Ibn Al-Haitham Journal for Pure and Applied Sciences
Journal homepage: jih.uobaghdad.edu.iq
PISSN: 1609-4042, EISSN: 2521-3407
IHJPAS. 2025, 38(2)

Contamination of Radioactivity with Uranium and Concentrations of Some Heavy Metals in Human Blood

Hala M. Hamza [1*] and **Hayder S. Hussain** [2]
[1,2]Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq.
*Corresponding Author.

Received :10 May 2024 Accepted :10 September 2024 Published: 20 April 2025
doi.org/10.30526/38.2.4004

Abstract

This research has been conducted to determine the level of radioactive contamination from uranium and some heavy elements (Pb, Cd, Ni & Cu) in 60 blood samples taken from individuals living in four areas (Ishtar, Jeser Diyala, AL-Wardiya, and Tameem) near the Iraqi Atomic Energy Organization, south of Baghdad, bordered by the Tigris River to the west and the Diyala River to the north. This organization was established in 1967 and was used for legitimate nuclear operations. It was targeted during the Gulf Wars in 1991 and 2003, leading to leaks of containers containing uranium oxides and radioactive sources from the organization to surrounding areas. Living near a nuclear testing site exposes residents to internal and external radiation. The nuclear track detector for solid-state (CR-39) and inductively coupled plasma optical emission spectrometry (ICP-OES) were used to determine the concentrations of uranium and heavy metals. The uranium concentration rates in Ishtar, Jeser Diyala, AL-Wardiya, and Tameem were 0.583±0.02μg/L, 0.546±0.04μg /L,0.439±0.05μg/L and 0.390±0.04μg/L, respectively. Based on the results obtained, it is noticed that the concentrations of uranium in the villages of Ishtar and Jeser Diyala are higher than in the rest of the areas, exceeding the acceptable limit set by the World Health Organization (WHO). The highest concentrations of Pb (0.084 ±0.007) ppm and Cd (0.026 ±0.006) ppm were found in Tameem, the highest concentration of Ni (0.038 ±0.008) ppm in Ishtar, and the highest concentration of Cu (0.168 ±0.033) ppm in Jeser Diyala.

Keywords: Contamination, Uranium, Heavy elements, Al-Tuwaitha nuclear site, Human blood.

1. Introduction

Uranium is a naturally occurring heavy, radioactive metal that contains numerous isotopes, including three primary ones: ^{238}U, ^{235}U, and ^{234}U. These isotopes decay by emitting alpha and beta. In the nuclear industry, the latter two isotopes are widely used (1). Extracting uranium ore, milling it, and processing it are examples of human activities that lead to the release and redistribution of uranium in the environment (2).The soluble part of uranium enters the bloodstream and accumulates in all organs (3). Humans can be exposed to uranium in several ways: either directly by inhaling dust particles containing uranium, indirectly by drinking contaminated water with uranium, or through fertile soil layers via the food chain (4). Uranium that has been inhaled or ingested through drinking water is stored in the bones, liver, and kidneys (5). Insoluble uranium particles can have harmful effects on the respiratory system when inhaled, according to research done on both people and animals (6). Only 2% of ingested uranium is absorbed into the body through food, with the remaining 98% excreted through feces. However, the rate of uranium entering the bloodstream via inhalation may exceed 20%, according to the World Health Organization (7). Among many other pollutants, heavy metals represent the most hazardous type of pollution (8). It is well known that heavy elements like arsenic (As), copper (Cu), lead (Pb), chromium (Cr), and cadmium (Cd) are highly toxic to human cells. In the last twenty years, increased industrial and agricultural activities have led to the accumulation of heavy metals in the environment. Consequently, abnormal levels of heavy elements can lead to health and environmental disasters (9). Eating, drinking, and breathing air are all factors that contribute to the entry of heavy metals into the body. Skin contact also contributes to this process, but to a lesser extent (10). When metals are present in sufficiently high concentrations, they can be harmful to human health. Long-term exposure to lead (Pb), cadmium(Cd), copper (Cu), and nickel (Ni) toxins increases the likelihood of developing heart and lung diseases, nervous system disorders, chronic inflammation, and various types of cancer (11). Identifying heavy metals in bodily fluids, such as blood, is one of the most efficient techniques. Heavy metal testing primarily utilizes blood samples because they represent the substance better (12). Blood is the body fluid in humans and animals that is tested to detect trace elements. Depending on how trace elements chemically bond with nutrients, the quantity of these elements entering the bloodstream after absorption in the digestive system is determined (13).The site of the Iraqi Atomic Energy Organization is one of the most polluted sites in Iraq, located 1 km east of the Tigris River and 20 km southeast of Baghdad. The nuclear research reactors were destroyed in 1991 during the Gulf War, and in 2003, barrels containing radioactive materials were taken from the site, leading to significant radiation pollution in the surrounding areas (14).Many studies have shown that soil and water in areas near the Atomic Energy Organization contain high concentrations of uranium (15,16). Therefore, the study aimed to determine the concentrations of uranium and some heavy elements (Pb, Cd, N I & Cu) in blood samples of people living in areas (Ishtar, Jeser Diyala, Al-Wardiya, and Al-Tameem) near the Atomic Energy Organization to see if the local high radiation background is reflected on the physiological fluids like blood.

2. Materials and Methods

Sixty blood samples were taken from donors (females and males) aged between 20-60 years from four areas near the Iraqi Atomic Energy Organization. The samples included 15 from each of Ishtar village (10 males and 5 females), Jeser Diyala region (7 males and 8 females), Al-Wardiya region (8 males and 7 females), and Tameem region (7 males and 8 females). Blood samples were collected from November 2022 to January 2023 to assess the uranium content and heavy elements (Ni, Cu, Cd, and Pb). The participant was then asked for personal information, which included a questionnaire about their medical history in addition to some general information like age, gender, blood pressure, and smoking habits. Five millimeters of venous blood were taken by venipuncture, using a disposable needle and a plastic syringe. after, it was put inside a vacuum tube with gel without anticoagulant and left at room temperature for 10 min until the blood clots. The centrifuge was used to separate the serum at 6000 revolutions per minute for 10 minutes (17), and then the serum samples were separated into two parts. The first part was put in new test tubes labeled with specific symbols and stored at a temperature of 20 °C (18) to estimate heavy elements in the current investigation. The second part was placed in test tubes with a nuclear track detector for solid-state (CR-39) in the refrigerator for 90 days to determine the uranium content (19). Half a milliliter of blood serum was placed in a plastic container measuring 10 cm in length and 1.5 cm in diameter (18). A CR-39 detector (500µm) (made by Pershore Molding LTD, United Kingdom) with an approximate area ($1x1cm^2$) was placed in the serum samples and left for 90 days (19) as shown in **Figure 1**

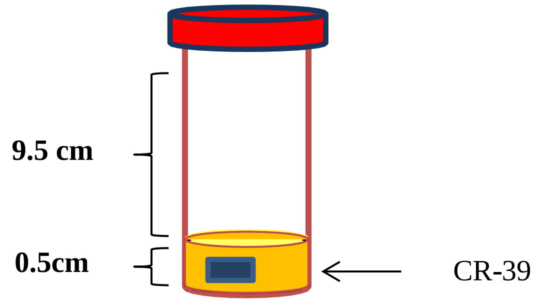

Figure 1. CR-39 in serum sample.

After 90 days of radiation exposure, a chemical etching process was conducted on the detectors using a sodium hydroxide solution (NaOH) with a concentration of (6.25 N), obtained by dissolving 250 g of sodium hydroxide pellets in 1 liter of distilled water. The concentration is calculated from Equation (1) (20).

$$W = N \times V \times W_{eq} \quad (1)$$

N= Normality=6.25
V= Volume of distilled water in 1 liter
W_{eq} = Equivalent weight of NaOH =40 g
W= Weight of NaOH= 250g

All detector pieces were placed in a 5 ml tube containing the etching solution and heated in a water bath (LABSCO, Germany) for 5 hours at 60°C. After the etching period, the detector pieces were removed, washed with distilled water, and dried at room temperature, and then counted per unit area using a light microscope (NOVEL, China) with a magnification power of 400 X to calculate the track density using Equation (2) (21).

$$\rho = \frac{N}{(A \times T)} \quad (2)$$

ρ is the track density (tracks $/cm^2$. h). N is the average number of tracks. A is the area of the field view (cm^2). T is the irradiance time (h).
The fitting equation that results from the calibration curve depicted in **Figure 2** can be used to determine the uranium concentration (Uc) in the blood sample (3):

$$Uc = (\rho + 12.5) / 18.6 \quad (3)$$

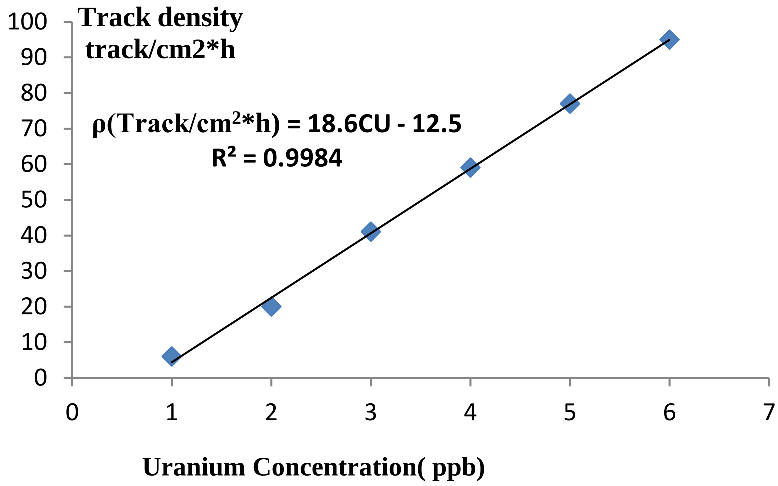

Figure 2. Curve of calibration for standard uranium (ppb)(3).

Quantities of various heavy elements, including Pb, Cd, Ni, and Cu, in liquid samples are determined using Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES). This method involves atomizing a liquid sample into atoms capable of absorbing energy to transfer electrons from the ground state to the excited state. The heat emitted by argon plasma, reaching its very height, serves as the energy source in this process. When electrons return from a higher energy level to a lower energy level, they emit light of a specific wavelength that identifies the element present in the sample (22). As for calculating the concentrations of heavy metals (Pb, Cd, Ni, and Cu), sixty blood serum samples from the same individuals were transferred from the refrigerated box to the Central Laboratory Directorate of the Atomic Energy Commission for the estimation of heavy elements using Inductively Coupled Plasma – Optical Emission Spectrometers (ICP-OES). Before the metal analysis, each sample (1 mL of serum) was individually digested with 4 mL of nitric acid (69%) and 2 mL of H_2O_2 (35%). Subsequently, the samples were sealed and placed in a microwave for 35 minutes at 180°C and 90 bar pressure. At the end of the digestion process, all samples were removed from the microwave and left to cool. Following this, the sample was filtered (0.45 micrometers) and transferred to a (25 mL) volumetric flask. Finally, the solution was ready for reading using ICP-OES(23). The ICP-OES used in our study from Agilent sps4 Auto Sampler Corporation, European Union (2021) was operated under suitable conditions, including choosing the suitable wavelength for each element (Pb) 220.353 nm, (Cd) 214.439 nm, (Ni) 221.647 nm, and (Cu) 324.754 nm with a nebulizer argon flow rate of 0.4 L/min, an auxiliary argon flow rate of 0.6 L/min, a plasma argon flow rate of 12 L/min, integration time of 100s, a read delay of 20 s, and a peristaltic pump flow rate of 1 mL/min.

3.Results

Table 1 shows the levels of uranium and heavy elements in blood samples taken from residents of the Ishtar village. Uranium concentrations ranged from 0.404 µg/L in sample B_3 to 0.752 µg/L in sample B_7, with an average of 0.583±0.025 µg/L. Pb concentrations ranged from 0.019 ppm in sample B_6 to 0.168 ppm in sample B_{11}, with an average of 0.073±0.010 ppm. Cd concentrations ranged from ND to 0.052 ppm in sample B_5, with an average of 0.015±0.004 ppm. Ni concentrations ranged from 0.014 ppm in sample B_{10} to 0.136 ppm in sample B_1, with an average of 0.038±0.008 ppm. Cu concentrations ranged from 0.012 ppm in sample B_{12} to 0.461 ppm in sample B_{11}, with an average of 0.135±0.030 ppm.

Table 1. Levels of uranium concentration and heavy elements concentration in blood samples taken from residents of Ishtar village.

Symbol code	Age (years)	Gender	U conc. (µg/L)	Heavy element conc. (ppm)			
				Pb	**Cd**	**Ni**	**Cu**
B_1	34	Male	0.463	0.078	0.031	0.136	**0.079**
B_2	38	Female	0.549	0.048	0.023	0.037	**0.019**
B_3	20	Male	0.404	0.071	0.004	0.043	**0.154**
B_4	47	Male	0.580	0.097	0.006	0.022	**0.222**
B_5	48	Male	0.528	0.112	0.052	0.017	**0.197**
B_6	29	Male	0.491	0.019	ND	0.047	**0.031**
B_7	35	Female	0.752	0.036	0.043	0.086	**0.185**
B_8	46	Female	0.708	0.083	ND	0.018	**0.016**
B_9	27	Male	0.629	0.027	0.003	0.024	**0.132**
B_{10}	43	Female	0.571	0.045	ND	0.014	**0.077**
B_{11}	55	Male	0.647	0.168	ND	0.037	**0.461**
B_{12}	25	Female	0.658	0.025	0.002	0.027	**0.012**
B_{13}	57	Male	0.671	0.119	0.034	0.032	**0.233**
B_{14}	44	Male	0.481	0.082	ND	0.018	**0.125**
B_{15}	36	Male	0.625	0.089	0.032	0.019	**0.079**
Min			**0.404**	**0.019**	**ND**	**0.014**	**0.012**
Max			**0.752**	**0.168**	**0.052**	**0.136**	**0.461**
Ave			**0.583±0.025**	**0.073±0.010**	**0.015±0.004**	**0.038±0.008**	**0.135±0.030**
Accepted limit			**0.5**	**>0.1**	**<0.005**	**……**	**……..**

Table 2 illustrates the levels of uranium and heavy elements in blood samples taken from residents of the Jeser Diyala. Uranium concentrations ranged from 0.282 µg/L in sample B_{23} to 0.913 µg/L in sample B_{29}, with an average of 0.546±0.044 µg/L. Pb concentrations ranged from 0.018 ppm in sample B_{22} to 0.149 ppm in sample B_{24}, with an average of 0.081±0.009 ppm. Cd concentrations ranged from ND to 0.047 ppm in sample B_{21}, with an average of 0.016±0.004 ppm. Ni concentrations ranged from 0.013 ppm in sample B_{29} to 0.095 ppm in sample B_{18}, with an average of 0.031±0.006 ppm. Cu concentrations ranged from 0.015 ppm in sample B_{30} to 0.472 ppm in sample B_{25}, with an average of 0.168±0.033 ppm.

Table 2. Levels of uranium concentration and heavy elements concentration in blood samples taken from residents of Jeser Diyala.

Symbol code	Age (years)	Gender	U conc. (µg/L)	Heavy element conc. (ppm)			
				Pb	**Cd**	**Ni**	**Cu**
B_{16}	51	Female	0.561	0.099	0.018	0.024	**0.465**
B_{17}	26	Female	0.520	0.053	ND	0.022	**0.104**
B_{18}	50	Female	0.733	0.138	0.035	0.095	**0.145**
B_{19}	31	Male	0.691	0.056	ND	0.013	**0.161**
B_{20}	39	Male	0.587	0.041	ND	0.017	**0.071**
B_{21}	42	Male	0.421	0.095	0.047	0.016	**0.150**
B_{22}	52	Male	0.625	0.018	ND	0.021	**0.144**
B_{23}	34	Female	0.282	0.081	0.012	0.086	**0.125**
B_{24}	58	Male	0.544	0.149	0.023	0.034	**0.179**
B_{25}	54	Male	0.575	0.143	0.046	0.029	**0.472**
B_{26}	37	Male	0.662	0.083	ND	0.016	**0.112**
B_{27}	28	Male	0.329	0.066	0.003	0.033	**0.128**
B_{28}	31	Female	0.298	0.057	0.031	0.015	**0.114**
B_{29}	45	Female	0.913	0.081	0.014	0.013	**0.145**
B_{30}	28	Female	0.448	0.051	0.016	0.035	**0.015**
Min			**0.282**	**0.018**	**ND**	**0.013**	**0.015**
Max			**0.913**	**0.149**	**0.047**	**0.095**	**0.472**
Ave			**0.546±0.044**	**0.081±0.009**	**0.016±0.004**	**0.031±0.006**	**0.168±0.033**
Accepted limit			**0.5**	**>0.1**	**<0.005**	**…….**	**…….**

Table 3 shows the levels of uranium and heavy elements in blood samples taken from residents of the AL-Wardiya. Uranium concentrations ranged from 0.275µg/L in sample B_{34} to 0.931µg/L in sample B_{43}, with an average of 0.439±0.054µg/L. Pb concentrations ranged from 0.008 ppm in sample B_{34} to 0.109 ppm in sample B_{32}, with an average of 0.072±0.007 ppm. Cd concentrations ranged from ND to 0.073 ppm in sample B_{43}, with an average of 0.019±0.005 ppm. Ni concentrations ranged from 0.011 ppm in sample B_{45} to 0.086 ppm in sample B_{41}, with an average of 0.029±0.004 ppm. Cu concentrations ranged from 0.011 ppm in sample B_{43} to 0.413 ppm in sample B_{41}, with an average of 0.141±0.031 ppm.

Table 3. Levels of uranium concentration and heavy elements concentration in blood samples taken from residents of AL-Wardiya.

Symbol code	Age (years)	Gender	U conc. (µg/L)	Heavy element conc. (ppm)			
				Pb	**Cd**	**Ni**	**Cu**
B_{31}	57	Female	0.632	0.096	0.022	0.017	**0.404**
B_{32}	58	Male	0.416	0.109	0.030	0.029	**0.155**
B_{33}	30	Male	0.321	0.061	0.017	0.042	**0.177**
B_{34}	24	Female	0.275	0.008	0.001	0.032	**0.148**
B_{35}	41	Male	0.314	0.099	0.014	0.013	**0.021**
B_{36}	55	Female	0.326	0.088	ND	0.024	**0.068**
B_{37}	23	Female	0.456	0.054	ND	0.022	**0.121**
B_{38}	34	Female	0.332	0.066	0.023	0.045	**0.132**
B_{39}	29	Female	0.290	0.028	0.013	0.035	**0.015**
B_{40}	53	Male	0.341	0.106	0.016	0.024	**0.157**
B_{41}	44	Male	0.325	0.101	0.053	0.086	**0.413**
B_{42}	39	Male	0.902	0.081	ND	0.016	**0.147**
B_{43}	27	Male	0.931	0.057	0.073	0.038	**0.011**
B_{44}	39	Female	0.336	0.074	0.014	0.011	**0.063**
B_{45}	34	Female	0.395	0.063	0.003	0.011	**0.091**
Min			**0.275**	**0.008**	**ND**	**0.011**	**0.011**
Max			**0.931**	**0.109**	**0.073**	**0.086**	**0.413**
Ave			**0.439±0.054**	**0.072±0.007**	**0.019±0.005**	**0.029±0.004**	**0.141±0.031**
Accepted limit			**0.5**	**>0.1**	**<0.005**	**……..**	**…….**

Table 4 shows the levels of uranium and heavy elements in blood samples taken from residents of the Tameem. Uranium concentrations ranged from 0.161µg/L in sample B_{59} to 0.942µg/L in sample B_{53}, with an average of 0.390±0.042µg/L. Pb concentrations ranged from 0.038 ppm in sample B_{54} to 0.127 ppm in sample B_{48}, with an average of 0.084±0.007 ppm. Cd concentrations ranged from ND to 0.072 ppm in sample B_{59}, with an average of 0.026±0.06 ppm. Ni concentrations ranged from 0.015 ppm in sample B_{46} to 0.079 ppm in sample B_{47}, with an average of 0.032±0.004 ppm. Cu concentrations ranged from 0.019 ppm in sample B_{51} to 0.410 ppm in sample B_{47}, with an average of 0.115±0.025 ppm.

Table 4. Levels of uranium concentration and heavy elements concentration in blood samples taken from residents of Tameem.

Symbol code	Age (years)	Gender	U conc. (µg/L)	Heavy element conc. (ppm) Pb	Cd	Ni	Cu
B_{46}	33	Male	0.347	0.057	ND	0.015	0.024
B_{47}	42	Female	0.349	0.121	0.029	0.079	0.410
B_{48}	36	Female	0.327	0.127	0.057	0.045	0.021
B_{49}	45	Male	0.329	0.098	0.058	0.016	0.042
B_{50}	23	Female	0.320	0.056	ND	0.035	0.133
B_{51}	30	Male	0.407	0.049	0.027	0.045	0.019
B_{52}	32	Male	0.341	0.086	ND	0.019	0.132
B_{53}	55	Female	0.942	0.102	0.039	0.024	0.174
B_{54}	40	Male	0.360	0.038	0.030	0.019	0.094
B_{55}	52	Female	0.375	0.094	0.015	0.025	0.128
B_{56}	56	Female	0.417	0.085	0.021	0.022	0.104
B_{57}	60	Male	0.370	0.113	0.033	0.023	0.154
B_{58}	38	Male	0.450	0.097	ND	0.055	0.054
B_{59}	21	Female	0.161	0.045	0.072	0.032	0.057
B_{60}	59	Male	0.355	0.099	0.013	0.021	0.188
	Min		**0.161**	**0.038**	**ND**	**0.015**	**0.019**
	Max		**0.942**	**0.127**	**0.072**	**0.079**	**0.410**
	Ave		**0.390±0.042**	**0.084±0.007**	**0.026±0.006**	**0.032±0.004**	**0.115±0.025**
	Accepted limit		**0.5**	**>0.1**	**<0.005**	**……**	**……**

4. Discussion

Based on the results obtained, it was found that the Ishtar village and Jeser Diyala have the highest concentration of uranium in blood samples, exceeding the permissible limit set by the World Health Organization (WHO), which is 0.5 µg/L (24).

The elevated uranium concentration in Ishtar and Jeser Diyala is due to its proximity to the Atomic Energy Organization, which housed numerous laboratories and storage facilities containing a lot of equipment and hundreds of containers of radioactive materials that were looted in April 2003. Containers of radioactive materials were poured into farms, rivers, and even household drains. Some empty containers were used as water vessels, and the individuals involved were unaware of the consequences of their actions (25).The scientist Tully, specializing in radiation, who visited Tuwaitha and its surroundings as part of the Greenpeace team, conducted field radiation measurements. She announced that people in areas close to the Atomic Energy Organization receive radiation within half an hour, equivalent to the maximum limit a person receives in a year, exposing them to significant risks of cancer and other diseases. Scientist Tully found radioactive contamination in one of the houses there that exceeded the permissible limit by more than 10,000 times (25).

Regarding gender, the findings indicated that males had higher uranium concentrations than females, as shown in **Figure 3**, most likely because females have a total blood volume of 4–5 liters as opposed to males 5–6 liters (26). However, statistical analysis demonstrated that there was no discernible variation in the amounts of uranium concentration between males and females. (P>0.01).

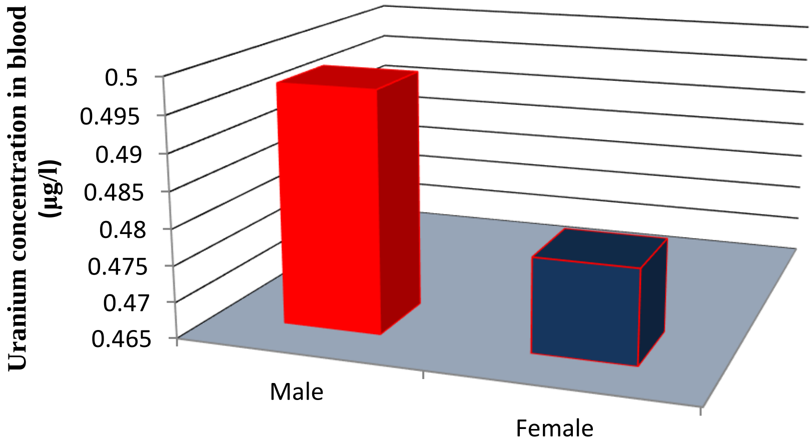

Figure3. Comparison of uranium concentration in terms of gender.

The blood samples from the research sites showed a weak positive relationship between age and uranium concentration (**Figure 4**). Food consumption and advancing age may be the reasons behind the accumulation of uranium in the body, which increases with exposure duration. Long-term effects may emerge due to continuous exposure to low levels of uranium over an extended period, including genetic effects and other impacts (27).

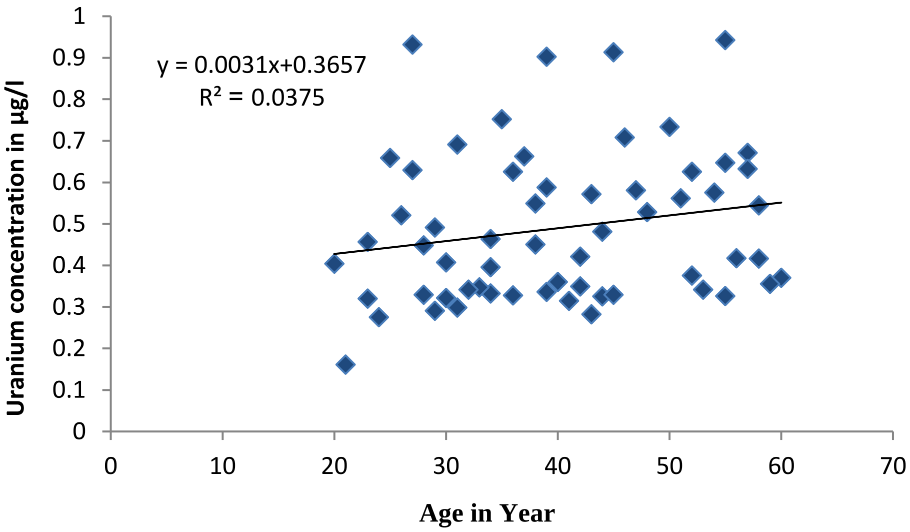

Figure 4. Relationship between age and uranium concentration in blood.

Many local and international studies have been conducted. The uranium content in blood samples of healthy individuals was found to be 0.28-0.83µg/L in Baghdad (28), 0.30-1.59µg/L in Babil, 0.91-2.15µg/L in Basra, 0.86-2.1µg/L in Thi-Qar, 0.92-2.029µg/L in Muthanna (29), and 0.032-0.202µg/L in Najaf (30). In Yugoslavia, uranium levels in blood samples from healthy persons were 0.005 µg/L. Factors such as sampling methods and analytical factors may contribute to the variations in the reported data regarding uranium concentration in blood samples (31).In this study, we also conducted an assessment of heavy metal (Pb, Cd, Ni, and Cu) pollution levels by collecting and analyzing 60 blood samples from the same individuals in the study areas using ICP-OES. The Tameem area had the highest Pb and Cd values. Emissions from vehicles using leaded gasoline, which is still used in many Middle Eastern countries, including Iraq, cause lead pollution. These findings align with those of another researcher in another country (32).The highest concentration of Ni was found in the village of Ishtar, and Cu was found in the Diyala Bridge area. This is attributed to the proximity of these two areas to the power generation station (such as the Egsyba station), which operates continuously, releasing gases and vapors into the surrounding areas around the clock. The results did not show any statistical significance in the average concentrations of heavy elements among the study areas.The average levels of heavy metals in blood samples from male and female subjects are shown in **Figure 5.** The average concentrations of heavy elements (Pb, Cd, and Cu) for males are higher than those for females, which may be attributed to working in various occupations (33).

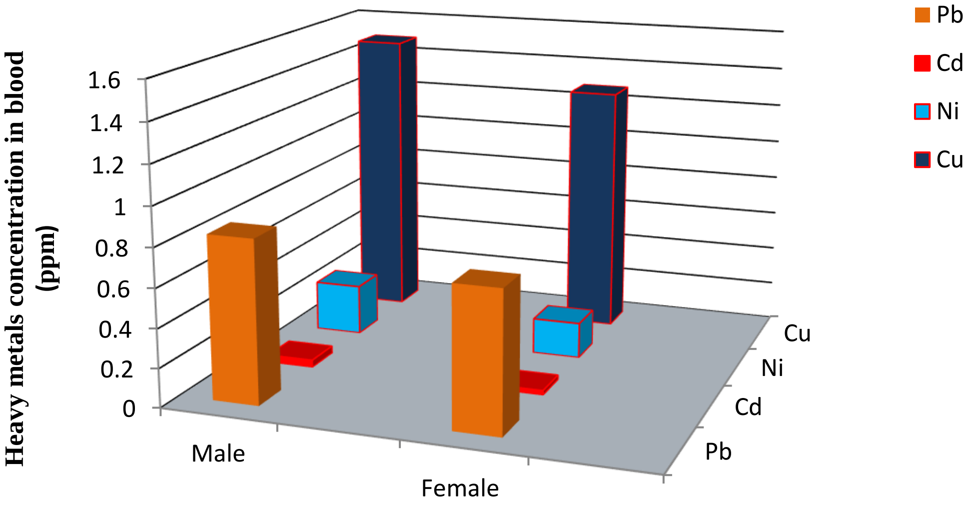

Figure5. Comparison of the concentration of heavy elements by gender.

The highest concentrations of Pb and Cu were found in the age group 51-60 years, the highest concentration of cadmium was found in the age group 31-40 years, and nickel in the age group 20-30 years as shown in **Figure 6**. The reasons for these differences in heavy metal concentrations may be attributed to variations in exposure through inhaling dust and emissions from vehicles, which can increase the emissions of heavy metals in certain areas (34).

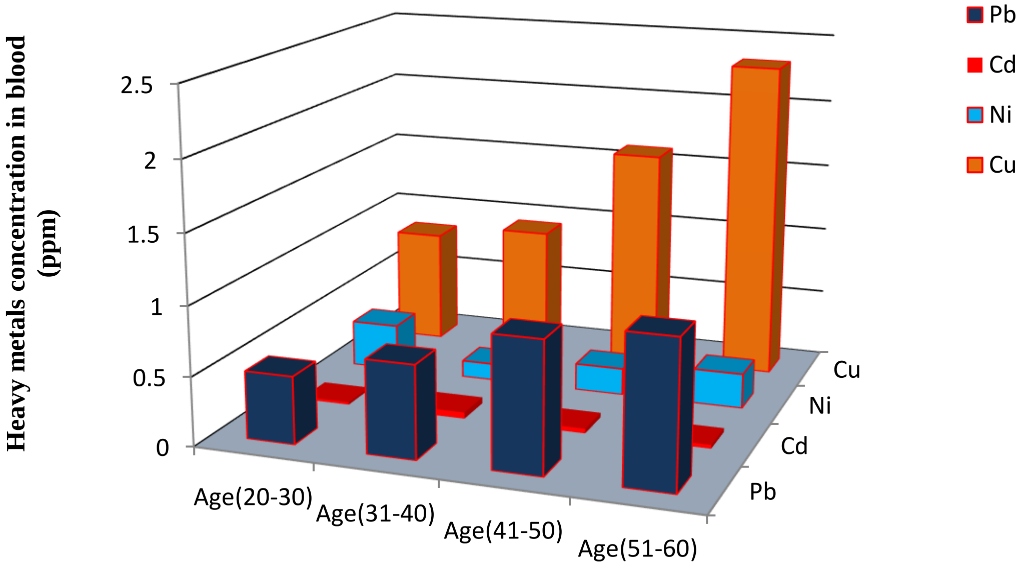

Figure 6. Comparison of the concentration of heavy elements by age.

The Pearson correlation between heavy metals is shown in **Table 5**. A weak correlation was found between Cu and Cd, Ni and Cu, Pb and Cd, and Pb and Ni. On the other hand, a moderate positive correlation was found between Pb and Cu.

Table 5. Correlation coefficient between Heavy element conc.

Parameters	Correlation coefficient-r	
	Correlation coefficient-r	**P-value**
Pb & Cd	0.30 *	0.021
Pb & Ni	0.11 NS	0.416
Pb & Cu	0.53 **	0.0001
Cd & Ni	0.27 *	0.042
Cd & Cu	0.11 NS	0.417
Ni & Cu	0.14 NS	0.298

* ($P \leq 0.05$), ** ($P \leq 0.01$), NS: Non-Significant.

Table 6. Comparison of previous studies of heavy metals(ppm) with this study in blood.

Country	Pb	Cd	Ni	Cu	Reference
Iraq(Diwanya)	0.0898±0.0008	0.0432±0.0060	………	0.1729±0.0004	(35)
Iraq(Najaf)	0.06	…….	…….	1.61	(36)
Iraq(Erbil)	6.67±0.26	1.39±0.04	2.04±0.08	…….	(33)
Jordan	……..	0.0245	0.02059	0.0067	(38)
Egypt	………	0.00328	……..	0.05032	(39)
Baghdad(Ishtar)	0.073±0.010	0.015±0.004	0.038±0.008	0.135±0.030	Present study
Baghdad(Jeser Diyala)	0.081±0.009	0.016±0.004	0.031±0.006	0.168±0.033	
Baghdad(AL-Wardiya	0.072±0.007	0.019±0.005	0.029±0.004	0.141±0.031	
Baghdad(Tameem)	0.084±0.007	0.026±0.006	0.032±0.004	0.115±0.025	

5. Conclusion

This study assessed the amounts of heavy metals and uranium in blood samples taken from 60 people living in four areas (Ishtar, Jeser Diyala, AL-Wardiya, and Tameem) near the Iraqi Atomic Energy Organization. The results of this investigation showed that the uranium concentration in the village of Ishtar and the Jeser Diyala area is higher than the acceptable limit set by the World Health Organization (WHO), which is 0.5µg/L. The high levels of uranium in these areas pose a danger to the public's health and safety. The increase in uranium concentration in blood samples can be attributed to several possible reasons, including water pollution, food type, inhaling polluted air, and living near nuclear test sites, which expose individuals to internal and external radiation.

The Iraqi Atomic Energy Organization in Baghdad can be considered a highly radioactive pollution site with a higher average dose than other areas, as it was heavily bombed during the wars in 1991 and 2003. Furthermore, we noticed that the highest concentrations of Pb and Cd was in the Tameem area, while the highest concentration of Ni was in the village of Ishtar and Cu in the Diyala Jeser area. The elevated concentrations of these elements in residential areas are attributed to pollution from vehicle emissions, sewage water, and solid waste. This leads to transferring these elements to humans and accumulating them in body tissues. To identify the possible causes, additional environmental and epidemiological research is desperately needed.

Acknowledgment

We thank the Ministry of Sciences and Technology/ Directorate of Central Laboratories in Al-Tuwaitha for your cooperation with us.

Conflict of Interest

There is no conflict of interest.

Funding

The article is not supported financially.

Ethical Clearance

The samples were obtained with the approval of the Municipal Council in Madain.

References

1. Mushtaq Z, Sharma M, Bangotra P, Gautam AS, Gautam S. Atmospheric aerosols: some highlights and highlighters, past to recent years. Aerosol Sci Eng. 2022;6:135–45. https://doi.org/10.1007/s41810-022-00133-w
2. Razzaq DF, Saleh DS, Al-Mashhadani AH. Studying the uranium pollution in reduction the levels of the C-Peptide and Vitamin D for healthy and diabetic patients in Najaf City Iraq. In: AIP Conference Proceedings. 2020;2290:030038. https://doi.org/10.1063/5.0027502
3. Abbas SK, Hussain HS, Saleh DS. Estimation of uranium concentration in urine samples of three age groups of healthy individuals in Najaf Governorate using CR-39 and LR-115 solid state detectors. Iraqi J Sci. 2022;63(8):3359–65.https://doi.org/10.24996/ijs.2022.63.8.11.
4. Hussein ZA. Assessment of natural radioactivity levels and radiation hazards for soil samples used in Erbil governorate, Iraqi Kurdistan. ARO-The Sci J Koya Univ. 2019;7(1):34–9. https://doi.org/10.14500/aro.10471.
5. Thorne MC. Background radiation: natural and man-made. J Radiol Prot. 2003;23(1):29–42. https://doi.org/10.1088/0952-4746/23/1/302.
6. Hussein ZA. Assessment of natural radioactivity levels and radiation hazards for soil samples used in Erbil governorate, Iraqi Kurdistan. ARO-The Sci J Koya Univ. 2019;7(1):34–9. https://doi.org/10.14500/aro.10471.
7. Thorne MC. Background radiation: natural and man-made. J Radiol Prot. 2003;23(1):29–42. https://doi.org/10.1088/0952-4746/23/1/302.
8. Shafik SS. Study and measurements of the uranium and amorphous crystals concentrations in urine samples of breast cancer female patients. Iraqi J Phys. 2014;12(25):113–22. https://doi.org/10.30723/ijp.v12i25.311.
9. Basu D, Kulkarni R. Overview of blood components and their preparation. Indian J Anaesth. 2014;58(5):529–37. https://doi.org/10.4103/0019-5049.144647.
10. Buxton S, Garman E, Heim KE, Lyons-Darden T, Schlekat CE, Taylor MD, Oller AR. Concise review of nickel human health toxicology and ecotoxicology. Inorganics. 2019;7(7):89. https://doi.org/10.3390/ijerph17030679.
11. Saleh DS, Al-Mashhadani AH, Razzaq DF. Estimate the toxic elements: cadmium and lead in serum of diabetics and healthy peoples in Najaf city. In: AIP Conference Proceedings. 2021;2372:1.
12. Aladdin D, Ismail AH, Taha AH, Hussein ZA. Evaluation of the trace element concentration in some livestock and poultry bone samples using X-ray fluorescence. ZANCO J Pure Appl Sci. 2022;34(4):67–73 https://doi.org/:10.21271/ZJPAS.34.4.7.
13. Ghorani-Azam A, Riahi-Zanjani B, Balali-Mood M. Effects of air pollution on human health and practical measures for prevention in Iran. J Res Med Sci. 2016;21(1):65. https://doi.org/10.1080/26395940.2023.2173657.

14. Lee JM, Suh JS, Kim YK. Red Blood Cell Deformability and Distribution Width in Patients with Hematologic Neoplasms. Clin Lab. 2022;68:10. https://doi.org/10.7754/clin.lab.2022.211260.
15. Ismail AH, Hussein ZA, Yaba SP. Investigation a relation between radioactivity concentrations of 40 Potassium (40K) in tooth and the various ethnic groups and its impacts on the rate of tooth damage. Environ Nanotechnology Monit Manag. 2020;14:100385. https://doi.org/10.14500/aro.10736.
16. Abbood SS, Alrekabi AG, Ali AK. Cytogenetic Evaluation of Micronucleus and Nuclear Division Index in Peripheral Blood Lymphocytes of Al-Tuwaitha Region, Iraq. Appl Phys. 2022;12:410–5.
17. Nassif WG, Wahab BI, Al-Jiboori MH, Ali AB. Temporal and spatial analysis of alpha and beta activity concentration at Al-Tuwaitha Site, Baghdad. Nat Environ Pollut Technol. 2020;19(4):1499-1505.https://doi.org/10.46488/NEPT.2020.v19i04.016.
18. Ahmed RS. The concentration of radioactive materials in Iraqi soils, water and plants: A review. J Radiat Res Appl Sci. 2022;15(1):245-256.https://doi.org/10.1016/j.jrras.2022.03.012.
19. Dacie JV. Dacie and Lewis practical hematology. 23rd ed. Elsevier Health Sciences; 2006.
20. Rodak BF, Keohane EM, Fritsma GA. Hematology-E-Book: Clinical Principles and Applications. 2nd ed. Elsevier Health Sciences; 2013.
21. Hassan A, Mohsen AAH, Zahed H, Abojassim AA. Determination of alpha particles levels in blood samples of cancer patients at Karbala Governorate, Iraq. Iran J Med Phys. 2019;16(1):41-47. https://doi.org/10.22038/ijmp.2018.32376.1383.
22. Al-Nia'emi SHS, Kasim YY. Determination of the Bulk etch rate of the nuclear track detector CR-39 using Le-D method. Jordan for Physics. 2013;6(1):23-45.
23. Otansev P, Erduran N. Determination of uranium and thorium concentrations in sediment samples by using solid state nuclear track detectors. Appl Radiat Isot. 2021;172:109652. https://doi.org/10.1016/j.apradiso.2021.109652.
24. Khan KF. Application, principle and operation of ICP-OES in pharmaceutical analysis. J Pharm Innov. 2019;8:281-282.
25. Alrobaian M, Arida H. Assessment of heavy and toxic metals in the blood and hair of Saudi Arabia smokers using modern analytical techniques. Int J Anal Chem. 2019;21:234. https://doi.org/10.1155/2019/7125210.
26. World Health Organization. Depleted uranium sources, exposure, and health
27. Rasheed NH. The spatial distribution for the radiation pollution in Iraq. J Hum Res. 2013;57:12-23.
28. Aziz AA, Majed FM, Tawfiq NF. Determination of uranium concentration in blood samples for patients with kidney failure in Salah Din Governorate. In: IOP Conference Series: Earth and Environmental Science. 2021;8771:012010. https://doi.org/10.1088/1755-1315/877/1/012010.
29. Urone PP. Physics with health science applications. 1985;512.
30. Al-Hamzawi AA, Jaafar MS, Tawfiq NF. The measurements of uranium concentration in human blood in selected regions in Iraq using CR-39 track detector. In: Advanced Materials Research. 2014;925:679-683 https://doi.org/10.4028/www.scientific.net/AMR.925.679.
31. Al-Hamzawi AA, Jaafar MS, Tawfiq NF. Concentration of uranium in human cancerous tissues of Southern Iraqi patients using fission track analysis. J Radioanal Nucl Chem. 2015;303:1703-9 https://doi.org/10.1007/s10967-014-3682-0.
32. Abdulwahid TA, Alsabari IK, Abojassim AA, Mraity HA, Hassan AB. Assessment of concentrations of alpha emitters in cancer patients blood samples. Sylwan. 2020;164(3):154-64.
33. Byrne AR, Benedik L. Uranium content of blood, urine and hair of exposed and non-exposed persons determined by radiochemical neutron activation analysis, with emphasis on quality control. Sci Total Environ. 1991;107:143-57.
34. Stojsavljević A, Vujotić L, Rovčanin B, Borković-Mitić S, Gavrović-Jankulović M, Manojlović D. Assessment of trace metal alterations in the blood, cerebrospinal fluid and tissue samples of patients with malignant brain tumors. Sci Rep. 2020;10(1):3816. https://doi.org/10.1038/s41598-020-60774-0.

35. bboud AH, Almayahi BA. Relationship between heavy metals and alpha emission rates in breast milk and blood of women. Heliyon. 2021;7(3):34-45. https://doi.org/10.1016/j.heliyon.2021.e06590.
36. Al-Shamri A. Determination of lead, copper, iron, and zinc in blood of fuel station workers at Al-Najaf City. J. al-Qadisiyah Pure Sci. 2010;10(4):80-89.
37. Massadeh A, Gharibeh A, Omari K, Al-Momani I, Alomari A, Tumah H, Hayajneh W. Simultaneous determination of Cd, Pb, Cu, Zn, and Se in human blood of Jordanian smokers by ICP-OES. Biol. Trace Elem. Res. 2010;133:1-11. https://doi.org/10.1007/s12011-009-8405-y.
38. Li J, Cen D, Huang D, Li X, Xu J, Fu S, Zheng J. Detection and analysis of 12 heavy metals in blood and hair samples from a general population of the Pearl River Delta area. Cell Biochem. Biophys. 2014;70:1663-1669. https://doi.org/10.1007/s12013-014-0110-6.
39. Motawei SM, Gouda HE. Screening of blood levels of mercury, cadmium, and copper in pregnant women in Dakahlia, Egypt: new attention to an old problem. Biol. Trace Elem. Res. 2016;171:308-314. https://doi.org/10.1007/s12011-015-0525-y