Relationship between heavy metals and alpha emission rates in breast milk and blood of women

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ABSTRACT
Background: The current study determines the relationship between heavy metals and alpha particles emission rates in milk and blood of lactating women in Diwanyah, Iraq.
Methods: Heavy metals and alpha particle emission rates have been measured using an Atomic Absorption Spectrophotometer and a Nuclear Track Detector.
Results: The results show that Pb, Cd, and Cu in milk are $0.2239 \pm 0.0007$ ppm, $0.0156 \pm 0.0001$ ppm, and $0.1811 \pm 0.0006$ ppm, respectively. Pb, Cd, and Cu in the blood were $0.0898 \pm 0.0008$ ppm, $0.0432 \pm 0.0010$ ppm, and $0.1729 \pm 0.0004$ ppm, respectively. The highest alpha particle emission rate was found to be in age interval from 23 y to 28 y in milk, while the highest alpha particle emission rate was found to be in the age interval from 35 y to 40 y.
Conclusions: This study concludes that no statistical significance between Pb, Cd, Cu and \( E_{\alpha} \) in milk and blood at level 0.01. The following order of bioavailability was found with heavy metals Cu $<$ Pb $<$ Cd.

1. Introduction

Heavy metals are one of the problems that have received widespread attention around the world. The importance of the toxic effects of these minerals lies in non-biodegradable, and it is found in low concentrations [1]. The World Health Organization (WHO) has indicated the limits of these metals in biomarkers such as blood and milk, but most studies are recorded levels higher than the permissible limits of these toxic metals in different countries such as Nigeria, China, and Egypt [2, 3, 4]. Which is the way to some undesirable elements such as lead, cadmium [5], then these minerals reach the other body tissues and organs such as the liver, kidneys, and milk [6, 7]. Human breast milk is essential for children and newborns because of its nutritional value as it contains carbohydrates, proteins, fats, and some of the necessary heavy elements for the growth of children and the performance of various functions of tissues and organs [8, 9]. These minerals transferred from the mother to the infants through breastfeeding [10]. It has many harmful health effects, such as increasing lead damage to the central nervous system, brain disruption, and blood disorders in mammals, kidney damage, reproductive failure while cadmium and copper cause cancer, osteoporosis, and irritation [11, 12]. The concentration of some heavy metals in breast milk and blood has been found using atomic absorption spectroscopy [13, 14, 15]. This source produced by the bombardment of nuclei of stable isotopes with other types of nuclear particles [16]. In addition to these sources, the human body contains the sources of internal nuclear particles such as potassium-40, carbon-14, lead-210, and other radioactive particles inside the body from birth [17]. The decomposition of radionuclides such as uranium, radium, and depleted uranium results from uranium. It emits alpha particles when analyzed then enter the human body through breathing or digestion, which is a common pathway to enter these particles into the body [18, 19, 20, 21]. Alpha particles are a dangerous type of ionizing radiation, which is harmful to human tissues because of their more density and high charge [21]. When these particles enter the human body, they are transferred to other organs through the blood, which is the way to pass and sedimentation of these particles in organs such as bones, teeth, and milk [22]. The risk of human exposure to alpha particles in many effects cannot be ignored, as these effects are divided into two parts, one of the acute effects. Which are manifested when exposure to large doses of radiation and for a short time in all organs and systems of the body and other delayed effects that result from exposure to low doses of radiation and long periods that result in satisfactory symptoms such as leukemia, breast cancer, thyroid cancer, shortage, and unwanted mutations of humans [23]. Some literature reviews were...
shown radionuclide concentrations in blood and breast milk using CR-39 detectors [24, 25, 26, 27, 28].

2. Study area

Diwaniyah governorate is located in the south of Iraq and the Euphrates region of the Middle and a branch of the Euphrates River passes through it, which is called the Diwaniyah River. The population of the city is 1,320,000 people, according to the 2014 census [29]. The city of Diwaniyah is located between two latitudes 31. 17, 32.24 North and longitudes 44.24, 45.49 East. It has four districts, and ten administrative units at the level of the city, as follows Diwaniyah district, which includes the center of Diwaniyah district, Dagra, Sannia, and Shafeia, while Afak district includes the center of Afak, Sumer, and Albadir. The Shamia district includes the center of the district of Shamia, Ghammas, Mahna-wia, and Al salathia. While, Hamzah district includes the center of the district of Hamzah, Shinafiyah, and Al sudair. The Babylon city was located at the north of the city and Muthanna in the south, and Dhi Qar cities were located in the east, while the city of Najaf was located at the west. Figure 1 shows the determination of heavy metals and alpha particle emission rates in breast milk and blood of women in Iraq.

3. Materials and methods

Eighty samples (milk and blood) from women with ages from 17 to 41 years (because of the difficulty of getting pregnant and childbearing after 40 years from lactating women). Samples were collected from hospitals and clinics (Women and Children Educational Hospital and Primary Healthcare Center in Imam Sadiq) and Hamiya General Hospital in Shamiya District and Afak General Hospital in Afak district in Diwaniyah governorate from 24/9/2018 to 28/10/2018. This study has approved by the Ethics Committee, University of Kufa. The study protocol was thoroughly explained for using milk and blood samples of women. All patients informed the aims of the work. Blood samples (5 ml) were collected from lactating women using a syringe then it placed in tubes with EDTA (Ethylene Diamine Tetra Acetic Acid). While, the milk samples (5 ml) were collected in sterilized cups using manual pressure after the wash and sterilize the breast by distilled water.

Then, all samples were stored in freezing at a temperature between 2 °C and 6 °C. Samples were transferred from the cool box to the laboratories of the Department of Ecology Sciences at the University of Kufa for the analysis of samples.

The Flame Atomic Absorption Spectrophotometer (FAAS) is a device used to measure various concentrations of heavy metals in liquid samples such as lead, cadmium, and copper. In the FAAS the liquid sample is atomized to convert it to atoms in the case of vapor. When the beam of electromagnetic radiation is passed through the vaporized sample, some of it has absorbed by element atoms. When the number of atoms in the vapor has increased, the absorption of the radiation is increased. The amount of light absorbed was proportioned to the number of element atoms in the sample. The concentration of the unknown element in the sample is determined through a calibration curve [30].

Solid-State Nuclear Track Detectors (SSNTDs) are used to measure the concentration of uranium and alpha particles in the blood, tissue, bone, teeth and breast milk samples [31, 32]. SSNTDs are electrical insulation materials that have a quality resistance ranging from 106 to 1020 Ohm cm. Where they generate narrow paths of radiation known as hidden tracks when the charged particles pass through them, such as alpha particles, protons, and fission matters. These tracks show the type and energy of the falling particle, so they use as detectors for charged particles and neutrons [33]. Detectors are classified into two categories: 1st, the detectors with no carbon and hydrogen elements in their chemical structure, so the atoms of the molecules are connected to ionic bonds such as silica detectors and glass [34]. 2nd the detectors with carbon and hydrogen in their composition, where the atoms of molecules are linked to the covalent bonds dominated by carbon-carbon or carbon-hydrogen and this easy to break when exposed to radiation, such as CR-39 (TAS-TRAK, UK) this detector is named relative to Columbia Risen [35]. This detector is made from liquid monomer polymerization (Allyl Diglycol Carbonate), which contains the general composition of the two groups of Allyl (CH2 = CHCH2) [36].

The detector has a high sensitivity to radiation because of its weak bonds [37]. The molecular formula for CR-39 is C12H18O7. The CR-39 detector is resistant to all chemical solutions, except the strong basics and acids that are oxidative [38]. All materials and tools were placed inside the big container for sterilization using a solution of 950 ml HCl + 9500 ml of distilled water for 2 h [39]. The tools are washed using tap water and deionized water, after that, it dried in the oven at 90 °C for 2 h. All samples were prepared at room temperature of 20 °C. Milk samples (2 ml) are diluted with 1 ml of H2O2 + 2 ml of HNO3 [40] and 10 ml of deionized water. Then, the mixture was completed in 25 ml of deionized water. Blood samples (2 ml) are diluted with 1 ml of H2O2 + 2 ml of HNO3 [40] and 10 ml of deionized water. Then, the mixture is completed with 25 ml of deionized water. All samples were digested to 2 ml using a heating digester (VELP SCIFICA, DK6, Europe) at 200 °C for 1 h.

All samples were cooled at room temperature after the digestion process. The samples have completed by deionized water (50 ml) [41] and filtered with 0.45 μm. Then, it was washed with water and acid [42]. Blood and milk (10 ml for each) were frozen at −20 °C. The heavy metals (Pb, Cd, and Cu) are analyzed using FAAS (PG, AA500, UK) with a wavelength of about 283.3 nm, 326.1 nm, and 327.4 nm, respectively, and lamp current is about 5.0 mA. SSNTDs are to determine the alpha emission rate in milk and blood samples using CR-39 detector (TAS-TRAK, UK) 2 cm × 2 cm. The filter is cute to small pieces with a size of about 2 cm × 2 cm similar in size to the CR-39 detector using a paper cutter. Then, milk and blood samples (0.5 ml) has transferred by syringe to the filter. Then, both of them have placed inside Petri dishes and left for 5 min for saturation.

The samples were dried using heating magnetic stirrer (VELP SCIENTIFICA, ARE, EUROPE) for removing moisture. Blood samples were dried at 40 °C for 5 min and 3 min for milk samples (because milk lighter than blood). The samples were putted with CR-39 detectors and keep it at −20 °C for 150 days. The chemical etchant solution can affect the damaged areas by alpha particles [42]. The chemical etchant solution has prepared by 62.5 gm of NaOH (6.25 N) with 250 ml of distilled water using Eq. (1) [43].

![Figure 1. Study design.](image-url)
Where:

\[ W = \text{Weight of NaOH} = 62.5 \text{ gm} \]
\[ \text{Weq} = \text{Equivalent weight of NaOH} = 40 \text{ gm} \]
\[ N = \text{Normality} = 6.25 \]
\[ V = \text{Volume of distilled water in milliliter} = 250 \text{ ml} \]

After the end of the exposure (150 days), the chemical etching process was conducted by immersing the CR-39 detector by a string in the conical flask containing the chemical etchant solution. Then the solution with the detector CR-39 is heated using a water bath (GFL, 1083, Germany) at 75 °C for 6 h [44], with sealed the conical flask firmly to prevent the evaporation of the solution and change of NaOH concentration. After the end of the chemical etching process, the detectors are washed with tap water and deionized water, then dried with filter paper for 10 min. The tracks of alpha particles are counted in CR-39 detectors using an optical microscope (KRUSS, Optronic, Germany), along with a camera (MDCE-5C) at 10× magnification to show the tracks on the computer using microscope software (DN-2 Microscopy Image Processing System).

The average of the tracks for each detector was calculated. The density of the tracks (\( \rho \)) for each detector was calculated according to Eq. (2):

\[ \rho = \frac{N_{\text{avg}}}{A} \]  

where:

\[ \rho = \text{The density of the tracks (track cm}^{-2} \text{)} \]
\[ N_{\text{avg}} = \text{Average number of total tracks} \]
\[ A = \text{Area of field of view} = 0.026 \text{ cm}^2 \]

The efficiency of CR-39 was found by Eq. (3) [45].

\[ \varepsilon = 1 - \frac{V_b}{V_T} \]  

Where:

\[ \varepsilon = 85\% \]
\[ V_b = \text{Bulk etch rate (} \mu\text{m h}^{-1} \text{)} \]
\[ V_T = \text{Track etch rate (} \mu\text{m h}^{-1} \text{)} \]

The alpha emission rate was calculated using Eq. (4) [45].

\[ E_a = \frac{\varepsilon (\rho_b - \rho_h)}{T} \]  

where:

\[ E_a = \text{The alpha emission rate (Bq cm}^{-2} \text{)} \]
\[ \varepsilon = \text{CR-39 efficiency} \]
\[ \rho_b = \text{Alpha track density of the milk and blood samples} \]
\[ \rho_h = \text{Number of background track in the detector (trackcm}^{-2} \text{)} = 5.688 \]
\[ T = \text{Exposure time (day)} \]

4. Data analysis

The results are analyzed using statistical methods. The average values, standard deviation (SD), maximum and minimum values were calculated using the SPSS program. One-way ANOVA test and Pearson correlation were used to compare the average of heavy metals and alpha particles between the city center and rural areas and age. \( p < 0.05 \) was considered a statistical significance. All samples were analysed using FAAS (PG, AA500, UK). These analyses were repeated to get good results and canceled some anomalous results directly after appearing by the device. Alpha tracks were analyzed using an optical microscope to survey about 76 sites to all CR-39 detector surface to reduce errors and get high quality in the analysis.

5. Results and discussion

This study includes the results of heavy metals and alpha particles emission rate that were obtained from both samples of milk and blood collected from the study area. These results include comparison on the average of heavy metals in milk and blood between the city center and rural areas and age as well as these results include the comparison on the average of alpha particle emission in milk and blood between the city center and rural areas and age, on the other hand, these results include the correlation between the heavy metals and alpha particles emission rates with the discussion of these results. This study also includes the statistical analysis of the results. The value of Pb found to be ranged from 0.027 ppm to 0.187 ppm, average = 0.2234 ± 0.0001. The value of Cd found to be ranged from ND to 0.083 ppm, average = 0.016 ±< 0.001). The value of Cu was ranged from 0.034 ppm to 1.921 ppm, average = 0.181 ± 0.001). The lowest and highest Pb, Cd, and Cu were 0.027 ppm and 0.187 ppm, ND and 0.083 ppm, 0.034 ppm and 1.921 ppm, respectively. The average Cu (0.22) in the city center is higher than Cu (0.13) in rural areas. The results show no statistical significance on the average heavy metals (Pb, Cd, Cu) in milk between the city center and rural areas. The highest Pb (0.75 ± 0.09 ppm) is found in the interval from 29 yr to 34 yr. The results show no statistical significance on the average of heavy metals (Pb, Cd, Cu) and women age in milk.

Table 1 shows the comparison between literature reviews and present studies of heavy metals in milk. This study shows that the average of Pb (0.224 ppm) in milk is higher than Iraq, Germany, Greece, Iran, Australia, Nigeria, Taiwan, China, Poland, Iran, and Turkey, except Saudi Arabia. The average Pb of Pb is found to be higher than the recommended limits by the World Health Organization (WHO) in the milk (0.005 ppm). The average of Cd (0.016 ppm) is lower than Cd Iraq, Germany, Poland, Greece, Iran, Australia, Nigeria, Sweden, China, Taiwan, Poland, and Iran, except Saudi Arabia. The average of Cd is found to be higher than the recommended limits by the World Health Organization (WHO) in the breast milk (0.0001 ppm). The average of Cu (0.18 ppm) is found to be lower than Cu in Poland, Japan, Greece, Nigeria, Sweden, and Turkey, except Poland.

The value of Pb is ranged from 0.049 to 0.164 ppm, average = 0.0898 ± 0.0008. The value of Cd ranges from ND to 0.396 ppm, average = 0.0432 ± 0.0010. The value of Cu ranges from 0.034 to 0.558 ppm, average = 0.1729 ± 0.0004. The lowest and highest Pb, Cd, and Cu were 0.049 ppm and 0.164 ppm, ND and 0.396 ppm, 0.034 ppm and 0.558 ppm. The average Cu (0.192 ppm) in the city center is higher than the average of Cu (0.154 ppm) in rural areas. The results show no statistical significance on the average of heavy metals between city center and rural areas in blood. The highest Pb (0.10 ppm) is found to be in the age interval from 29 to 34 yr, the highest Cd (0.066 ppm) and Cu (0.206 ppm) are found to be in the age interval from 17 to 22 yr. The results show no statistical significance on the average of heavy metals and women age in blood. Table 2 shows the comparison between literature reviews and present studies of heavy metals in the blood. This study shows that the average of Pb (0.09 ppm) is higher than Barazil, Iraq, Korea, Egypt, Germany, and Singapore, except China. In this study, Pb is found to be lower than the recommended limits by WHO in the blood (<0.1). The average of Cd (0.04 ppm) is higher than Cd in Korea, Germany, Singapore, and Egypt. The average Cd was found to be higher than the recommended limits (WHO) in the blood (<0.005). The results show that the average of Cu (0.17 ppm) is lower than Iraq, Egypt, and Singapore, except China.

The highest alpha emission rate is found to be 0.67 mBq cm⁻² (SC280), while the lowest emission rate of alpha is found to be 0.01 mBq cm⁻² (SC161) in milk. The average diameter value of tracks in milk was 9.83 ± 0.68 μm. Generally, the average of alpha emission for milk was
The results show no statistical significance on the average of alpha particle emission between the city center and rural areas. The average alpha particle emission was 0.12, 0.25, 0.19, and 0.22 mBq cm\(^2\) in age intervals 17–22 yr, 23–28 yr, 29–34 yr, and 35–40 yr, respectively (Figure 2). The highest average of alpha particle emission is found to be 0.25 mBq cm\(^2\) in age interval 23–28 yr.

The removal of radiation in the body depends on the sex and age of person and chemical forms of radioactive [26]. The results show no statistical significance between the average of alpha particles and lactating women age intervals in milk.

Table 1. Comparison Previous studies of heavy metals (ppm) with this study in milk.

| Country               | Pb   | Cd   | Cu    | Year [Reference] |
|-----------------------|------|------|-------|-----------------|
| Germany               | 0.013| 0.017| …     | 1985 [46]       |
| Poland                | …    | 0.0-0.001| 0.12-0.70| 2001 [47]       |
| Japan                 | …    | 0    | 0.26  | 2003 [48]       |
| Saudi Arabia          | 3.167| 0.173| …     | 2003 [49]       |
| Greece                | 0    | 0    | 0.38  | 2005 [13]       |
| Iran                  | 0.002| 0.010| …     | 2009 [50]       |
| Australia             | 0.002| 0.001| …     | 2011 [51]       |
| Nigeria               | 0.009| 0.001| 0.83  | 2011 [52]       |
| Sweden                | 0.001-0.006| 0| 0.32-0.67| 2012 [2]       |
| Iraq, Babylon         | 0.026| 0.006| …     | 2013 [53]       |
| China                 | 0.041| 0.007| …     | 2013 [54]       |
| Iran                  | 0.015| 0.012| …     | 2013 [55]       |
| Poland                | 0.006| 0.002| 0.14  | 2014 [56]       |
| Taiwan                | 0.003| 0.001| …     | 2014 [57]       |
| Turkey                | <0.001| 0.54| …     | 2018 [58]       |
| WHO                   | 0.005| 0.0001| 0.181| 1993 [59]       |
| Iraq, Diwaniyah       | 0.224| 0.016| 0.181| Present Study   |

Table 2. Comparison of previous studies of heavy metals (ppm) with this study in blood.

| Country               | Pb   | Cd   | Cu    | Year [Reference] |
|-----------------------|------|------|-------|-----------------|
| Germany               | 0.04 | 0.01 | …     | 1988 [50]       |
| Singapore             | 0.05 | 0    | 2.22  | 1993 [61]       |
| Iraq, Najaf           | 0.06 | …    | 1.61  | 2010 [62]       |
| Korea                 | 0.04 | 0    | …     | 2012 [5]        |
| Brazil                | 0.02 | …    | …     | 2013 [40]       |
| China                 | 0.16 | 0.03 | 0.50  | 2014 [3]        |
| Egypt                 | …    | 0.03 | 0     | 2016 [18]       |
| WHO                   | >0.1 | <0.005| …     | 2000 [63]       |
| Iraq, Diwaniyah       | 0.09 | 0.04 | 0.17  | Present Study   |

0.22 mBq cm\(^2\). The results show no statistical significance on the average of alpha particle emission between the city center and rural areas. The average alpha particle emission was 0.12, 0.25, 0.19, and 0.22 mBq cm\(^2\) in age intervals 17–22 yr, 23–28 yr, 29–34 yr, and 35–40 yr, respectively (Figure 2). The highest average of alpha particle emission is found to be 0.25 mBq cm\(^2\) in age interval 23–28 yr. The removal of radiation in the body depends on the sex and age of person and chemical forms of radioactive [26]. The results show no statistical significance between the average of alpha particles and lactating women age intervals in milk.

Table (3) shows the comparison of previous studies of alpha particles rate with this study in milk. This study shows that the alpha particle emission rates (0.122–68.4992 Track.cm\(^2\)) are higher than Iraq [28]. A good positive correlation was found between Pb and Cd (level 0.01) in milk, while a weak negative correlation was found between Pb and Cu and weak correlation was found between \(E_\alpha\) and Pb, Cd, and Cu in milk. Statistical significance was found between Cd and Cu at level 0.01 in milk. While no statistical significance between \(E_\alpha\) and Pb, Cd, and Cu in milk at level 0.01. The highest emission of alpha rate was found to be 0.68 mBq cm\(^2\) in SC 211. The lowest emission of alpha rate was found to be 0.04 mBq cm\(^2\) in SC 262. The average value of track in blood was 13.01 ± 0.53 μm.

Generally, the average of alpha particle emission for blood is 0.33 ± 0.15 mBq cm\(^2\). Figure 3 shows the comparison of the average of alpha particle emission between the city center and rural area in blood. The average of alpha particle emission in the city center (0.374 mBq cm\(^2\)) is higher than the average of alpha particle emission in rural areas (0.295 mBq cm\(^2\)). The results show no statistical significance on the average of the alpha particle rate in blood between the city center and rural areas.

Figure 4 shows the difference in the average of tracks of alpha particles in blood according to the age intervals. The average of alpha particle emission (0.47 ± 0.30 mBq cm\(^2\)) in age interval 35–40 yr was higher than other age intervals. The removal of radiation from the body depends on the sex and age of person and chemical forms of radioactive

Figure 2. The average tracks of alpha particle emission vs. age intervals.

Figure 3. The average alpha particle emission in milk versus age intervals.
Table 3. Comparison of previous studies of alpha particles rate with this study in milk.

| Country          | Track.cm⁻² | Year [References] |
|------------------|------------|------------------|
| Iraq             | 0.0241–0.0846 | (Awad, 2003).   |
| Iraq, Diwaniyah  | 0.1220–68.4992 | Present Study   |

Figure 3. Comparison of the average of alpha particle rates.

Figure 4. The average of tracks of alpha particle emission vs. age intervals.

compounds [30, 64]. The results show no statistical significance in the average of alpha particles rate and average of women age in blood.

When heavy elements and alpha particles enter the human body through inhalation and digestion leads to many harmful health effects such as leukemia (an increase in leukocytes), anemia (a decrease in the erythrocytes), and bleeding (a decrease in the Platelets) [64, 65]. Nassir et al. (2013) measured Pb and Cd in breast milk of nursing mothers in Hilla city in Iraq using FAAS. Where found that the average Pb and Cd in human milk was 0.0259 ppm and 0.0056 ppm, respectively. The milk of mothers was unusually contaminated (Pb and Cd) [53]. Awad (2003) measured the concentration of uranium in breast milk in the central and southern regions of Iraq using a CR-39. The highest concentration of uranium was 1.804 ppm in Muthanna province, while the lowest was 0.514 ppm in Najaf province [28]. Kazem (2004) measured the concentration of depleted uranium in human milk using a CR-39. The highest DU in milk was about 4.183 ppm in Muthanna province, while the lowest DU was about 0.230 ppm in Maysan province [66]. Alshamri (2010) determined Pb, Cu, Fe, and Zn levels in the blood of fuel station worker at Najaf city using an atomic absorption spectrophotometer. The results showed that the concentrations of Pb, Cu, Fe, and Zn in the people who work in contaminated environment. The results are higher than the peoples who work in unpolluted environment [61]. Aljubouri et al. (2013) evaluated the levels of Cd in blood, hair, saliva, and teeth in Iraqi workers using FAAS. Cd is increased with some factors like a smoking habit, residency, age in males than in females [38]. Hassan (2019) determined U in human blood in some governorates of Iraq using CR-39 detector. The results show that the highest U was 1.654 ppm in Basra governorate while the lowest U was 0.153 ppm in the Baghdad governorate [67]. Altememy (2007) measured U using CR-39 trace detector in human blood. The highest U was about 0.00199 ppm in the people who work in the field of radiation in Basra. The lowest concentration of U was about 0.000095 ppm from the people who work in the field of radiation Baghdad. The maximum concentration of U is 0.00189 ppm in non-working people in the field of radiation in Muthana, while the minimum concentration of U was about 0.00025 ppm in Ramadi governorate [68]. Alrubyie (2007) used CR-39 trace detector to measure radiation levels in the human blood of patients with cancer. The results show that the highest concentration was about 0.256 ppm in Alzaifraanea city and Alsaers city. The lowest concentration was about 0.052 ppm in Alshaab city [69]. Abbas et al. (2010) used CR-39 to measure U concentrations in human blood in the regions of Baghdad province in Iraq, where found that the highest uranium concentration was 0.256 ppm in Alzaifraanea region and Alsaers region while the lowest uranium concentration was about 0.052 ppm in Alshaab region and found that the minimum uranium concentration in the blood was 0.008 ppm (male, 39 years old) live in Alshaab region, while the maximum uranium was found to be 0.44 ppm (female, 55 y) in Alsaers region in the blood [24]. Tawfiq et al. (2013) measured U in human blood in Iraq using a CR-39. The results show that the highest U in workers in the Ministry of Science and Technology was 0.0019 ppm (male, 36 y, 12 ys, Basrah), while the lowest concentration was 0.0003 ppm (female, 40 y, 10 ys, Baghdad), and the highest U concentration was 0.00176 ppm for non-occupational worker (female, 63 y, Almuthana). The lowest uranium concentration is 0.00028 ppm (female, 20 ys, Baghdad). U in the blood of workers was higher than that of non-occupational workers and the uranium for non-occupational workers were higher than those for male and non-occupational workers [25]. Alhamzawi et al. (2014) determined U in the blood of humans in Southern Iraqi leukemia patients using CR-39. The results show that the highest U in the blood of patients with leukemia was 0.00471 ppm (female, 45 ys, Basrah) while the lowest uranium was 0.00191 ppm (male, 3 ys, Muthanna), whereas find that the highest uranium was 0.00215 ppm (female, 55 ys, Basrah) and the lowest uranium was 0.00086 ppm (male, 5 ys, Dhi-Qar) in the healthy group [26]. Salih et al. (2013) used the plastic detector (CR-39) to measure the effects of alpha emitters in blood for women's infertility in Kurdistan in Iraq. The average concentration of alpha particles in Erbil (0.0085 ppm) was higher than the average concentration of alpha particles in Sulaimania (0.0062 ppm) [70]. Alhamzawi et al. (2014) determined the concentration of Uranium in the blood of humans in Basra and Babylon regions. The results show that the range of U in the blood of Basra were ranged from 0.00083–0.00247 ppm, whereas the range of U in the blood of a population in the Babylon region was ranged 0.0003 ppm–0.00159 ppm also found that the concentration of U in the blood of population in Basra region was higher than the concentration of U in the blood of the population in a Babylon city [26]. Rasheed (2016) used a track detector (PM-355) to determine the uranium concentration in the blood of...
humans, where found that the mean of uranium in the healthy group was 0.121 ppm, whereas the mean of uranium in leukemia was 1.671 ppm [71]. Sternowsky et al. (1985) used a FAAS to identify the high levels of Pb and Cd in human milk in urban and rural mothers during 3 months of lactation. The results show that the lowest Cd in rural women was 0.0173 ppm, while the highest Cd in urban mothers was 0.0246 ppm and showed that the lowest content of Pb in rural mothers was 0.0091 ppm while the highest content of Pb in urban mothers was 0.0133 ppm [49]. Wasowicz et al. (2001) measured Se, Zn, and Cu in the milk of lactating women in Poland using inductively Coupled Plasma–Atomic Electron Spectrometry. The average Se, Zn, and Cu in milk was 0.02 ppm, 8.2 ppm, and 0.45 ppm, respectively [50]. Honda et al. (2003) measured Cd, Ca, Mg, Na, K, P, Cu, Zn in human milk in Japan using inductively coupled plasma atomic emission spectrometry, flame atomic absorption spectrophotometry, and flameless atomic absorption spectrophotometry. The average Cd, Cu, Zn, Na, K, Mg, Ca, and P were 0.004 ppm, 0.263 ppm, 5.4 ppm, 371.5 ppm, 678.3 ppm, 32.2 ppm, 344.4 ppm, and 191.6 ppm, respectively [51]. Alsaleh et al. (2009) measured the concentrations of Cd and Pb in human milk using a Graphite Furnace Atomic Absorption Spectrophotometry (GF-AAS). The results show that the average concentrations of Cd and Pb in human milk were 0.0033 ppm, 0.0037 ppm, and 0.8126 ppm, respectively [72]. Lee et al. (2012) analyzed the heavy metals in the blood of the population living in the vicinity of municipal waste incinerators in Korea using a Graphite Furnace Atomic Absorption Spectrophotometry (GF-AAS). The results show that the average of Pb, Cd, and Hg was 0.0431 ppm, 0.0017 ppm, and 0.0013 ppm, respectively [73]. Andrade et al. (2013) identified the concentration of Pb in blood of nursing mothers in an inland city of Brazil using the Mass Spectrometer with the associated inductive plasma, where found that the average Pb was 0.01801 ppm [40]. Li et al. (2014) detected content of 12 heavy metals in blood from a general population of the pearl river Delta area using an Inductively Coupled Plasma Mass Spectrometry. The average heavy metals in blood was Al (0.214 ppm), Cr (0.09282 ppm), Mn (0.02143 ppm), Ni (0.02059 ppm), Cu (0.00067), Zn (0.0115 ppm), As (0.00055), Cd (0.04 25 pp), Sn (0), Sb (0.00192) ppm, Pb (0.15884 ppm), and Hg (0.00119) ppm [3]. Motawe et al. (2016) measured heavy metals (Hg, Cd, and Cu) in the blood of pregnant women in Dakahlia, Egypt using an Atomic Absorption Spectrophotometry, where found that the mean of the element in blood was 0.0033 ppm, 0.00328 ppm, and 0.05032 ppm, respectively, and showed that these levels were far from the levels that determined by the Agency for Toxic Substances and Disease Registry (ATSDR) in and developed countries [15]. Almayahi (2015) evaluated the emission of alpha particles rate (Eα) from human blood using a nuclear track from different regions of Najaf city in Iraq. Where found that the concentration of alpha particles in females was (0.0340 mBq cm⁻²), which was slightly higher than the concentration of alpha particles in males (0.0336 mBq cm⁻²). Whereas the concentration of alpha particles in Najaf city was (0.0341 mBq cm⁻²) slightly higher than alpha particles in Mananthis (0.0336 mBq cm⁻²) [27]. Table (4) shows comparison previous studies of alpha particles rate with this study in blood. This study shows that the value of alpha particles (4.3595–69.2246 Track.cm⁻²) is within previous studies.

Table (5) shows the Pearson correlation between heavy metals and alpha particles in blood, a weak negative correlation was found between Pb and Cd also between Pb and Cu in blood, while a good positive correlation was found between Cd and Cu and a weak correlation was found between Eα with Pb, Cd, and Cu in blood.

Table (6) shows statistical significance between heavy metals and alpha particles at (level 0.01) in blood. Statistical significance was found between Cd and Cu in blood at level 0.01, while there is no statistical significance between Eα with Pb, Cd, and Cu at level 0.01 in blood.

Overall, the correlation was a weak between heavy metals and alpha particle emission rate in milk and blood samples.

6. Conclusions

Statistical significance in the average Pb in milk was found. The correlation was positive between Pb and Cd and negative between Pb and Cu in milk. No correlation was found between Pb and Cd, also between Pb and Cu in blood. A positive correlation between Cd and Cu. There is no correlation between heavy metals and alpha particle emission rate in milk and blood. The data showed no heavy metal contaminants/pollutants in the blood and milk of Iraqi women at concentrations of potential harm. The alpha particle emission rates in milk and blood were similar to those observed in previous studies. Overall, the data present no implications for public health policies.
Compliance with ethical standards

This study was approved by the Ethics Committee, University of Kufa. The study protocol was thoroughly explained for using milk and blood samples of women and written informed consent were obtained from them prior to participation in the study. This investigation was done according to the principals of the Declaration of Helsinki. All patients were informed about the aims and protocol of the study.

Declarations

Author contribution statement

Basim Almayahi: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Asmaa H. Abboud: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Table 4. Comparison of previous studies of alpha particles rate with this study.

| Country         | Track.cm⁻² | Year [References] |
|-----------------|------------|-------------------|
| Iraq            | 0.13 × 10⁵ - 1.58 × 10⁵ | 2006 [70]         |
| Iraq            | 0.2 × 10⁵ - 0.7 × 10⁵ | 2007 [71]         |
| Iraq            | 0.012 × 10⁵ - 0.7 × 10⁵ | 2007 [72]         |
| Iraq            | 0.18 - 0.03 | 2010 [24]         |
| Iraq            | 0.01 - 0.03 | 2013 [25]         |
| Iraq Basra (A)  | 28.3 - 83.7 | 2014 [26]         |
| Iraq Babylon (B) | 15.5 - 65.9 | 2014 [26]         |
| Iraq, Diwaniyah | 4.3959 - 69.2246 | Present Study     |

Table 5. Pearson correlation between heavy metals and alpha particles.

| Pearson Correlation | Pb       | Cd       | Cu       | Eα       |
|---------------------|----------|----------|----------|----------|
| Pb                  | 1        | -0.084   | -0.010   | -0.242   |
| Cd                  | -0.084   | 1        | 0.572**  | -0.091   |
| Cu                  | -0.010   | 0.572**  | 1        | -0.136   |
| Eα                  | -0.242   | -0.091   | -0.136   | 1        |

** Good correlation.

Table 6. Statistical significance between heavy metals and alpha particles.

| Sig. (2-tailed) | Pb       | Cd       | Cu       | Eα       |
|-----------------|----------|----------|----------|----------|
| Pb              | ....     | 0.000    | 0.916    | 0.492    |
| Cd              | 0.000    | ....     | 0.772    | 0.384    |
| Cu              | 0.916    | 0.772    | ....     | 0.350    |
| Eα              | 0.492    | 0.384    | 0.350    | ....     |

7. Compliance with ethical standards

This study was approved by the Ethics Committee, University of Kufa. The study protocol was thoroughly explained for using milk and blood samples of women and written informed consent were obtained from them prior to participation in the study. This investigation was done according to the principals of the Declaration of Helsinki. All patients were informed about the aims and protocol of the study.

Declarations

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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