral levels, such as gender, smoking habits, age, and exposure duration to determine the level of health risk in the workplace were also investigated.

2. Materials and Method
2.1 Ethical Statement
The Ethics Committee of the University of Baghdad/ College of Science approved this work (Ref.: CSEC/0421/0030. Date: April 14, 2021).

2.2 Study Sites:
This study was conducted in 4 academic laboratories including two chemistry (Lab1, Lab2) and two biochemistry (Lab3, Lab4), in the Chemistry Department of College of Science, Baghdad and Al-Nahrain universities in the south of Baghdad city. The dimensions of all laboratories (Lab1, Lab2, Lab3, and Lab4) were approximately equal and they occupied a size of about 75 m3 with medium ventilation. The control site was an empty classroom within the College of Science that had almost the same dimensions as the laboratories with moderate ventilation.

2.3 Air Samples Inside Laboratories
To quantify the heavy metals in air dust, the low volume sampler (Sniffer air vacuum sampler of US origin) and specific cellulose filters (pore size1.2µm) were used. Air samples were obtained from all laboratories (Lab1, Lab2, Lab3, Lab4 and control site). Prior to sampling, cellulose filters were dried in an oven for 45 minutes at 70^{o}Cto eliminate water content. The samples were also weighed with a precise scale to record the initial weight and were then kept in a sealed container in preparation for use in the sample locations. In the sampling locations, the filter was placed in the sampler equipment (Sniffer) which was placed on a table inside the chemical lab and elevated 1 m above the floor level as suggested by [13]. Each site received five (5) samples as well as control site and every sample lasted for 1 hour. During sampling, the volume of air was measured at the start and end of the sampling period (V1 and V2 respectively), and the latter quantities were used to determine the total volume of air at time (Vt) (Equation 1). The exposed filter was maintained in a sealed container and weighed in the laboratory after sampling was completed. This weight served as the final weight.

$$VT = V2 - V1\ (m3/min) * t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The temperature (^{o}C) and relative humidity (RH) were evaluated during the sampling period in all experimental and control sites by using Temtop LKC-1000S+ Air Quality Detector/IAQ monitor.

2.3 Heavy Metals Measurement
The digestion of air filter sample and atomic absorption spectrometry (AAS) examination were the two procedures applied in the determination of heavy metals in dust [14].

2.3.1 Air Sample Filters Digestion
In order to change the sample solid state into a liquid condition that can be detected by an atomic absorption spectrometer, the digestion procedure entails dissolving filter solid samples with acids. This process stood for the following [14]:
1. The sample of an air filter was divided into small pieces and placed in a Teflon beaker.
2. The shared sample was mixed with 5 ml of (HNO_3) acid.
3. The samples were dried using a heater and were then allowed to cool.

4. Three ml of HClO4 acid was added to the cooled sample before reheating.
5. The sample was then taken of the heat before being dried and then allowed to cool.
6. Each sample had 2ml of hydrofluoric acid (HF) added to it before being covered and left to allow the solution to clear for 24 hours.
7. A volumetric flask of 50 ml size was used to filter each sample.
8. De-ionized water to a volume of 50 ml was added to each sample volume (Vi). Prepared samples for atomic absorption spectrometry analysis were kept in plastic containers.

Under the same conditions as the samples during analysis, the blank solution represented the digestive acids at a specific concentration. Nitric acid, perchloric acid and hydrofluoric acid were utilized to break down the samples.

2.3.2 AAS (Atomic Absorption Spectrometry) Analysis

The amounts of the heavy metals in the sample solution were detected using AAS.

The heavy metal concentrations calculations were done by applying the following equation [14]

$$\text{Metal Conc. } (\mu g/m3) = C * Vi / VT \quad \ldots\ldots\ldots\ldots\ldots\ldots (2).$$

Where: C is the metal concentration in the sample (ppm).
Vi: The volume of sample (ml).
VT: The total volume of air drawn with time (m3).

2.4 Personal Information Collection:

Details related to the employees of the chemical laboratory such as age, sex, smoking habit and working time (duration of exposure) in chemical laboratories were gathered as a questionnaire before collecting the hair sample. A total of 40 adult chemical laboratory employees (20 men and 20 women), aged 30-60 years, were chosen to collect hair samples. Staff known as chemical laboratory employees were classified as chemists and biochemists. They worked for 5 days/week for at least 6 hours a day. The control group represented 20 hair samples collected from men and housewives who spent most of the time at home [15].

2.5 Hair Samples Collection:

The sampling of hair was done only with hair that not had been bleached, colored or had any chemical therapies. Before analysis, each individual hair sample was cut (only the first 1-2 inch close to the scalp) by using steel scissors. The collection of approximately 250 mg of hair from the neck nape was used. For each person, hair sample was placed into separate plastic envelope indicating the ID number of the participant. Every top was closely stitched in a plastic envelope which was then attached to a survey [16].

2.5.1 Hair Samples Washing:

After cutting, each sample was rinsed with distilled and deionized water [17]. To eliminate exogenous pollutants the hair samples were individually washed by using acetone, and then with water and again with acetone [18]. After the washing process was over, hair samples were cut into small pieces andthen cleaned and placed in plastic bags at room temperature. The samples were dried in an oven at 58-75°C [19].

2.5.2 Samples Digestion and Analysis Method:

Approximately 250 mg of each sample in locked teflon containers was digested in the microwave system by means of acids (2 ml of nitric acid HNO3 and 1 ml of 30% of H2O2). Before the vial release, Teflon vessels were placed in the freezer for 3/4h. The solvent had been purified and the contents were then transferred quantitatively into a 50 mL volumetric flasks until they were loaded to marks. These ready solutions were used for the metal

determination [20][21]. Using the AAS (NOVAA-400) model, the control and test samples were examined to detect elements such as Cu, Zn, Cd, Pb and Fe.

Statistical Analysis

Data were presented as mean ± standard deviation. -test and the statistical significance set at $P<0.05$ and $P<0.01$ were performed using the Statistical Package for the Social Sciences (SPSS), version 17.0 to compare metal concentrations between the examined study sites, as well as the various employee groups [22].

3. Results and Discussion

Table 1 demonstrates the mean concentrations of Pb, Zn, Cd, Cu, Fe, temperature (˚C) and relative humidity percentage in the indoor air for both chemistry and biochemistry labs. The results referred that most of examined heavy metals in chemistry labs were higher than those in biochemistry levels. Statistical analysis referred that the differences were considered to be extremely significant when $p<0.01$.There was a 95% confidence interval when these levels were compared with the control site. It was anticipated that both laboratories' interior dust air would have higher metal concentrations than the control site.

For temperature, the highest mean value 36 ±0.61 ºC was recorded in biochemistry laboratories, and the variations that were determined to be significant at $p< 0.05$ in comparison to the control site (34±1.73 ºC).While that for chemistry laboratories, the differences were not significant ($p>0.05$). Regarding RH% mean value, both chemistry and biochemistry sites were considered not to be significant ($p>0.05$) as compared with the control site. The moderate ventilation in both chemistry and biochemistry laboratories may have influenced temperature and relative humidity which made these variables to be not statistically significant as compared with control site.

Table 1: mean ± SD of heavy metals (µg/m3), temperature (˚C) and relative humidity (%) collected from indoor air of academic chemical laboratories and control site.

Sites	Heavy Metals Concentrations µg/m3					Temp. ˚C	RH. %
	Pb	Zn	Cd	Cu	Fe		
Chemistry Labs.	9.21±1.13**	200.79±0.70**	0.07±0.00**	12.37±0.69**	103.25±4.36**	35±1.30	20±1.10
Biochemistry Labs.	7.40±0.68**	161.60±7.00**	0.04±0.01**	9.08±0.65**	86.15±4.13**	36±0.61*	19±2.03
Control	1.04±0.31	0.4±0.05	0.0± 0.00	0.11±0.01	23.67±2.62	34±1.73	21±1.22

**Significant at p<0.05 **Highly significant at p<0.01*

Ugranli *et al.* mentioned that the location of the building and the activities around had an impact on the metal concentrations in indoor dust [2]. Chemistry labs use a greater variety of chemicals than other types of laboratories. Ambient air PM-bound trace elements can be carried into the laboratories from outdoors by ventilation and infiltrations. In addition, it can also be transported via shoes and clothing of individuals. However, the main trace element source may have been some specific operations and procedures that were being carried out in the laboratories involving chemical materials, samples, etc., that could be rich in trace element content. Long-term inhalation exposure to some trace elements may also have a variety of negative health impacts on people, ranging from cardiovascular disease and cancer to tracheal mucosal irritation and coughing [2].

The effects of employees' age categories in mean values of heavy metals in hair samples have been demonstrated in Table 2. In both chemistry and biochemistry labs, the average

levels of Pb were found to be 5.6±3.4µg/g in the hair of employees between the ages of 51 and 60.This value exceeded the normal value in hair <1.0µg/g and was the highest among the other groups. While the lowest mean was 3.5±0.8 in 30-40 years old group. Also the mean concentration of Zn, Cd, Fe recorded high values (352±208.1, 0.04±0.03, 95.6±23.1, 95.6±23.1 µg/g repectively in 51-60years age category, except Cu which recorded high value in 41-50 years age category.

Table 2: mean ± SD of heavy metal concentrations in hair samples of different age categories in chemical lab employee

Heavy Metal Concentrations µg/g	Age Categories/Year					
	Exposed			Control		
	30-40	41-50	51-60	30-40	41-50	51-60
Pb	3.5±0.8*	4±1.5*	5.6±3.4*	0.48±0.23	0.8±0.25	0.74±0.11
Zn	211.5±72.2	224.6±38.8*	352±208.1*	30±7.21	26.8±5.40	29.8±7.22
Cd	0.02±0.01*	0.03±0.01*	0.04±0.03*	0.008±0.01	0.006±0.00	0±0
Cu	10.5±1.3	10.6±2.9*	9.6±2.7*	2.00±0.70	3±1.00	3.8±1.64
Fe	83.7±30.1*	90.6±20.6*	95.6±23.1*	25±2.549	34.8±4.81	36.2±4.26

**Significant at p<0.05*

T-test results between all age groups and control groups revealed significant differences at $p<$ 0.05. According to the findings of the study, heavy metal concentrations gave higher readings as the ages increased. Heavy metal bioaccumulation may be impaired by age and sex in human bodies [23]. Life does not alter and is not constantly intaking and excreting kinetics of heavy metals through human development. Previous research found a favourable association between Pb in hair and age. It is absorbed very fast into the bloodstream and the toxicity of inhaling lead for long time may cause blood pressure, psychiatric illnesses such as nausea, dizziness, impairment of concentration, irritability, restlessness, confusion and discouraged memory, body discomfort, pre-menstrual syndrome, reduced immunity [24].A previous study has linked the fluctuation of heavy metal levels between age groups to metal accumulation, lifestyle and dietary choices [7]. .

The current study revealed the effects of duration of exposure in heavy metals levels in employees and the control group (Table 3).

Table 3: mean ±SD of heavy metal contents in hair samples of chemical laboratory employees grouped according to exposure length.

Duration of Exposure/Year	Heavy Metal Average Concentrations µg/g				
	Fe	Cu	Cd	Zn	Pb
Control	32.0±6.3	2.9±1.3	0.0±0.0	28.8±6.3	0.6±0.2
5-10	90.3±25.0*	10.6±2.0*	0.03±0.02*	232.0±103.4*	4.0±1.6*
11-20	90.4±27.3*	10.2±2.5*	0.03±0.02*	279.8±169.7*	4.6±2.8*
21-30	94±24.5*	10±2.8*	0.04±0.03*	321.7±175.4*	4.8±3.1*

**Significant at p<0.05*

The employees who spent long period (21-30 years) of work in laboratory recorded high concentrations (94, 0.03, 321.7and 4.8 µg/g) for different heavy metals (Fe, Cd, Zn and Pb respectively), as well as for both 5-10 and11-20 years of exposure as compared with the control group. Copper (Cu) concentrations recorded approximately equal levels at all

durations of exposure. *P*-value and statistical analysis is considered to be extremely statistically significant at $p<0.05$. In a research carried out by Husin *et al.*, they found that the duration rate (DR) was used in chemical laboratories to assess normal or chronic exposure to heavy metals. Most workers who spent 4-7 hours on job, the percentage corresponded to a high value of 50-87.5% work time in the normal working hours (8 hours/day) (DR).They also found that cadmium and lead recorded high levels in the indoor air that contained dust. These heavy metals were added to chemists' hair due to polluted interior environment [25]. Human hair can absorb heavy metals as an excretory system and as metabolic products. It can incorporate metals into its structure throughout the growth phase. As a result, heavy metal concentrations in hair can represent the average level in the human body, reflecting the population's duration of exposure to heavy metals [7]. Long-term body retention of heavy metals can slow down the development of the degenerative physical, muscle and neurological processes that mimic diseases like Parkinson's and Alzheimer's [26]. In addition, it could also destroy nucleic acids, induce mutation, reproduction of the hormone, and possibly increase the risk of cancer [27]. Long-term exposure to cadmium contributes to bone Atherosclerosis and pulmonary deposition, and can even cause damage of these tissues, hypertension, and decreased immunity [28]. Cadmium build-up will replace zinc in the arteries, thereby leading to fragility and rigidity of the arteries resulting in high blood pressure [29]. Due to the chemical similarities between calcium and lead, lead builds up in a person's bones, nails and hair after prolonged exposure. Significant amount of lead in the body is regarded as poisonous [30]. Long term exposure to iron shows Hemochromatosis headache, shortness of breath, increased degeneration of liver, pancreas, heart and diabetes [31]. Although metals such as copper Cu, iron Fe and Zn are required for living organisms in small amounts, chronic and prolonged exposure causes adverse effects to tissues and organs, eventually leading to carcinogenesis [28].

Table 4 illustrates the examined heavy metals values in hair samples of smoker and non-smoker employees. The statistical analysis in Table 4 shows that the difference was considerably significant at $p<0.05$ between smoker and non-smokers for lab. employees as compared with the control group.

Table 4: mean ±SD of heavy metal concentrations (µg/g) in hair samples of employee grouped according to smoking habits.

Age Categories	Smoking Habit	Heavy Metal Concentrations µg/g				
		Fe	Cu	Cd	Zn	Pb
40-30	Non-smoking Smoking	79.0±33* 96.6±17.1*	10.3±1.4* 10.8±1.4*	0.02±0.01* 0.03±0.1*	199.2±80.7* 245.1±24.1*	3.4±0.8* 3.7±0.8*
	Control	25±2.54	2± 0.70	0.08± 0.01	30± 7.21	0.48± 0.2
50-41	Non-smoking Smoking	88.0±21.1* 101.3±9.2*	10.0±2.*8 13.0±1.7*	0.03±0.01* 0.04±0.0*	217±36.9* 255.3±25.4*	4±1.4 * 4±1.8*
	Control	34.8± 4.81	3± 1	0.06± 0.0	26.8± 5.40	0.8± 0.25
60-51	**Non-smoking** **Smoking**	**87.8±25*** **111.4±0.5***	**8.7±2.8*** **11.6±0.5***	**0.04±0.03*** **0.05±0.0***	393.6±205.8** 268.8±208.1**	5.8±3.7* 5.4±2.8*
	Control	**36.2± 4.26**	**3.8± 1.64**	**0±0**	29.8± 7.22	0.74± 0.11

**Significant at p<0.05* ***Highly Significant at p<0.01*

High levels of metals (Fe, Cu, Cd andPb) were detected in smokers as compared with non-smokers, especially in 51-60 years age category which appeared to be highly significant at $p<0.01$ for Zn (268.8±208.1 µg/g)for smoker employees.

Tobacco leaves are generally used in smoking products [32]. Tobacco plants usually absorb from the soil, fertilizers, pesticide treatments, handling, and refining, packaging and other processes a lot of necessary, non-essential and toxic elements. Cu sources in smokers can be caused by soil-producing tobacco insecticide sprayed as well as Cd [32]. Smoking was found to contribute to increased bioaccumulation of Cd in scalp hair of smokers [33] . Sukumar and Subramanian found that Pb concentration was high in scalp hair tests for staff who suffered from chronic headache and dizziness. There were also different levels of concentration associated with Pb in the hair. For adults, Pb in hair and smoking were found to be in a good relationship [34].

The results in Table 5 show the effects of laboratory employees' genders on the heavy metals levels in scalp hair samples.

Table 5: mean ±SD of heavy metal concentrations in hair samples of chemical lab employee classified according to sex.

Age Categories	Experimental Groups	Sex	Heavy Metal Concentrations µg/g				
			Fe	**Cu**	**Cd**	**Zn**	**Pb**
30-40	Exposed	Females	83.75±30.6*	10.3±1.4*	0.02±0.01*	209.5±80.7*	3.4±0.7*
		Males	83.75±32.5*	11.7±2.8*	0.02±0.01*	211.5±78.0*	3.5±0.9*
	Control	Females	23.3±1.50	2.0±1.0	0.01±0.0	30.1±2.0	0.4±0.2
		Males	27.5±0.70	2.0±0.0	0.0±0.0	30.0±14.1	0.55±0.3
41-50	Exposed	Females	92.8±21.0*	10.7±2.8*	0.03±0.01*	220±40.3*	4.05±1.4*
		Males	86.4±21.2*	10.6±3.5*	0.03±0.01*	234.3±38.2*	3.9±1.7*
	Control	Females	36.0±4.0	3±1	0.0±0.0	28.2±2.0	0.8±0.2
		Males	33±7.0	3±1.4	0.0±0.0	25.±9.8	0.8±0.4
51-60	Exposed	Females	87.8±25*	8.7±2.8*	0.04±0.01*	393.6±205.8*	5.8±3.7*
		Males	111.4±0.5*	11.6±0.5*	0.05±0.01*	268.8±208.1*	5.4±2.8*
	Control	Females	36.0±4.0	3.0±1.0	0.0±0.0	31.6±3.2	0.7±0.1
		Males	38.0±0.0	4.5±2.1	0.0±0.0	27.0± 12.7	0.8±0.1

**Significant at p<0.05*

Generally, the statistical analysis revealed that the differences between exposed male and female groups were considered to be not significant ($p>0.05$) for all examined heavy metals (Fe, Cu, Cd, Zn and Pb) in 30-40 and 41-50 years age categories. Whereas difference was significant at $p<0.05$ in 51-60 years age category. A comparison was made between exposed and the control group for females and males in each 30-40, 41-50 and 51-60 years age categories and the statistical analysis referred to be significant at $p<0.05$. These results agree with a previous study which referred that there were no major differences in the contents of trace elements for male and female hair. Also women's hair contained less iron and more zinc

than men's hair. For both sexes the mean amount of copper was identical [35]. Bucław *et al.* mentioned that sex was the major variable in hair quality that influences Cd, Zn and Pb. Some researchers, however, found no important gender differences [36]. Due to monthly bleeding in women, the average Fe values were found to be lower than in men [37].

For both males and females in the same age group, no distinct associations for metal concentrations distribution were found. Hence, the gender of an individual has no effect on the accumulation of heavy metals in the scalp hair samples, and this was observed through the differences in values of heavy metals. For instance, the average levels of Pb for males in hair samples were lower than those for females. While Cd was comparable for women as well as Cu especially in 30-40 and 41-50-years age categories. Fe, on the other hand, was higher in males than in the females. For Zn the results showed higher levels in males than in females in 30-40 and 41-50-years age categories. Zn recorded low values in males as compared with females in 51-60-years age category. The key reasons for these variations in heavy metals distribution in ages are metabolism, occupational toxicity and gender's physiological factors [38]. Also, the gender was not a crucial factor for assessing metal concentrations in human hair [39].

Conclusion: This study concluded that the indoor air of academic (chemistry and biochemistry) laboratories were polluted with different levels of heavy metals (Pb, Cd, Cu, Zn, Fe) which was proved through the use of employees scalp hair as a biomarker to estimate their concentrations. Hair, unlike the other body compartments, is hypothesized to integrate trace elements into its structure during the growth process. Hence, old employees with long working periods and smoking habit were found to have a significant effect in increased heavy metals levels in scalp hair. The genders of the employees did not have a significant effect on the concentrations of heavy metals.

Conflict of Interest:

The authors declare that they have no conflicts of interest.

References

[1] Y. Zhang et al., "Assessing the Safety Risks of Civil Engineering Laboratories Based on Lab Criticality Index: A Case Study in Jiangsu Province," International Journal of Environmental Research and Public Health, vol. 17, no. 17, p. 6244, Aug. 2020, doi: https://doi.org/10.3390/ijerph17176244.

[2] T. Ugranli, E. Gungormus, A. Sofuoglu, and S. C. Sofuoglu, "Indoor Air Quality in Chemical Laboratories," The Quality of Air, vol. 73, pp. 859–878, 2016, doi: https://doi.org/10.1016/bs.coac.2016.04.007.

[3] V. V. Tran, D. Park, and Y.-C. Lee, "Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality," International Journal of Environmental Research and Public Health, vol. 17, no. 8, p. 2927, Apr. 2020, doi: https://doi.org/10.3390/ijerph17082927.

[4] D. J. Leggett, "Identifying hazards in the chemical research laboratory," Process Safety Progress, vol. 31, no. 4, pp. 393–397, Aug. 2012, doi: https://doi.org/10.1002/prs.11518.

[5] S. E. Anderson and B. J. Meade, "Potential Health Effects Associated with Dermal Exposure to Occupational Chemicals," Environmental Health Insights, vol. 8s1, no. suppl 1, p. EHI.S15258, Jan. 2014, doi: https://doi.org/10.4137/ehi.s15258.

[6] T. Ugranli, M. Toprak, G. Gursoy, A. H. Cimrin, and S. C. Sofuoglu, "Indoor environmental quality in chemistry and chemical engineering laboratories at Izmir Institute of Technology," Atmospheric Pollution Research, vol. 6, no. 1, pp. 147–153, Jan. 2015, doi: https://doi.org/10.5094/apr.2015.017.

[7] G. Liang, L. Pan, and X. Liu, "Assessment of Typical Heavy Metals in Human Hair of Different Age Groups and Foodstuffs in Beijing, China," International Journal of Environmental Research and Public Health, vol. 14, no. 8, p. 914, Aug. 2017, doi: https://doi.org/10.3390/ijerph14080914.

[8] E. Solgi and S. Mahmoudi, "Arsenic and heavy metal concentrations in human hair from urban areas," Environmental Health Engineering and Management, vol. 9, no. 3, pp. 247–253, Aug. 2022, doi: https://doi.org/10.34172/ehem.2022.25.

[9] Y. Li, Y. Yu, N. Zheng, S. Hou, X. Song, and W. Dong, "Metallic elements in human hair from residents in smelting districts in northeast China: Environmental factors and differences in ingestion media," Environmental Research, vol. 182, p. 108914, Mar. 2020, doi: https://doi.org/10.1016/j.envres.2019.108914.

[10] M. N. Rashed and F. Hossam, "Heavy Metals in Fingernails and Scalp Hair of Children, Adults and Workers from Environmentally Exposed Areas at Aswan, Egypt," Environmental Bioindicators, vol. 2, no. 3, pp. 131–145, Sep. 2007, doi: https://doi.org/10.1080/15555270701553972.

[11] M. Usman, A. Naseer, Y. Baig, T. Jamshaid, M. Shahwar, and S. Khurshuid, "Forensic toxicological analysis of hair: a review," Egyptian Journal of Forensic Sciences, vol. 9, no. 1, Apr. 2019, doi: https://doi.org/10.1186/s41935-019-0119-5.

[12] P. Kintz, A. Ameline, and J. Raul, "Human hair tests to document drug environmental contamination: Application in a family law case involvingN,N -dimethyltryptamine," Drug Testing and Analysis, vol. 13, no. 2, pp. 447–450, Oct. 2020, doi: https://doi.org/10.1002/dta.2948.

[13] H. Fromme et al., "Indoor air contamination during a waterpipe (narghile) smoking session," Food and Chemical Toxicology, vol. 47, no. 7, pp. 1636–1641, Jul. 2009, doi: https://doi.org/10.1016/j.fct.2009.04.017.

[14] Ali, Lamya Abd al-Amir. Environmental impact assessment of Kirkuk Oil Refinery. (Master's theses Thesis and Dissertations Master). University of Baghdad. 2013. https://search.emarefa.net/detail/BIM-609501.

[15] Nnorom, Igwe, and Ejimone, "Multielement analyses of human scalp hair samples from three distant towns in southeastern Nigeria," African Journal of Biotechnology, vol. 4, no. 10, pp. 1124–1127, Oct. 2005, doi: https://doi.org/10.5897/ajb2005.000-3222.

[16] M. Usman, A. Naseer, Y. Baig, T. Jamshaid, M. Shahwar, and S. Khurshuid, "Forensic toxicological analysis of hair: a review," Egyptian Journal of Forensic Sciences, vol. 9, no. 1, Apr. 2019, doi: https://doi.org/10.1186/s41935-019-0119-5.

[17] A. Müller and S. Iwersen-Bergmann, "Determination of Ethyl Glucuronide in Human Hair Samples: Decontamination vs Extraction," Drug Testing and Analysis, vol. 12, no. 7, Mar. 2020, doi: https://doi.org/10.1002/dta.2791.

[18] J. A. Baker and N. I. Ward, "Determination of Minor elements of Human Scalp Hair from Karbala, Iraq," Journal of Physics: Conference Series, vol. 1032, p. 012067, May 2018, doi: https://doi.org/10.1088/1742-6596/1032/1/012067.

[19] V. Bencko, "Use of human hair as a biomarker in the assessment of exposure to pollutants in occupational and environmental settings," Toxicology, vol. 101, no. 1–2, pp. 29–39, Jul. 1995, doi: https://doi.org/10.1016/0300-483x(95)03018-b.

[20] K. Gellein et al., "Trace Element Profiles in Single Strands of Human Hair Determined by HR-ICP-MS," Biological Trace Element Research, vol. 123, no. 1–3, pp. 250–260, Feb. 2008, doi: https://doi.org/10.1007/s12011-008-8104-0.

[21] O. O. Peter, I. S. Eneji, and R. Sha'Ato, "Analysis of Heavy Metals in Human Hair Using Atomic Absorption Spectrometry (AAS)," American Journal of Analytical Chemistry, vol. 03, no. 11, pp. 770–773, 2012, doi: https://doi.org/10.4236/ajac.2012.311102.

[22] S. Landau, Handbook of statistical analyses using spss. Chapman &Hall/CRC Press LLC, 2017, pp339.

[23] Dorota Cygan-Szczegielniak and K. Stasiak, "Effects of age and sex on the content of heavy metals in the hair, liver and the longissimus lumborum muscle of roe deer Capreolus capreolus L.," Environmental Science and Pollution Research, vol. 29, no. 7, pp. 10782–10790, Feb. 2022, doi: https://doi.org/10.1007/s11356-021-16425-6.

[24] A. K. Zgair, H. Jabbar, and J. A. Ghafil, "Biosorption of Pb and Ni From Aqueous Solution by Staphylococcus Aureus, Pantoea and Pseudomonas Aeruginosa", Iraqi Journal of Science, vol. 60, no. 4, pp. 739–744, May 2019.

[25] S. N. H. Husin, A. B. Mohamad, S. R. S. Abdullah, and N. Anuar, "Chemical Health Risk Assessment at The Chemical and Biochemical Engineering Laboratory," Procedia - Social and Behavioral Sciences, vol. 60, pp. 300–307, Oct. 2012, doi: https://doi.org/10.1016/j.sbspro.2012.09.383.

[26] M. Jaishankar, T. Tseten, N. Anbalagan, B. B. Mathew, and K. N. Beeregowda, "Toxicity, mechanism and health effects of some heavy metals," Interdisciplinary Toxicology, vol. 7, no. 2, pp. 60–72, Jun. 2014, doi: https://doi.org/10.2478/intox-2014-0009.

[27] M. Balali-Mood, K. Naseri, Z. Tahergorabi, M. R. Khazdair, and M. Sadeghi, "Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic," Frontiers in Pharmacology, vol. 12, no. 643972, Apr. 2021, doi: https://doi.org/10.3389/fphar.2021.643972.

[28] A. Bernard, "Cadmium and its adverse effects on humans," The Indian Journal of Medical Research 128(4):557-64, vol. 128, no. 4, pp. 557–564, Nov. 2008.

[29] J. Chmielnicka and M. G. Cherian, "Environmental exposure to cadmium and factors affecting trace-element metabolism and metal toxicity," Biological Trace Element Research, vol. 10, no. 3, pp. 243–262, Sep. 1986, doi: https://doi.org/10.1007/bf02795623.

[30] A. Q. Muryoush, "The Effect of Cold Plasma on pH, Creatine, and the Concentration of the Most Trace Elements in Human's Nails by Using X-ray Fluorescent Method," Iraqi Journal of Science, vol. 63, no. 5, pp. 2057–2062, May 2022, doi: https://doi.org/10.24996/ijs.2022.63.5.21.

[31] World Health Organization. Regional Office for Europe and J. Who. T. F. on the H. A. of A. Pollution, Health risks of heavy metals from long-range transboundary air pollution. World Health Organization. Regional Office for Europe, 2007. Accessed: Nov. 14, 2022. [Online]. Available: https://apps.who.int/iris/handle/10665/107872

[32] T. Martinez, J. Lartigue, G. Zarazua, P. Avila-Perez, M. Navarrete, and S. Tejeda, "Application of the Total Reflection X-ray Fluorescence technique to trace elements determination in tobacco," Spectrochimica Acta Part B: Atomic Spectroscopy, vol. 63, no. 12, pp. 1469–1472, Dec. 2008, doi: https://doi.org/10.1016/j.sab.2008.10.008.

[33] W. I. Mortada, M. A. Sobh, and M.M. El-Defrawy, "The exposure to cadmium, lead and mercury from smoking and its impact on renal integrity.," Medical Science Monitor, vol. 10, no. 3, pp. CR112-6, Mar. 2004.

[34] A. Sukumar and R. Subramanian, "Elements in hair and nails of residents from a village adjacent to New Delhi," Biological Trace Element Research, vol. 34, no. 1, pp. 99–105, Jul. 1992, doi: https://doi.org/10.1007/bf02783902.

[35] Kałuza J, M. Jeruszka, and A. Brzozowska, "[Iron, zinc and copper status in the elderly living in Warsaw district determined by hair analysis].," Roczniki Państwowego Zakładu Higieny, vol. 52, no. 2, pp. 111–8, Jan. 2001.

[36] M. Bucław, D. Majewska, D. Szczerbińska, and M. Ligocki, "The influence of age and gender on emu (Dromaius novaehollandiae) fat," Scientific Reports, vol. 10, no. 1, p. 11082, Jul. 2020, doi: https://doi.org/10.1038/s41598-020-68103-1.

[37] J. Jian et al., "Effects of iron deficiency and iron overload on angiogenesis and oxidative stress—a potential dual role for iron in breast cancer," Free Radical Biology and Medicine, vol. 50, no. 7, pp. 841–847, Apr. 2011, doi: https://doi.org/10.1016/j.freeradbiomed.2010.12.028.

[38] L. Chang, S. Shen, Z. Zhang, X. Song, and Q. Jiang, "Study on the relationship between age and the concentrations of heavy metal elements in human bone," Annals of Translational Medicine, vol. 6, no. 16, pp. 320–320, Aug. 2018, doi: https://doi.org/10.21037/atm.2018.08.09.

[39] A. Baran and J. Wieczorek, "Concentrations of heavy metals in hair as indicators of environmental pollution," E3S Web of Conferences, vol. 1, p. 21005, 2013, doi: https://doi.org/10.1051/e3sconf/20130121005.