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Assess Uranium Concentration Levels in Blood Samples of Iraqi Personnel at the Tuwaitha Nuclear Site

Lina S.Al-Jameel*
National diabetes center, Mustansiriyah University, Baghdad, Iraq

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ABSTRACT

Exposure to uranium within occupational settings or surrounding environments has the potential to cause cellular damage and elevate the risk of carcinogenesis. This study aimed to assess the level of uranium toxicity in the blood and the possibility of health impact occurring on the personnel at The Tuwaitha site, which was previously utilized for nuclear activity and may contain a considerable amount of radioactive waste. Personnel at this facility are at risk of pollution due to the highly polluted environment of uranium. Statistical analysis was performed using the SPPS software application .Thirty-six blood samples were taken from personnel at The Tuwaitha site, categorized in to two distinct cohorts: 8 personnel lacking protective measures and 28 personnel utilizing protective equipment, along- side 30 control subjects who had no prior occupational exposure to The Tuwaitha nuclear facility .The CR-39 track detector has been utilized to evaluate the concentration of uranium in blood samples by depositing a droplet of blood on the detectors ,followed irradiation of CR-39 detectors with a neutron source **.**The findings showed elevated uranium concentrations in personnel lacking protective measures compared to those with protective measures and the control .Furthermore, the results demonstrated a significant correlation between uranium concentrations and the duration of employment**.** Uranium concentration was found higher in blood samples in personnel than individuals who had never worked at Tuwaitha site, also there is a relation between uranium concentrations and the duration of employment. The study suggests that personnel wear a hazmat suit and also taking oral antioxidants to protect from radiation.

Corresponding Author:

* Lina S. Al-Jameel
National Diabetes Center, Mustansiriyah, University, Baghdad, Iraq
Email: linaaljameel@uomustansiriyah.edu.iq

1- INTRODUCTION

Radiation contamination refers to the release of radioactive substances into the environment, which adversely impacts both human health and wildlife. Such contamination can originate from natural sources, including primordial and cosmogenic radionuclides, as well as from anthropogenic activities, which encompass the disposal of radioactive waste, accidental discharges of radioactive materials, regulated emissions from nuclear power facilities, and inadvertent discharges of radioactive materials [1, 3]**.** The analysis of uranium traces in the blood specimens provides a reliable indicator of the concentration of heavy metals within various bodily tissues. Uranium (U) is a dense metallic element within the actinide series. It is characterized by its radioactivity and its chemical toxicity [4, 5]. It is naturally prevalent in the atmosphere, hydrosphere, lithosphere, and geological formations [6, 7]. Uranium is one of the most significant contaminants due to its toxicological properties as a heavy metal and its inherent radioactivity [8].The toxicity exhibited via uranium poses a substantial risk to ecological stability and public health [9, 10]. Personnel in Al-Tuwaitha site exposure to uranium may occur through various modes of contact, which include dermal exposure, inhalation of dust particles, and entry through contaminated food, water, and injuries. The ingestion and inhalation of uranium-derived dust particles caused the late effect of radio-toxicological hazard [11, 12]**.** Human and animal studies have established a correlation between oral exposure and inhalation of uranium oxides increased risk of cancer as well as developmental malformations [13]. A study on uranium concentration in some Iraqi companies indicates a high level of uranium concentration in blood samples of Iraqi workers employed in certain government companies. This study assessed the initial level of uranium toxicity in the personnel's blood and the possibility of health problems occurring [14]. Uranium poses the capacity to traverse both the blood-brain barrier and the placental barrier with relative ease. Many studies have demonstrated a significant association between uranium consumption associated and detrimental clinical consequences, including an elevation in reactive oxygen species, DNA damage, and alterations in gene expression [15, 16]. Cute toxicity elicits notable manifestations, which encompass weight reduction, cognitive dysfunction, renal impairment, alterations in the reproductive system, carcinogenic implications, and modifications in osseous development. In contrast, the biological ramifications of prolonged exposure to minimal doses remain largely uncharted [17]. Several studies have examined a link between the level of uranium concentration in the human body and cancer rates [18, 20]. Another study observed a rise in cancer cases attributed to the existence of DU in Iraq as a result of the war. In addition, five common types of cancers were identified, particularly in females [21]. The toxicological properties of uranium are closely associated with its solubility characteristics. Soluble uranium variants are correlated with chemical toxicity and pose significant risks to the respiratory system, being absorbed within several days, while insoluble uranium variants are associated with radiological toxicity and present dangers to renal function, with absorption occurring over durations ranging from months to years [22, 23]. Historically, Al-Tuwaitha nuclear site has been utilized for nuclear operations and possesses potentially substantial quantities of radioactive waste. Personnel at this center are exposed to hazards as they engage in dismantling, removing, and packaging radioactive waste, and then wrapping radioactive waste in a thick nylon stratum and stored in a freight container**.** The detector was employed to measure the concentration of uranium. The fission track method developed via Fleischer [24] involves the compression of two films and their subsequent exposure to thermal neutron irradiation to dry the blood. The present study aimed to determine the concentration of uranium in blood samples obtained from personnel at The Tuwaitha center and control groups using the fission track method with a CR-39 detector. This technique has proven to be highly effective for measurement of uranium concentrations in human blood.

2- SUPJECTS AND METHODS

2.1. Study Subjects

Two distinct directorates: the directorate of the management and treatment of radioactive waste and the decommissioning directorate, where in personnel are exposed to radioactive element such as uranium as they engage in dismantling, removing, and packaging radioactive waste and then wrapping radioactive waste in a thick nylon stratum and stored in a freight container were studied; all individuals assigned to these sectors consented to participate in the study .A total of 36 personnel with age ranging (28-63yars) ,18 personnel from the directorate of the management and treatment of radioactive waste and 18 personnel from the decommissioning directorate. Personnel divided into two groups: 8 personnel lacking protective measures and 28 personnel utilizing protective equipment, who reside near The Tuwaitha nuclear site, were excluded from the study. The control group consisted of 30 individuals aged between (30-58years) who had no prior occupational exposure to The Tuwaitha nuclear site.

2.2. Measurement the Concentration of uranium

CR-39 (ColumbiaResinNo.3) with a thickness of (250μm) was used in the present study and was manufactured by Pershore Moulding LTD company, United Kingdom was divided into 126 small pieces (1x1cm), a single drop of blood samples pipetted onto each piece of the detector. The drop of the blood was left to desiccate and then was covered via another piece to create a sandwich configuration, adhered to another using transparent adhesive tape and then coated. The samples were sent to the College of Education of Pure Science (Ibn-Al-Haitham) / physics department, University of Baghdad, to irradiate the sandwich with an Am-Be neutron source encased within paraffin wax, the paraffin wax served the purpose of moderating the energies of fast neutrons to those characteristic of Thermal neutrons. An Am-Be irradiation source irradiated the detector sandwiches at a flux of ($5x10^3 n.cm^{-2}.s^{-1}$) over 7 days to cause latent damage to the CR-3 detectors due to (n,f) reaction [25]. The sandwiches of detectors were positioned at a distance of 5cm from the Am-Be neutron source, as illustrated in Figure1 [26]. After CR-39 irradiation, the detector is immersed in an etching solution (NaOH) to enhance the clarity of the tracks produced on the detector; the alkali solution was prepared by dissolving 125 grams of sodium hydroxide (NaOH) into 500 milliliters of distilled water, resulting in a concentration of 6.25 moles of NaOH. The cylinder containing the solution was securely sealed to prevent vaporization, thereby maintaining the normality of the solution at a constant level. The detectors were immersed in the etching solution for six hours in a water bath maintained at, a temperature of 70°C.

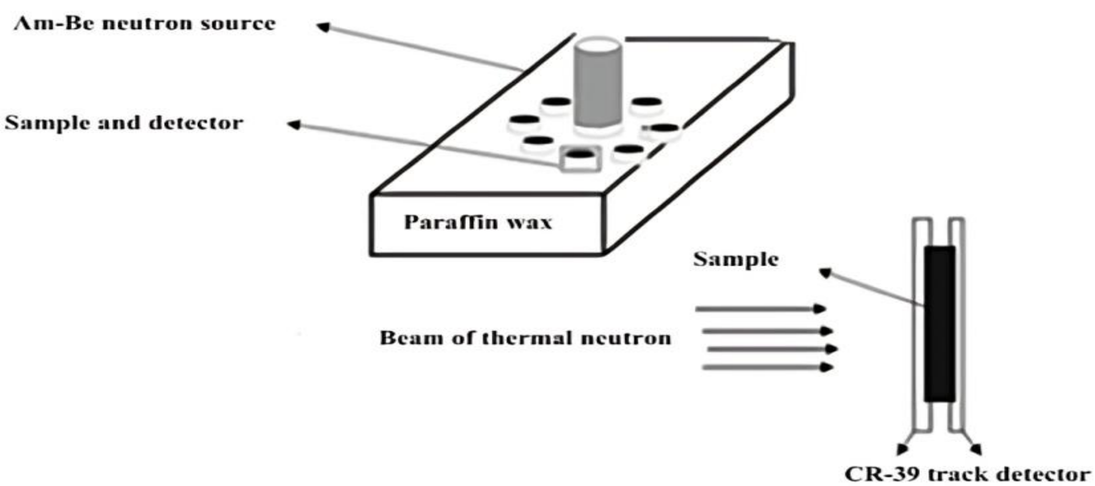

Figure1: The irradiation of the CR-39 detectors and blood samples to the Am-Be source of neutron.

The primary objective of the etching process is to facilitate the visualization of latent tracks induced by irradiation, which can be enhanced through magnification when exposed to sodium hydroxide solution under elevated temperature conditions After the etching procedure, the detector components were rinsed with distilled water, followed by drying and cleaning in preparation for microscopic examination at a magnification of 400 times as shown in figure2.

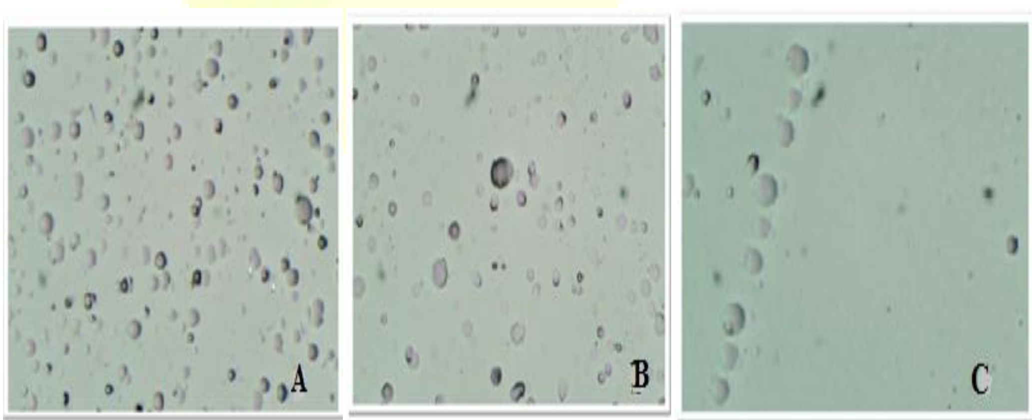

Figure2: The tracks formed on CR-39 detectors magnified by a light microscope 400x for personnel and control group**.** (a) personnel lacking protective measures (b) personnel with protective measures (c) control group.

2.3. Track Counting and Calculation of the Concentration of Uranium

After the enumeration of tracks within each segment of the detectors, the fission track density (ρx) in the samples was calculated by relation: [27].

$$\text{Thedensityoftracks}(\rho x) = \frac{\text{Averagenumberoftrack}}{\text{Areaoffieldofview}} \quad (1)$$

The concentration of uranium was determined by comparing the track densities on the detectors in each sandwich with those of the standard samples, using the following equations.2 and3 [28, 29].

$$Cx(sample)/\rho x(sample) = Cs(standard)/\rho s(standard) \quad (2)$$

$$Cx = \rho x.(Cs/\rho s) \quad (3)$$

Where: ρ_x: Density of fission track of unknown sample (tracks/mm^2).
ρ_s: Density of fission track of standard sample (tracks/mm^2).
C_x : Concentration of uranium of unknown sample (ppb).
C_s: Concentration of uranium of standard sample (ppb).

The slope of the linear relation between the density of the fission track and uranium concentration for standard samples is shown in Figure3 [30].

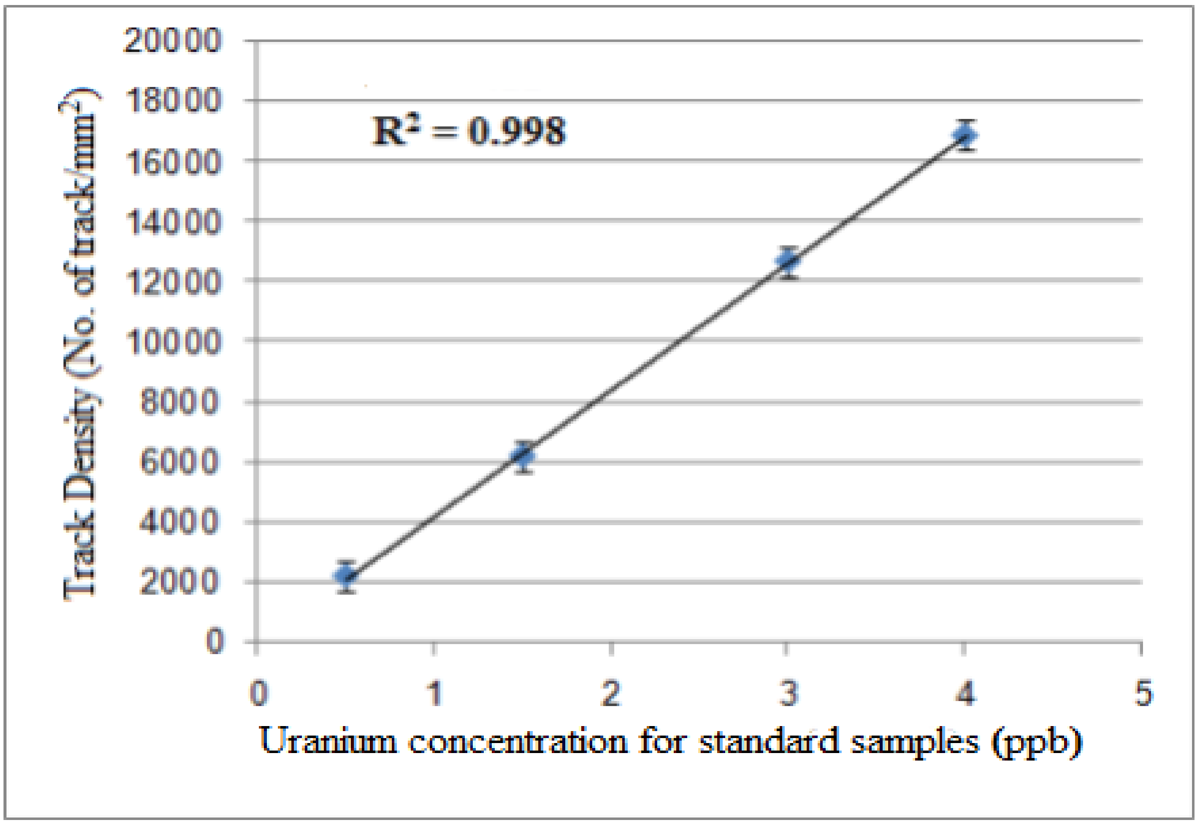

Figure.3: The relationship between fission track density and concentration of uranium (ppb) for standard samples.

2.4. Statistical Analysis

The Statistical Package for Social Sciences (SPSS, version23) served as the analytical tool for this study. The analyzed data is expressed as mean ± standard deviation (SD). For group comparisons, One-way analysis of variance (ANOVA) was employed to assess uranium concentration. Furthermore, linear correlation analysis was utilized to determine the relationship between the duration of employment and uranium concentration.

3- RESULTS AND DISCUSSION

Previous studies presented findings regarding uranium concentrations in blood and human tissue [31-33]. In this study, the track densities and concentrations of uranium within the blood sample are presented in Tables 1, 2 and 3. In the first group, the samples collected from personnel lacking protective measures with aged between (52 to 59 years) and duration of employment from (30 to 35 years), were given numbers from 1 to 8 as in Table 1. The maximum and minimum obtained values of uranium concentrations were (0.273 ± 0.038 ppb) and (0.170 ± 0.024 ppb) respectively with an average value of (0.211 ± 0.033 ppb). The higher track density was found in this group (8.845 ± 1.363) Fig 2 A. The second group of personnel with protective measure aged between (28 to 63 years) and with duration of employment from (5 to 25 years), were given a number from 9 to 36 as in Table 2. The maximum and minimum obtained values of uranium concentrations were (0.109 ± 0.015ppb) and (0.076 ± 0.007 ppb) respectively with an average of (0.090 ± 0.009 ppb). The track density was found in this group (3.687 ± 0.628) Fig 2 B. For the control group, the samples were collected from 30 individuals who had never dealt with uranium with aged between (30 to 58 years old), they were given number from 37 to 66 as in Table 3. The maximum and minimum obtained values of uranium concentrations were (0.086 ± 0.012 ppb) and (0.025 ± 0.005 ppb) respectively with an average of (0.056 ± 0.015 ppb). The track density for the control group was found to be less than the personnel (2.393 ± 0.975) Fig 2c.

Table1: Sample number, age, duration of employment, track densities and uranium concentration (ppb) for personnel lacking protective measures.

NO. of samples	Age(year)	Duration of employment(year)	Track densities (No. of tracks/mm^2) Mean± SD	Uranium concentration(ppb) Mean± SD
1	54	32	8.553±1.010	0.204±0.024
2	52	30	9.133±1.556	0.217±0.037
3	58	35	9.473±1.416	0.226±0.034
4	52	30	8.960±2.152	0.213±0.051
5	54	32	8.133±1.078	0.194±0.026
6	58	35	1.146±1.596	0.273±0.038
7	59	34	7.126±9.876	0.170±0.024
8	58	33	7.923±1.110	0.189±0.026
Average	55.625	32.625	8.845±1.363	0.211±0.033

Table2: Sample number, age, duration of employment, track densities and uranium concentration(ppb) For personnel with protective measure.

NO. of samples	Age(year)	Duration of employment(year)	Track densities (No. of tracks/mm^2) Mean± SD	Uranium concentration(ppb) Mean± SD
9	47	18	4.013±0.936	0.096±0.022
10	30	6	3.456±0.157	0.082±0.004
11	50	20	3.442±0.401	0.082±0.009
12	52	20	3.416±0.310	0.081±0.007
13	48	19	3.420±1.059	0.081±0.025
14	49	20	4.063±0.395	0.097±0.009
15	46	23	3.700±0.416	0.088±0.001
16	43	19	3.426±0.779	0.082±0.019
17	30	6	4.040±0.565	0.096±0.013
18	45	25	3.453±0.399	0.082±0.010
19	49	18	3.193±0.294	0.076±0.007
20	45	25	3.876±0.613	0.092±0.015
21	28	5	3.483±0.566	0.083±0.013
22	41	19	3.973±0.435	0.095±0.010
23	47	16	4.056±1.018	0.097±0.024
24	47	20	4.610±0.629	0.109±0.015
25	35	6	3.310±0.808	0.079±0.019
26	49	23	3.313±0.464	0.079±0.011
27	31	5	4.173±0.664	0.099±0.016
28	32	9	4.030±0.528	0.096±0.012
29	56	20	3.903±0.234	0.093±0.006
30	55	25	3.746±0.545	0.089±0.013
31	50	20	4.200±0.418	0.1±0.010
32	58	25	4.370±0.491	0.104±0.011
33	55	24	4.446±0.510	0.105±0.012
34	47	24	3.480±1.528	0.083±0.036
35	43	16	3.390±1.715	0.081±0.041
36	63	20	4.070±0.718	0.097±0.017
Average	45.392	17.714	3.787±0.628	0.090±0.009

Table3: Sample number, age, track densities and uranium concentration (ppb) for the control group

NO. of samples	Age(year)	Track densities (No. of tracks/mm^2) Mean± SD	Uranium concentration(ppb) Mean± SD
37	51	2.643±1.541	0.062±0.036
38	35	1.303±0.329	0.031±0.007
39	38	2.876±1.425	0.068±0.033
40	36	1.673±0.853	0.039±0.020
41	37	2.776±0.899	0.066±0.021
42	51	2.500±1.535	0.060±0.036
43	51	1.060±0.194	0.025±0.005
44	46	1.230±0.369	0.029±0.009
45	33	2.356±1.349	0.056±0.032
46	35	2.890±0.629	0.069±0.015
47	42	1.056.±0.457	0.025±0.011
48	51	2.340±1.349	0.056±0.039
49	34	2.563±1.203	0.061±0.029
50	37	2.376±1.125	0.057±0.027
51	58	2.426±1.334	0.058±0.032
52	31	2.537±1.147	0.061±0.014
53	40	1.356±0.599	0.032±0.014
54	53	2.366±1.879	0.056±0.045
55	40	3.613±0.496	0.086±0.012
56	39	2.563±1.056	0.061±0.025
57	40	2.216±1.162	0.053±0.028
58	34	3.170±0.887	0.075±0.021
59	41	2.813±1.163	0.067±0.028
60	41	2.523±0.408	0.059±0.010
61	52	2.356±1.598	0.056±0.038
62	30	2.070±1.114	0.049±0.027
63	42	3.030±0.755	0.086±0.012
64	32	3.613±0.496	0.061±0.025
65	42	2.563±1.056	0.053±0.028
66	31	2.933±0.856	0.069±0.020
Average	40.1	2.393±0.975	0.056±0.015

The results of the groups are represented in figure4 uranium concentrations with their mean value in the personnel lack protective measures, with protective measures, and control group. The result of linear correlation between uranium concentrations and duration of employment are presented in figure 5.

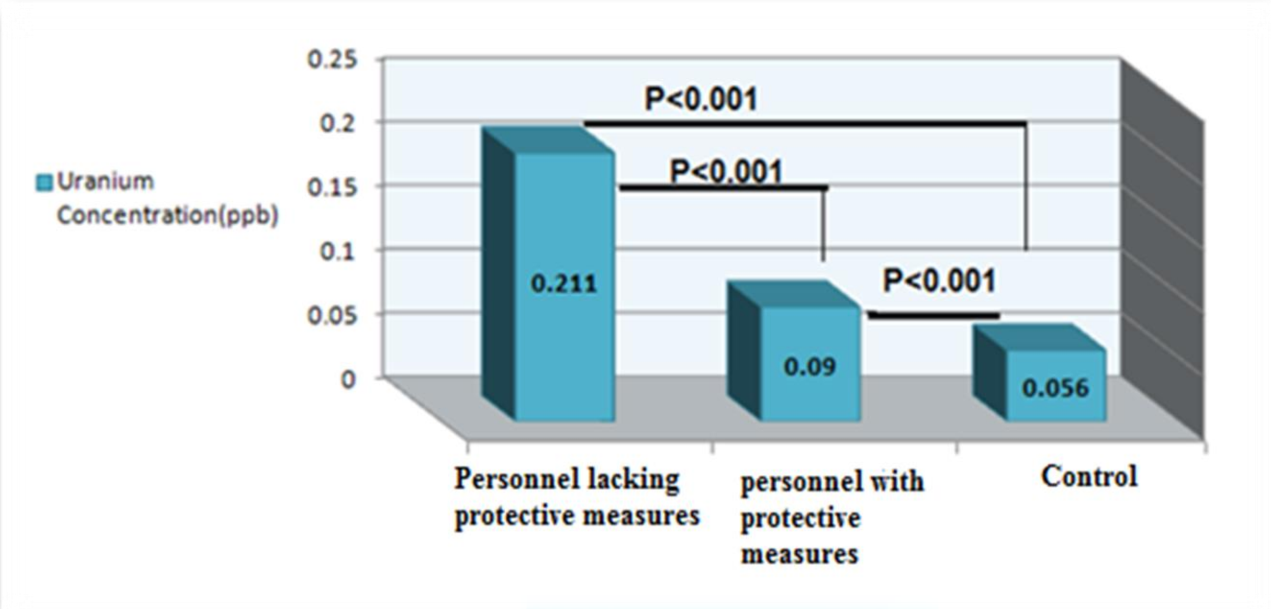

Fig4: Mean values of uranium concentration in personnel lack protective measures ,personnel with protective measure, and control.

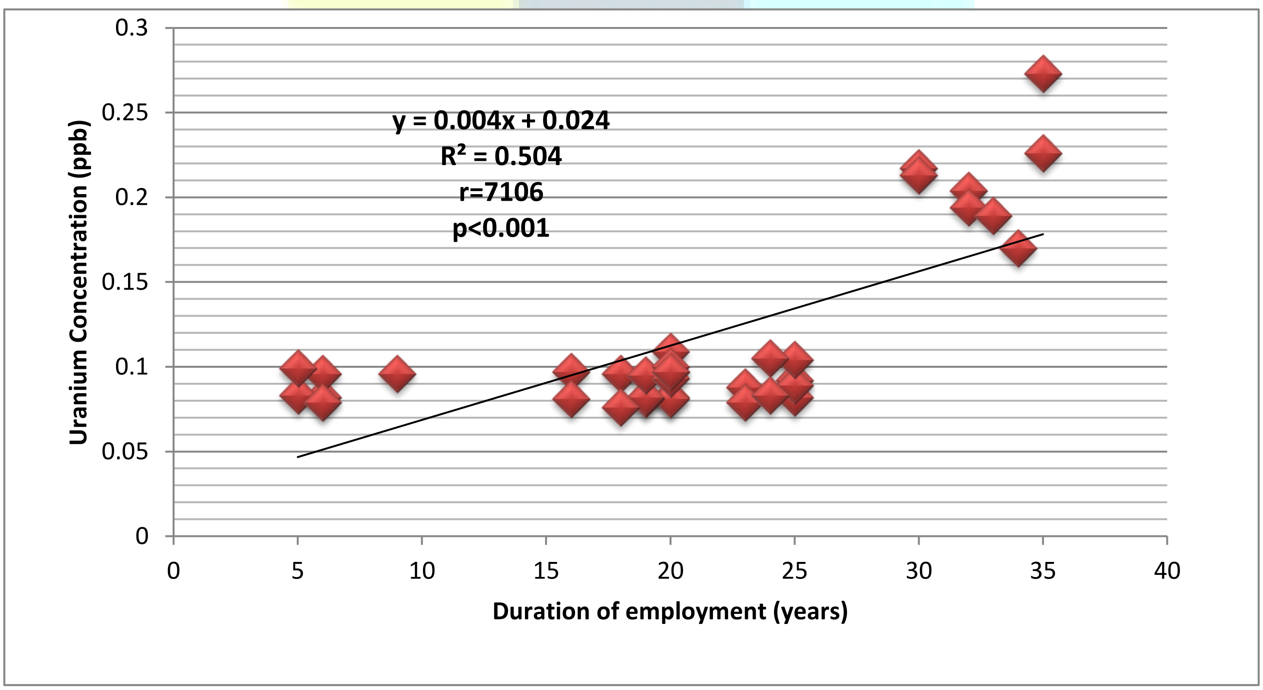

Figure5: Linear correlation association between duration of employment and uranium concentration**.**

The highest uranium concentration was observed in the blood of personnel who lacked protective measures compared to personnel with protective measures and control subjects. This study's results also show a high uranium concentration in the personnel with protective measures compared to the control subjects. Statistical analysis indicates a highly significant difference ($p<0.001$) in uranium concentration between the groups. The elevated values of uranium concentration in a blood sample of personnel in The Tuwaitha site may be due to inner uranium contamination. Inner contamination with uranium is hurtful because the intact epidermis is serves as an effective barrier against external environmental factors, inner uranium contamination occurs through the mechanisms of inhalation, ingestion, and dermal or wound contact [34]. The result of this study indicates a correlation between uranium concentrations and duration of employment. This correlation demonstrated a positive linear relationship ($r=0.7106$, $P<0.001$), indicating that uranium concentration increases with increased duration of employment. High uranium concentrations were obtained ranging from (0.170 ± 0.024ppb) to (0.273 ± 0.0ppb) with a duration of employment ranging from (30-35years), which a rises the occurrence of the stochastic effects. The stochastic effects manifest as a consequence of minimal exposure received over a long time, leading to genetic alterations through modifications of the genetic code, which subsequently result in the development of various malignancies and morphological anomalies [35-37] Uranium is postulated to function as both a clastogen and an aneugen; it possesses the ability to induce various forms of chromosomal aberrations and DNA damage via incorrect rejoining and double- strands DNA breaks [38,39]. Ionizing radiation that emit from uranium (α-particles and γ-rays) can cause heritable damages even at very low doses and considered a genotoxic factor for human. Previous study showed that higher DNA damage in personnel of Tuwaitha site due to exposure to radiation at their place of employment [40, 41]. Ionizing radiation has the potential to cause various kinds of mutations. Radiation exposure increases the rate of mutations in cells, which can result in alterations to the organism's genetic material [42]. Working suits can utilize to protect personnel from radiation and radioactive elements. The results of the present study showed a significant decrease in uranium concentration in the personnel with protective measures .However, complete protection from radiation and radioactive materials is not guaranteed by wearing working suit. This is because the staff handled and used the working suits incorrectly. Numerous factors can decrease personnel protection such as improper storage, use, and quality of working suits. This could be the reason why personnel with protective measures had higher uranium concentrations than those who had never worked at the Tuwaitha site.

4- CONCLUSION

The estimated concentrations of uranium in personnel blood are essential for predicting the entries in Iraq's database, which serve to estimate future personnel's health records. Uranium concentration was found higher in the blood samples of personnel at The-Tuwaitha site than in the blood samples of the control group. The increase in uranium levels could be linked to the existence of uranium contamination in the Tuwaitha environment and found that uranium concentration increases with increased duration of employment, while there is no relationship between age and uranium concentrations in this study. This indicates that other factors play a prominent role in influencing levels of uranium, such as personnel exposure, the type of protective measures utilized, and the efficiency of biological processes in eliminating heavy metal contaminants .The study suggested that personnel should carefully comply with radioactive elements and radiation protective measures such as the personal radiation detection device and wearing a HazMat suit, Also, taking oral antioxidants to protect from radiation.

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تقييم مستويات تركيز اليورانيوم في عينات الدم من الموظفين العراقيين في موقع التويثة النووي

الخلاصة

يمكن أن يؤدي التعرض لليورانيوم في البيئات المهنية أو المناطق المحيطة لها إلى تلف خلوي وزيادة خطر الإصابة بالأورام السرطانية. هدفت هذه الدراسة إلى تحديد تركيز اليورانيوم باستخدام طريقة أثر الانشطار في عينات الدم لموظفي موقع التويثة، وهو موقع كان يستخدم سابقًا للنشاط النووي وقد يحتوي على كمية كبيرة من النفايات المشعة. يتعرض العاملون في هذه المنشأة لخطر التلوث بسبب البيئة ذات التلوث العالي لليورانيوم .

تم إجراء التحليل الإحصائي باستخدام برنامج SPSS, حيث تم جمع 36 عينة دم من الموظفين العاملين في موقع التويثة، مقسمة إلى مجموعتين: 8 موظفين غير مستخدمين لمعدات الحماية و 28 موظفًا يستخدمون معدات الحماية ، بالإضافة إلى 30 فردًا من مجموعة التحكم لم يكن لديهم أي تعرض مهني للإشعاع أو العمل في موقع التويثة النووي . تم استخدام كاشف الأثر النووي CR–39 لتقييم تركيز اليورانيوم في عينات الدم عن طريق وضع قطرة دم على الكاشف، تليها عملية حساب تركيز اليورانيوم من خلال عملية تشعع كاشفات CR–39 بمصدر نيوتروني .

أظهرت النتائج ارتفاع تركيز اليورانيوم في دم الموظفين الذين لم يستخدموا معدات الوقاية مقارنة بالذين استخدموا معدات الوقاية وأفراد المجموعة الضابطة. بالإضافة إلى ذلك، كشفت الدراسة عن علاقة ارتباط إيجابية ذات دلالة إحصائية بين تركيز اليورانيوم ومدة العمل في موقع التويثة. كان تركيز اليورانيوم أعلى لدى الموظفين العاملين في الموقع مقارنة بالأفراد الذين لم يعملوا فيه مطلقًا ، مما يؤكد وجود تأثير التعرض المهني لتراكم اليورانيوم في الدم.

تقترح الدراسة أن يرتدي الموظفون بدلات الحماية واستخدام المضادات الأكسدة الفموية للحد من آثار الإشعاع وتعزيز الحماية من التعرض الإشعاعي في بيئات العمل النووية .