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Measuring uranium concentration in Um Qasr district, southern Iraq, in two different ways

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ABSTRACT

The current study uses ICP-MS (inductively coupled plasma mass spectrometry) and SSNTDs (solid-state nuclear track detectors) to measure uranium concentrations in 12 surface soil samples from selected locations in Um Qasr in the Southern Basrah governorate. In the ICP-MS technique, uranium concentrations ranged from 0.6 to 2.2 ppm, with an average value of 1.3 ppm. In the SSNTDs technique, uranium concentrations ranged from 1.4 ± 0.3 ppm to 1.6 ± 0.2 ppm, with an average value of 1.5 ± 0.2 ppm. The results obtained from the soil samples were within the permissible limits recommended by the UNSCEAR Committee of 11.7 ppm.

1. Introduction

Uranium is a silvery, shiny metal with a long half-life as a natural radionuclide. Uranium is the heaviest element in nature. It is one of the most significant environmental dangers due to its radioactivity. Uranium and its compounds are very toxic and threaten human health and the environment (Salman and Algrifi, 2022a). Uranium is a common element that may exist as a solid, liquid, or gas. It may be contained in food, water, soil, rocks, natural materials, and the environment. When uranium combines with other elements, it easily creates uranium oxide, silicates, hydroxides, and carbonates (Salman and Algrifi, 2022b). Their solubility determines the physiological action of uranium compounds. The chemical toxicity of soluble uranium is regulated, but the radiological properties of insoluble (less soluble) uranium are not. However, because of its slow absorption via the lungs and long retention time in human tissues, it will significantly harm internal organs through radiological damage (cancer mortality risk) rather than a chemical hazard to the kidneys (Todorov and Ilieva, 2005). Uranium may enter the human body through a variety of pathways. It enters the body either by breathing uranium-containing dust particles, drinking uranium-contaminated water, or indirectly through the food chain from the fertile soil layer (Al-Hamzawi et al., 2015). This study aims to examine the uranium content in selected soil samples taken from various residential, industrial, and agricultural sectors in the Um Qasr region in southern Iraq using ICP-MS technology and neutron activation technique for nuclear pathway detectors CR-39. This study was conducted in the Um Qasr region due to the lack of previous research and the establishment of a database of uranium concentrations in soil samples.

The study site was chosen because of its importance in terms of the use of many weapons in it, and these two techniques were chosen to obtain the best results.

1.1. Toxicity of uranium

The chemical and radiological consequences of uranium and its derivatives are hazardous. The renal and respiratory effects of uranium exposure in humans and animals are usually attributed to its chemical properties. In contrast, hypothetically, probable excess malignancies are generally induced by its radiation properties (Dockery et al., 1993).

1 Chemical toxicity of uranium

The chemical toxicity of an elemental compound is related to the substance's interaction with the biochemical processes of the human body. Some of these interactions may be beneficial or even required, whereas others may be detrimental (US Department of Health and Human Services, 1990). Uranium's toxicity is a crucial aspect. Its chemical and radioactive characteristics determine the harmful effects of uranium exposure. The toxicity of uranium compounds is directly related to their solubility; the more soluble a uranium compound is, the more poisonous it is; soluble uranium compounds are harmful when breathed in or eaten. UF_6, $UO_2(NO_3)_2$, UO_2Cl_2, UO_2F_2, and carbonates

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Table 1
The uranium concentration of soil sample Um Qasr by ICP -MS.

Sites numbers	Sites	Uranium Concentration in ppm
S1	Um Qasr farm 1	1.6
S2	Um Qasr farm 2	1.1
S3	Um Qasr farm3	0.6
S4	Um Qasr farm4	1.0
S5	Um Qasr farm5	0.9
S6	Um Qasr farm6	0.9
S7	Um Qasr Center	1.3
S8	Al Hadaama	1.2
S9	Khor Al Zubair Center	2.2
S10	Khor Al Zubair Farm1	1.7
S11	Khor Al Zubair Farm2	1.2
S12	Khor Al Zubair Farm3	1.9
Average		1.3
max		2.2
min		0.6

2 Table (2) presents uranium concentrations for soil samples in Um Qasr district measured using the irradiation method (the CR-39 detector). The uranium concentrations for soil range from 1.4 ± 0.3 ppm to 1.6 ± 0.2 ppm, with an average value of 1.5 ± 0.2 ppm. The highest concentration for uranium, 1.6 ± 0.2 ppm, was observed, as shown in Figure (1), which indicates that this site is higher than other regions, whereas the lowest value is 1.4 ± 0.3 ppm. The average value of specific activities is 18.71025 Bq/kg, with the maximum and minimum values of 28.0345 Bq/kg and 8.0275 Bq/kg, respectively.

Table 2
Uranium Concentration and specific activities in Um Qasr in soil by SSNTDs.

Sites numbers	Sites	Uranium Concentration (ppm)	Specific Activity (Bq/kg)
S1	Um Qasr farm 1	1.62 ± 0.12	20.007
S2	Um Qasr farm 2	1.4 ± 0.3	17.29
S3	Um Qasr farm3	0.65 ± 0.12	8.0275
S4	Um Qasr farm4	1.3 ± 0.3	16.055
S5	Um Qasr farm5	0.94 ± 0.05	11.609
S6	Um Qasr farm6	0.97 ± 0.05	11.9795
S7	Um Qasr Center	1.7 ± 0.2	20.995
S8	Al Hadaama	1.83 ± 0.10	22.6005
S9	Khor Al Zubair Center	2.27 ± 0.21	28.0345
S10	Khor Al Zubair Farm1	1.8 ± 0.3	22.23
S11	Khor Al Zubair Farm2	1.6 ± 0.2	19.76
S12	Khor Al Zubair Farm3	2.1 ± 0.2	25.935
Average		1.515 ± 0.17	18.71025
max		2.27 ± 0.21	28.0345
min		0.65 ± 0.12	8.0275

(Craig, 2001) are the most soluble compounds of uranium. When uranium hexafluoride (UF_6) is emitted into the air, it quickly interacts with water vapor, forming uranium oxyfluoride and hydrogen fluoride.

Because the chemical reaction produces heat, a plume of these chemical compounds may become buoyant and ascend. The substances produced by the result cause three toxic consequences:

(a) The uranyl complex contains uranium, a heavy metal toxin that can harm the kidneys.
(b) Hydrogen fluoride is an acid that, when concentrated, may inflict acid burns on the skin or lungs;
(c) If excessive amounts of fluorides (uranium oxyfluoride and hydrogen fluoride) are consumed, fluoride poisoning can occur.

2 Radiological **toxicity**

Dosage of radiation is critical in radiation protection (ionizing radiation energy absorbed per unit mass by a target organ or tissue). The ability of various radionuclides' ionizing radiation to infiltrate materials varies depending on the kind of radiation and its energy. External and internal radionuclide exposures are also possible, and their relative importance varies depending on the type of radiation and radionuclides involved. Because of their massive size and charge, alpha particles quickly lose their kinetic energy and have little penetrating power; hence, the health repercussions of external exposure are limited to skin contact. As a consequence, assuming no uranium redistribution or sorption into the epidermis, the penetrating range for an alpha particle from ^{238}U in soft tissue is approximately 28 μm. Alpha particles cannot penetrate the outer layer of skin when discharged outside the body and do not represent a hazard. Beta particles can penetrate the outer layers and deliver a localized dose when they come into contact with the skin. Gamma radiation can penetrate further into the body and deposit energy in interior organs, depending on the strength of the gamma radiation emitted. The precise mechanisms by which radiation interacts with biological materials are still being investigated. However, the energy of radiation may injure cells by causing changes in deoxyribonucleic acid (DNA). This physiologically necessary molecule governs cell structure and function and is found mainly in cell nuclei, and ionizing radiation has been shown to damage individual chromosomes. DNA damage or fragmentation is the most prevalent negative effect of low-level ionizing radiation exposure. Viable cells heal the damage; errors might produce gene mutations or chromosomal abnormalities. The risk of lung cancer has been connected to alpha particle radiation from ^{222}Rn and its decay products, which occur in uranium mines due to the dissolution of ^{238}U. Inhaled particle irradiation of the lungs is principally responsible for the enhanced toxicity of insoluble compounds. The ability of various radionuclides' ionizing radiation to infiltrate materials varies depending on the radiation emitted and its energy (Cléro et al., 2019; Zarkadas et al., 2001).

2. Materials and methods

1 Collection of soil samples

In this study, 12 soil samples were obtained from 12 separate places in southern Iraq's Basrah governorate, one from each. Soil samples were taken at the depth inside the soil of 15 cm (at one depth to obtain soil free of impurities). The research areas, which included residential, agricultural, and industrial zones, are depicted in Table 1. After cleaning and removing stones, pebbles, and root sections from 12 soil samples, they were dried in an oven at 70 °C for a few hours before being powdered and using a special sieve with a diameter of 75 μm for the sieve holes (Salman and Algrifi, 2022c).

2 Analytical Determination of Uranium

The presence of uranium in the soil is noteworthy due to its extreme chemical toxicity. This section summarizes several analytical techniques used in this research to determine uranium in different soil samples. Among the most used methods are:

2.1. Inductively Coupled Plasma Techniques/ICP-MS

Inductively Coupled Plasma Techniques have the potential to be highly effective techniques for identifying and studying trace and ultra-trace components. It's an intriguing alternate way of determining uranium. This approach offers various advantages, including a rapid analysis time and low detection limits. Low sample consumption with little spectrum interferences (Himri et al., 2000). ICP-MS has been the technique of choice in many analytical laboratories in recent years for providing the accurate and exact measurements required for today's demanding applications and the required lower limits of detection. Mass spectrometry has high sensitivity as well as accuracy. In ICP-MS, Argon

Fig. 1. Uranium concentration in soil samples from Um Qasr.

gas is used to create plasma or gas containing ions, electrons, and neutral particles, which are then used to atomize and ionize the elements in the sample matrix. These ions are then passed via a succession of apertures (cones) into a high vacuum mass analyzer, where the element isotopes are identified based on their mass-to-charge ratio. The strength of a particular peak in the mass spectrum is related to the quantity of the elemental isotope present in the original sample (Chan and Hieftje, 2013). A high-temperature ICP (Inductively Coupled Plasma) source is combined with a mass spectrometer in an ICP-MS. The atoms of the elements in the sample are converted to ions by the ICP source. The mass spectrometer then separates and detects these ions. Ions created in the plasma (at atmospheric pressure) flow via a sampler and skimmer cone assembly to a highly evacuated MS region in ICP-MS. Ions are focused on an ion optic system, which monitors the mass-to-charge ratios of the ions. The common quadrupole MS works as a mass filter, allowing only a specific mass-to-charge ratio of ions to get through to the detector. The ions moving through the MS are deflected to an ion detector, which transforms the ionic energy into electric energy, allowing the analytic concentration to be measured (Kalinitchenko, 2003).

2.2. Neutron induced fission track technique

Many researchers have used the neutron-induced approach to determine uranium in solid materials. The ^{235}U (n,f) reaction is used in this approach. The primary idea behind this approach is to employ the ^{235}U (n,f) reaction, which has a fission cross-section of 4.2 neutrons. The soil samples were dried in an electric oven at 70 °C for 6 h, after which they were ground with a grinder. (0.5 g) powder soil was combined with (0.1 g) methylcellulose as a binder. A manual piston with a diameter of 1 cm and a thickness of 1.5 mm was used to crush the mixture into a pellet. A CR-39 track detector with a size of (1.5 × 1.5 cm) was coated on both sides of the pellets. The pellets were subsequently irradiated in a paraffin wax dish for 7 days at a distance of 5 cm from the neutron source (^{241}Am-^{9}Be) source with a flux of (2.3×10^5 n/cm^2. s) to cause latent damage on the detector due to the ^{235}U reaction (n,f). After the irradiation technique, the detectors are etched in a (6.25 N) NaOH solution at a temperature of 70 °C for (6 h). The detectors are removed at the end of the etching process, washed in distilled water, and dried. The optical microscope was then used to count the number of alpha tracks (Salman and Algrifi, 2022d). As a result, if an unknown soil sample and a known uranium standard are both irradiated and brought into contact with the detector at the same time in the reactor with the same integrated flux of thermal neutrons, the uranium content of the unknown sample is calculated after chemical etching by calculating and comparing the total number of thermal neutrons in the reactor. Observed fission routes arising in detectors owing to uranium in samples and expected result (n, f) nuclear reaction in the reactor. This technique makes use of SSNTDs. Solid-state nuclear trajectory detectors have become essential instruments in many fields of research and technology, including neutron dosimetry, gamma ray detection, cosmic rays, heavy ions, and nuclear physics. SSNTDs have been adjusted and evaluated in several laboratories to increase detection sensitivity, charge accuracy, and power (Durrani and Bull, 2013).

3. Results and discussion

1 Table 1 presents uranium concentrations for soil samples measured by ICP/MS. The uranium concentrations range from 0.6 ppm to 2.2 ppm, with an average value of 1.3 ppm. The maximum uranium concentration of 2.2 ppm was in station number S9. The minimum value of 0.6 ppm was observed in station number S3 as shown in Fig. 1.

4. Conclusion

Uranium content in soil samples was determined using ICP-MS and SSNTDs. This study's findings revealed that uranium concentration increases in industrial regions more than in residential areas because the industrial areas contain repair workshops and the disposal of industrial wastes in them, thus increasing the concentration of this element in these areas. However, the results were within acceptable levels and not cause for concern (the levels set by the World Health Organization).

CRediT authorship contribution statement

Mostafa A. Algrifi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Thaer M. Salman:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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