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الكشف عن مستويات التلوث الإشعاعي في أنسجة العضلات والعظام في المجترات (الأبقار والأغنام) في بعض محافظات العراق.

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المستخلص:

تتعرض جميع الكائنات الحية للإشعاع الطبيعي من الماء أو الهواء أو التربة. وبالتالي، يمكن أن يدخل الإشعاع إلى النبات عبر التربة التي ينمو فيها، أو الماء الذي يروى به، أو كليهما. بمجرد وصول الإشعاع إلى النبات، ينتقل إلى الحيوانات، والتي بدورها تنتقل إلى البشر. ولأن الإشعاع ينتقل من الحيوانات إلى البشر عبر السلسلة الغذائية، فإن تناول اللحوم يمكن أن يكون له آثار صحية سلبية. في هذا البحث، تم فحص ٢٠٠ عينة من عظام وعضلات الأغنام والأبقار المتوفرة في العراق من حيث النشاط الإشعاعي بمعدل ٢٠ عينة من كل مدينة (١٠ عينات من الأغنام، ١٠ عينات من الأبقار). ولتحديد كميات إشعاع ألفا المنبعث من العينات، التي جمعت من عشر مدن عراقية، استخدم كاشف الأثر النووي CR-39. وُجد أن العينات التي جمعت من الموصل احتوت على أدنى مستويات من اليورانيوم، بينما وُجدت أعلى مستويات لليورانيوم في العينات المأخوذة من مدن بغداد، تكريت، وكركوك على التوالي. أذ أظهرت نتائج التحليل الإحصائي وجود فروق معنوية في



مستويات اليورانيوم ما بين بغداد وبنينوى (١٢.٤٩٦) وما بين كركوك وبنينوى (١١.٨٢٦) على التوالي، بحسب اختبار الشيفيه للمقارنات الزوجية.

كما أظهرت نتائج الدراسة الحالية ارتفاعاً معنوياً في مستويات اليورانيوم في العظام (١.٨٢٩±١٢.٠٨٧) مقارنةً بمستوياته في العضلات (١.٤٥٥±٨.٨٢٣) عند مستوى دلالة (٠.٠٥) في كلا الأغنام والأبقار. ويعود ذلك إلى قدرة أنسجة العظام العالية على امتصاص المواد الثقيلة. في حين لم يُلاحظ فرق معنوي في مستويات اليورانيوم بين الأغنام والأبقار، سواءً في أنسجة العظام أو العضلات. وتُعدُّ النتائج المُحصَل عليها أقل من ٣٥ بيكريل/كجم-١، وهي القيم العالمية المسموح بها وفقاً للجنة العلمية التابعة للأمم المتحدة (UNSCEAR)، وهي آمنة للاستهلاك.

الكلمات المفتاحية: الأبقار، الأغنام، العضلات، العظام، المواد المشعة.

Detection of the levels of radioactive contamination in the muscle and bone tissues of ruminants (cattle and sheep) in some governorates of Iraq

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Abstract:

Every living organism exposed to the natural radiation from water, air, or soil. Consequently, radiation can enter a plant through the soil it grows in, the water it is watered with, or both. Once the radiation hits the plant, it spreads to animals, which then spread to people. Because radiation is passed from animals to people through the food chain, eating meat can have negative health effects. In the present investigation, 200 samples of the bones and muscles of sheep and cattle that were available in Iraq were



examined for radioactivity., at a rate of 20 samples from each city (10 sheep samples, 10 cow samples). To determine the amounts of alpha emitter radiation released from the samples, which were gathered from ten Iraqi cities, the CR-39 nuclear trace detector was used. Samples taken from Mosul were found to contain the lowest levels of uranium, While the highest levels of uranium were found in samples taken from the cities of Baghdad, Tikrit, and Kirkuk, respectively. The results of the statistical analysis showed significant differences in uranium levels between Baghdad and Nineveh (12.496) and between Kirkuk and Nineveh (11.826) respectively, According to Scheffe's paired comparisons test. The results of the current study also showed a significant increase in uranium levels in bones (12.087 ± 1.829) compared to its levels in muscles (8.823 ± 1.455) at a significance level of (0.05) In both sheep and cattle. This is because the bones' tissue structure has a high capacity to absorb heavy substances. While there was no significant difference in uranium levels between sheep and cows, whether in bone or muscle tissue. The obtained results are lower than 35 Bq.kg^{-1} the global allowed values according (UNSCEAR), and are safe for consumption.

Keywords: Cattle, Sheep, Muscles, Bones, Radioactive materials.

Introduction.

Livestock, especially in Iraq, is of great importance to humans as economic and capital resources in the field of the agricultural economy in terms of local production of meat, hides, bones, dairy products, and in terms of economic and food development. The tremendous civilizational progress that the world is witnessing today has had many negative effects on the environment and on various living organisms, including humans. Therefore, is no secret there is a strong relationship between the environment and the organism (Levis and Pfennig, 2017), (Martins, 2024). One of the main problems resulting from industrial and urban development and the excessive increase in factories and various means of transportation is the increase in environmental pollution in its various forms and manifestations, including radioactive pollution in water, air and soil (Baxter, 1993), (Azeez et al., 2018). Which in turn automatically led to an increase in radioactive materials in plants, which are a source of food for both animals and humans. Consequently, radiation levels in food samples began to raise concerns and became an important matter since ingestion is most common way for radionuclides to enter in the living organisms (Sarcheshmeh et al., 2018). Since the bones and muscles of cows and sheep are thought to be the primary source of nourishment for humans, we chose to measure the amounts of radioactive elements in these tissues in this study. As



radionuclides penetrate animal tissues through radioactive decay through ingestion or inhalation, resulting in internal radiation doses, consumed food is thought to be the primary source of human exposure to radioactive elements (Luz Filho et al., 2016). The path of radiation exposure is defined as the path by which radioactivity is transmitted through the ecosystem and its three elements: air, water, soil, and the organisms that live in it, and ultimately to humans. This transmission occurs either directly, through external exposure to materials deposited on the ground or inhalation of suspended matter in the atmosphere, or through indirect transmission of radiation, which is through ingestion of food and water contaminated with radioactive materials (Howard, 2021), (Gasó et al., 2000). The methods of radioactive elements entering the food chain depend on direct concentration in edible parts, their deposition in the soil layers, and the drainage of water from the deep layers of the earth into water sources. These methods depend on the radionuclides half-lives, the time period for their deposition, the type of food and its production methods, as well as nature. The geology of the region and the influence of weather conditions are all important matters for studying environmental pollution and its transmission routes to humans (Beresford et al., 2007). Examining radioactive isotopes in the environment and the effect they leave on living organisms has attracted increasing attention, as the increasing concentration of radionuclides in the environment threatens the life of living organisms through the entry of radionuclides into food chain, there from plants to animals transfer, and finally to humans (Carter, 2012). There are different types of cells in its cells, and the level of effect varies depending on the treatment and the difference in radiation in terms of concentration and increasing the duration of treatment, which the more we ask them to affect and damage and record this damage. Then, the effect of cell cells in its various forms, its other effects such as cancers, infertility and deformities. Uranium enters the human body either through breathing when it is in the form of uranium oxide (UO_2) or particles suspended in the air that settle after inhalation in the lungs, or it enters through the digestive system after entering the food chain that humans eat, and thus its effect is directly to the kidneys. Causing increase in the uranium level of the blood. From this standpoint, the effect of radiation on the body divided into two basic groups: animals in this category that have brief exposure to high radiation doses, and the group of animals that are exposed to hidden doses of radiation for long periods of time, as high doses of radiation lead to the killing and damage of a large number of cells, causing damage organs and tissues of the body in a condition called acute radiation syndrome (ARS), as low doses of radiation do not cause direct damage to cells and tissues, it appears after several years, causing a state of chronic or long-term effects (Al-Shammari, 2016). Despite the many biological effects on the body, there is now a clear difference in the degree of vulnerability and sensitivity of different body tissues to radiation of all types. It has been found that there are cells that are



highly sensitive to radioactive materials and others that are less sensitive, and the reason for this is due to several factors and reasons, the most important of which is the ability of cells to divide and reproduce, Accordingly, it was observed that the cells and tissues most affected by radiation (at any dose) are embryonic stem cells, reproductive cells, bone marrow, lymphocytes, and blood cells, in addition to hair follicles, while non-dividing cells are less sensitive, Another factor affecting the response of the body's cells to radiation is the availability of oxygen. It has been found that tissues whose cells have high levels of oxygen are more sensitive to radiation. Another factor is age. It has been found that young and young tissues are more sensitive than old tissues. As noted, The chemical composition of tissues also determines the extent of cells' sensitivity to radioactive materials (Ochiai, and Ochiai, 2014). The effects of radioactive contamination were not limited to humans only, but also extended to include animals, especially sheep and cows, as an unusual increase in fetal deformities and the birth of structurally deformed calves and sheep was observed, in addition to a decline in the ability of animals to fertilize. This leads us to say that radioactive contamination is not limited to Air pollution includes soil, water, and plants, and this is what makes radioactive pollution include all components of the environment and later enters the human food chain (Partow ,2008) .In this test, three types of radioactive elements were measured: uranium, radium, and radon gas, as uranium is found in the earth's crust and in most types of rocks. It is also present in soil, water, animals, plants, and the human body, and is transmitted to humans through water and plants, contributing to the internal radiation dose. The rate of daily human exposure to uranium through food is 1.7 $\mu\text{g/d}$, whereas the permissible limit for the dose of uranium is about 1.48 mg. (Al-Hamzawi et al., 2014), (IAEA, 1998-2024).

The present study aims to measure the concentration of radioactive uranium emitted from the dissolution of radioactive elements present in the bone tissue and muscles of ruminants in selected Iraqi governorates. CR-39 nuclear trace detector method was adopted for measurement.

Materials and Methods.



Two hundred different samples of bovine and sheep bone and muscle were collected from the local market from various Iraqi cities, 10 bone samples and 10 muscle samples from each city. After sample collection, preparation, and mass measurement, the samples were placed in a plastic cylindrical container at a fixed height (3 cm) for the muscle and bone samples. The nuclear detector was placed in an area (1 x 1 cm²) and secured with double-sided tape at the bottom of the cylinder lid. The CR-39 plastic track detector can detect alpha particles of all energies emitted by radon gas. Some alpha particles reach the detector and leave traces, and the number of traces is proportional to the average radon concentration. The distance between the sample surface and the detector was 7 cm, as illustrated in Figure 1. The containers were sealed with a tight lid and labeled with the sample type, mass, and storage date, leaving them for 60 days. The reagents were then removed and scraped with 6.25N sodium hydroxide solution, followed by a water bath at 70 ± 1 °C for three hours to detect any traces. After the scraping period, the reagents were removed from the solution and washed thoroughly with distilled water to remove any remaining residue from the scraping solution. The surface of the detector was then dried with soft paper, after which the microscopic observation process began, where an optical microscope was used to count the strong traces zoom 400X (Kheder, 2023), (Azeez et al., 2024).

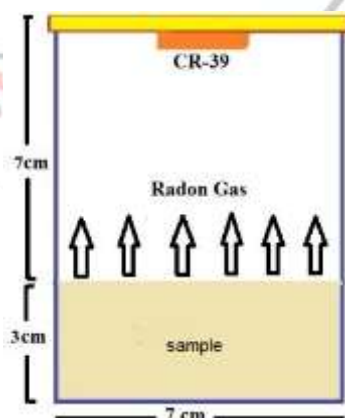


Fig 1. Plastic cylinders container.

1- Radon concentrations.



The amount of radon in the air space inside the container C_{Rn} in units of $[Bq/m^3]$ was calculated via the formula (Chibowski and Gladysz, 1999).

$$C_{Rn} = \rho(KT)^{-1}$$

where $K=0.05916 [Tr/cm^2.d/Bq.m^{-3}]$ is the calibration factor of the CR-39 detector, T represents the exposure time 60 [days], and ρ is the track density (Kheder and Azeez 2022).

2- Radium concentrations.

The radium concentration $C_{Ra} [Bq/kg]$ was calculated via the following equation (Khan et al., 2012).

$$C_{Ra}(Bq.kg^{-1}) = (\rho/(KTe))(HA/M)$$

where A , M , and H represent the sealed container cross-sectional area in meters, the sample mass in kilograms, and the sample surface to detector distance in meters respectively, and where Te denotes the effective exposure period during the day calculated from the formula.

$$Te = [T - \lambda_{Rn}^{-1}(1 - e^{-\lambda_{Rn}T})]$$

(Kheder and Azeez, 2024)

where λ_{Rn} is the radon decay constant $0.1814 [day^{-1}]$.

3- Uranium concentrations.

The uranium activity concentration is expressed in units of $[Bqkg^{-1}]$, in the form.

$$Ac = \lambda_U N_{avo}. C_U(a_U)^{-1} \quad (\text{Howard, 2021})$$

where $\lambda_U = 4.883 \times 10^{-18} [s^{-1}]$ is the uranium decay constant, $N_{avo} = 6.02 \times 10^{23}$ [atom

/Mol] is the number of Avogadro, a_U is the uranium mass number 238, and The uranium content; was determined by.

$$C_U = W_U / W_S \quad (\text{Luz Filho et al., 2016})$$

W_S represents the wight of samples in [gm], C_U represents the uranium concentration in $[\mu g/g \text{ (ppm)}]$ units, W_U is the uranium nuclei wight in the samples measured in micrograms $[\mu g]$ determined from equation.

$$W_U = a_U N_U / N_{avo}.$$

(Sarcheshmeh et al., 2018).



where N_U is the uranium atom number was computed from the equation of the equilibrium between the uranium and its daughter (secular activity equilibrium between the uranium with its daughters and the radon concentration measured with the CR-39 detector) via the following equation (Kheder et al., 2019).

$$\lambda_U N_U = \lambda_{Rn} N_{Rn} \quad (\text{Azeez et al., 2018})$$

where N_{Rn} is the number of radon atoms calculated from the formula.

$$\lambda_{Rn} N_{Rn} = A_{Rn}$$

(Thannon et al., 2024).

The activity of radon A_{Rn} in a sample may be calculated (Cember and Johnson, 2009)

$$A_{Rn} = C_S V$$

(Kheder et al., 2023)

where V is the volume of the sample $V = \pi r^2 L = 115.4 \times 10^{-6} \text{ [m}^3\text{]}$, the thickness $L = 0.03 \text{ [m]}$, and the radon dosimeter radius is $r = 0.035 \text{ [m]}$, and C_S represents the radon concentration released inside in the samples $[\text{Bq/m}^3]$. The radon concentrations released inside the samples were determined via the following formula (Kheder et al., 2020).

$$C_S = \lambda_{Rn} C_{Rn} H T (L)^{-1}$$

(Martins, 2024)

T represents the exposure time 60 [days], L represents the sample thickness 3 [cm], and H represents the air gap height in the plastic can 7 [cm].

Results and Discussion.

Results of bone samples of cow and sheep listed in the table 1, for muscle samples listed in table 2. The uranium concentrations of bone samples demonstrated in Fig 2., for muscle samples detailed in Fig 3.

Table (1) Radon concentration in the sample C_{Rn} , Radium concentration in the sample C_a , Uranium concentration C_U , in cattle bone and sheep bone samples.

No.	Region	Cattle bone			Sheep bone		
		C_{Rn} (Bq.m^{-3})	C_a (Bq.Kg^{-1})	C_U ($\mu\text{g.Kg}^{-1}$)	C_{Rn} (Bq.m^{-3})	C_a (Bq.Kg^{-1})	C_U ($\mu\text{g.Kg}^{-1}$)



1.	Baghdad	61.707	8.175	13.74	67.452	8.838	14.855
2.	Biji	52.275	6.849	11.51	60.707	7.954	13.370
3.	Tikrit	60.707	7.954	13.37	61.807	8.396	14.112
4.	Kirkuk	57.334	7.512	12.62	62.393	8.617	14.484
5.	Mosul	33.726	4.419	7.427	43.844	5.744	9.656
6.	Babylon	45.530	5.965	10.02	52.275	6.849	11.513
7.	Najaf	48.903	6.407	10.77	53.961	7.070	11.884
8.	Al-Qadisiya	50.589	6.628	11.14	55.648	7.291	12.255
9.	Diyala	55.648	7.291	12.25	62.393	8.175	13.741
10.	Karbala	43.844	6.407	10.77	52.275	7.512	12.627
Min		33.726	4.419	7.427	43.844	5.744	9.656
Max		61.707	8.175	13.74	67.452	8.838	14.855
Mean		50.926	6.760	11.361	57.275	7.644	12.849

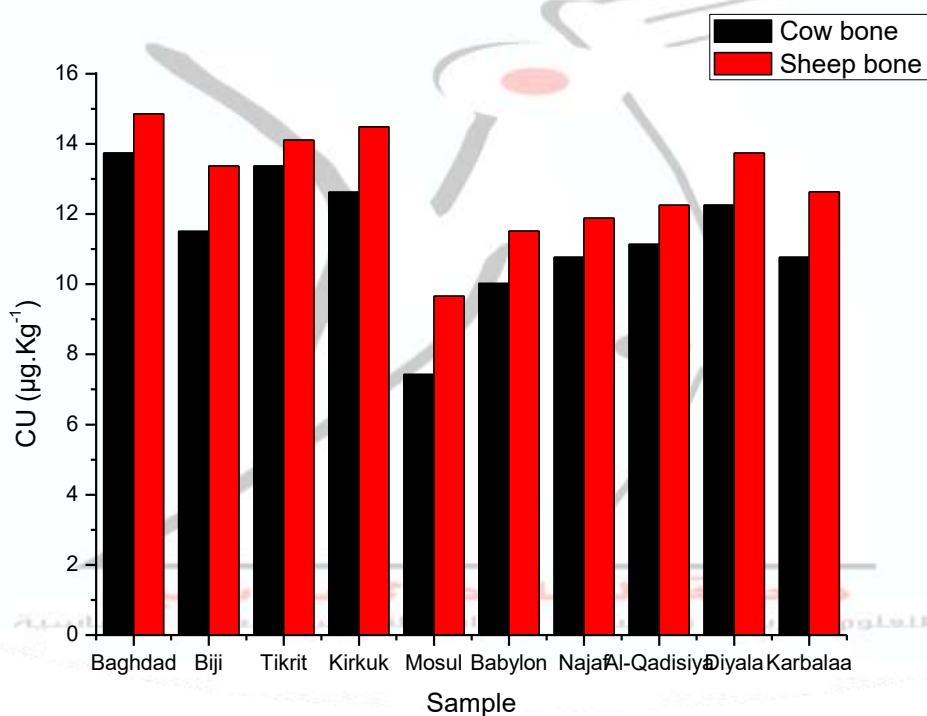


Fig 2. The uranium concentrations of bone samples

Table (2) radon concentration in the sample C_{Rn} , radium concentration in the sample C_a , uranium concentration C_U , in cow muscle and sheep muscle samples.

No	Sample	Cattle muscle			Sheep muscle		
		C_{Rn} (Bq.m ⁻³)	C_a (Bq.Kg ⁻¹)	C_U (µg.Kg ⁻¹)	C_{Rn} (Bq.m ⁻³)	C_a (Bq.Kg ⁻¹)	C_U (µg.Kg ⁻¹)



			١)			١)	١)
1.	Baghdad	60.707	6.540	10.993	58.334	6.186	10.398
2.	Biji	55.848	5.933	9.904	48.903	5.126	8.616
3.	Tikrit	55.648	6.186	10.398	57.334	6.010	10.101
4.	Kirkuk	57.334	6.363	10.696	53.961	5.656	9.507
5.	Mosul	38.785	4.065	6.833	30.353	3.181	5.348
6.	Babylon	42.157	4.249	7.319	42.157	4.419	7.427
7.	Najaf	47.216	4.949	8.319	45.530	4.772	8.022
8.	Al-Qadisiya	50.589	5.303	8.913	47.216	4.949	8.319
9.	Diyala	55.648	5.833	9.804	52.275	5.479	9.210
10.	Karbalaa	47.216	5.101	8.613	40.471	4.595	7.724
Min		38.785	4.065	6.833	30.353	3.181	5.348
Max		60.707	6.540	10.993	58.334	6.186	10.398
Mean		51.114	5.452	9.179	47.653	5.037	8.467

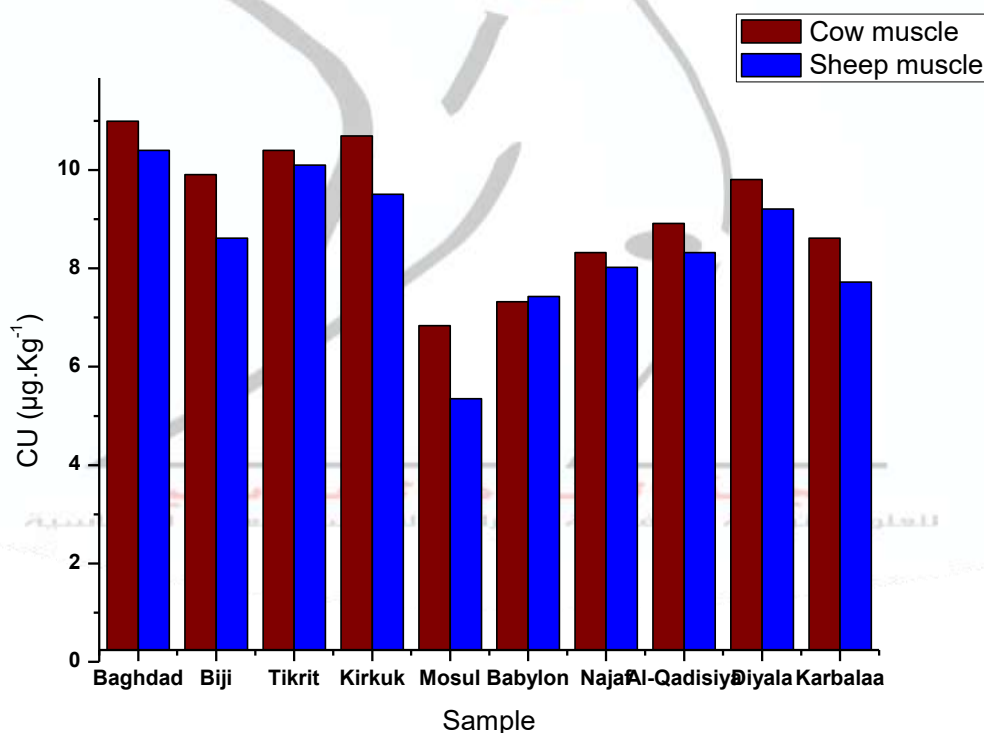


Fig 3. The uranium concentrations of muscles samples.

The current study included several aspects, namely (determining radiation levels in each governorate and then the highest and lowest levels of



radiation, determining the difference between radiation levels between bones and muscles, determining the difference in radiation levels between sheep and cows in cows that are higher). As presented in Table 1 and Figure 2, the obtained results were 7.427 - 13.74 $\mu\text{g.Kg}^{-1}$ with the average 11.361 $\mu\text{g.Kg}^{-1}$ for cow bone, 9.656- 4.855 $\mu\text{g.Kg}^{-1}$ the average 12.849 $\mu\text{g.Kg}^{-1}$ for sheep bone, as in table 2 and figure 3 the results 6.833- 10.993 $\mu\text{g.Kg}^{-1}$ the average 9.179 $\mu\text{g.Kg}^{-1}$ for cow muscle, 5.348- 10.398 $\mu\text{g.Kg}^{-1}$ with the average 8.467 $\mu\text{g.Kg}^{-1}$ for sheep muscle. The results lower than 35 Bq.kg⁻¹ according (UNSCEAR)[27]. The results of the current study suggest that the highest levels of radioactive materials (radon, radium, and uranium) in all samples (bones and muscles of both cows and sheep) were in Baghdad. After conducting statistical analysis using variance analysis and the Scheffé test, results revealed significant differences in uranium levels as a primary indicator of radiation levels. The results indicated significant differences in radiation levels between the cities of Iraq, with the highest differences observed between Mosul and Baghdad (12.496), followed by Mosul and Kirkuk (11.826), which is close to the difference between Mosul and Tikrit (11.975). Meanwhile, the lowest differences were between Baghdad and Kirkuk and Baghdad and Tikrit (7.316, 7.204) respectively, and so on. The reason may be attributed to the presence of oil refining fields there, which causes an increase in In the levels of radioactive materials in water, soil, and animal bodies, according to previous studies (Desouky, 2021),(Hilal et al, 2014). Also, in another study by researchers, waste resulting from the oil and gas industries generates high levels of radiation, especially radon gas, which has a high ability to dissolve in the organic part of petroleum in gas plants, in addition to the presence of a high concentration of radioactive radium isotopes, which exceeded The internationally permissible limit according to the decisions of the World Health Organization and the International Atomic Energy Agency (ElAfifi et al., 2023). It was noted that there was an increase in the levels of radioactive materials in Baghdad, which may be due to the high population density, which is estimated at about 9 million people in a land area of “4,555 km²,” according to statistics from the Ministry of Planning - Central Statistical Organization (CSO) (Elias, 2023). In another



study, it was reported that high population density, in addition to the increase in industrial activities in urban areas, increases the thermal and radioactive materials in the environment, especially the quality of drinking water, and increases its contamination with radioactive materials (Imam et al., 2024). The reason may also be attributed to the type of feed that may be contaminated with radioactive materials. A study by researchers in New Mexico City stated that radioactive materials may reach the tissues of sheep through the food chain contaminated with radioactive materials, as eating feed contaminated with radionuclides increases radiation levels. In the bodies of these animals (Nakamura et al., 2017). It was also noted in this study that the lowest levels of radionuclides (for all samples) were in Mosul. The reason for this may be attributed to the lack of radioactive contamination of water and soil, as a study by researchers in Mosul reported that radiation levels in the water were low and much lower than the index set by the organization. World Health Organization, where values were less than 30 micrograms/L (Ali et al., 2024), (Azeez, 2023). Also, the reason for the low concentration of uranium in the Mosul samples may be that the feed used to feed these animals is of high quality and has low levels of radioactive materials. A study confirmed that cattle eating feed contaminated with heavy metals and radioactive materials increases the levels of radioactive materials in their bodies and tissues different. A study by researchers showed low levels of radioactive materials in feed found in Mosul, which are less than the internationally permissible limit, as radionuclides are transmitted from soil, water, and plants to animals in general through food, ingestion, and absorption (Kheder, 2023). The results of the current study also showed that the levels of radioactive materials are higher in the bones of both cattle and sheep (12.087 ± 1.829) compared to their concentrations in muscles (8.823 ± 1.455), which is similar to the researchers' study (Mathloom et al., 2021). In the report of the United Nations Scientific Committee on the Effects of Atomic Radiation for the year 2016 submitted to the General Assembly, it indicated that the greatest value of radium gas was concentrated in the bones of sheep, in which radioactive materials are concentrated. It also revealed that bone cells are considered the main cellular targets for the



combination of uranium and its concentration in the body, as well. A study was conducted on the distribution of uranium in the bodies of a group of people exposed to high levels of uranium in drinking water. It found that the highest levels of uranium were in the bones by (75%) in the skeleton, 20% in the muscles, and 16% in the fat, but it was (0.99-0.40%) in the brain. Similar results were also observed in other animals, such as dogs and mice. The highest concentration of uranium was found in the bones of these animals. The 2016 report of the United Nations Scientific Committee on the Effects of Atomic Radiation also illustrated that older animals were more poisoned and had higher concentrations of uranium compared to young animals (United Nations Scientific, 2016). In a study by researchers, the damage resulting from radiation depends primarily on the type of tissue, and that the damage occurring in the bones is caused by a defect in the structural structure of the collagen network. However, the results of this revealed no significant differences in uranium levels between sheep bones (12.849 ± 1.587) and cow bones (11.361 ± 1.829). Although there were higher levels of uranium in cattle muscles (9.179 ± 1.417), compared to its levels in sheep muscles (8.467 ± 1.477), there was no significant difference and the reason may be attributed to the fact that both are ruminants. Slight differences in uranium levels in the muscles are due to the age difference, meaning that the samples may be from old cattle. This finding differs from those reported by (Donaubauer et al., 2020), (Sauer et al., 2022). Differences that were observed at the levels of radioactive materials in the muscles of cows were higher than their levels in the muscles of sheep, and the reason may be attributed to the ages of the animals from which the samples were taken, as it found that in old animals the levels of radioactive materials are higher than small animals (Al-Hamzawi, 2017).

Conclusions.

- 1.This study finds an increase in the levels of radioactive materials radon and uranium in the bones and muscles of both cattle and sheep in various Iraqi governorates.
- 2.This study uncovers remarkably higher levels of radiation across all samples whether in cows or sheep in the governorates situated oil refineries,



including Tikrit and Kirkuk, than those which are far from such industries, such as Mosul. This indicates that oil industry contributes to increasing concentrations of radioactive materials.

3.The study indicates that radiation levels (uranium) were higher in bone tissue than in muscle tissue across all samples. Notwithstanding these levels, there were no significant differences in radiation levels in the bones and muscles of cows compared to those in sheep.

Statements and Declarations

Conflict of Interest: The authors declare no conflicting interests.

Ethics Approval: The authors used no animal-based or human-based projects or experiments.

Author Contribution

The authors contributed significantly to conception and design, data collection, analysis, and interpretation, work drafting, critical revisions for significant intellectual content, and publication approval.

Data Availability: There is no data contained or used in this research

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