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دراسة تركيز السيزيوم 137 في التربة السطحية بمنطقة الزاوية في ليبيا أثره الإشعاعي

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الملخص:

إن التركيزات العالية للعناصر المشعة مؤشرّ على احتمالية وجود خطر إشعاعي، ويعد السيزيوم 137 أحد أهم هذه العناصر المشعة، وتهدف هذه الدراسة إلى تقييم تركيز نظير السيزيوم 137، ومدى تأثيره الإشعاعي بمنطقة الزاوية في ليبيا. تم جمع 19 عينة تربة سطحية من مواقع مختلفة في سبتمبر 2024 داخل الحدود الإدارية لمدينة الزاوية والتي شملت أيضاً مواقع قريبة من مصفاة الزاوية لتكرير النفط، وجهزت العينات بالتجفيف والغربلة والحفظ في أكواب مارينيللي لمدة 30 يوماً. وحددت مستويات النشاط الإشعاعي باستخدام مطياف أشعة (جاما) المزود بكاشف الجرمانيوم عالي النقاوة ذي نظام محوري نوع (GR6022). وتم حساب النشاط الإشعاعي للسيزيوم 137 من ذروة الطاقة 661.66 keV، وتم استخدام معاملات التحويل القياسية للحصول على معدلات الجرعة الممتصة والجرعات السنوية الفعالة.

تم اكتشاف السيزيوم 137 في 9 عينات (بنسبة 47.37%)،وتراوحت تركيزات نشاطه الإشعاعي بين 0.133 و 2.4037 بيكريل/كجم، بمتوسط حسابي بلغ 06727 بيكريل/كجم. إن أعلى القيم المسجلة لم تكن من العينات بالقرب من المصفاة، مما يشير إلى أن مصدرها هو تساقط إشعاعي ناتج عن حوادث نووية سابقة وليس تلوثًا محلياً. وتعد معدلات الجرعة الممتصة الناتجة (0.0041 – 0.0721 نانو جراي/ساعة) والجرعات السنوية الفعالة (0.0050 – 0.0109 ميكرو سيفرت/سنة) أقل بكثير من الحد المسموح به للجرعة للعامة والذي يبلغ 1 ميللي سيفيرت/سنة، وهي ضئيلة جداً مقارنة بالإشعاع ذي الخلفية الطبيعية.

الكلمات المفتاحية: تركيز، سيزيوم 137، كاشف الجرمانيوم، تربة سطحية، الفاعلية الإشعاعية.

Studying the Concentration and Radiological Impact of Cesium-137 in Surface Soils of Al-Zawiya, Libya

A B S T R A C T:

High concentrations of radioactive elements are an indicator of the risk of radioactivity. The cesium radionuclide is one of the most important radionuclides. This study investigates the concentration and radiological impact of Cesium-137 (Cs-137) in surface soils within the Al-Zawiya region, Libya. A total of 19 soil samples were collected from various locations in September 2024, including areas near the Al-Zawiya oil refinery. Samples were prepared by drying, sieving, and sealing in Marinelli beakers for 30 days. Activity concentrations were determined using gamma-ray spectroscopy with an n-type HPGe coaxial detector system (GR6022). The specific activity of Cs-137 was calculated from the 661.66 keV photopeak, and corresponding absorbed dose rates and annual effective doses were derived using standard conversion factors.

Cs-137 was detected in 9 samples (47.37%), with activity concentrations ranging from 0.1338 to 2.4037 Bq/kg and a mean of 0.6727 Bq/kg. The highest values were not associated with refinery infrastructure, indicating a fallout origin from historical nuclear events rather than local contamination. The resultant absorbed dose rates (0.0041 - 0.0721 nGy/h) and annual effective doses (0.0050 - 0.0109 µSv/year) are orders of magnitude below the public dose limit of 1 mSv/year and negligible compared to natural background radiation.

Keywords: Concentration, Cs-137, Germanium detector, Surface soil, Specific activity.

Introduction:

Soil is composed of a wide variety of minerals, some of which contain naturally occurring radioactive elements that emit ionizing radiation capable of affecting both ecosystems and human health. Natural radioactive sources include the decay of uranium (U−238), thorium (Th−232), and potassium (K−40), as well as cosmic radiation. In recent decades, anthropogenic radioactive elements have also been introduced into the soil, primarily through nuclear weapons testing, industrial processes, and nuclear accidents [1–3]. Globally, natural sources dominate human radiation exposure, contributing approximately 80% of the total annual effective dose (~2.4 mSv), whereas anthropogenic activities account for the remaining 20% (~0.6 mSv) [4]. Among artificial radionuclides, Cesium−137 (Cs−137) is of particular concern due to its environmental persistence and health risks. Following nuclear events, Cs−137 spreads worldwide through atmospheric currents, with the highest concentrations found near historical nuclear weapons testing sites (e.g., the Nevada Test Site in the United States and the Semipalatinsk Test Site in Kazakhstan) and regions impacted by major nuclear accidents, such as Chernobyl (1986) and Fukushima (2011). The Chernobyl disaster released >37 PBq of Cs−137 into the environment [5], while the Fukushima accident emitted ~17 PBq [6]. Due to its long−range atmospheric transport [7], Cs−137 is now ubiquitous in surface soils globally [8]. The health hazards of Cs−137 stem from its long half−life (30.2 years), high solubility, and chemical similarity to potassium, which promotes its uptake into biological systems. Upon ingestion or inhalation, Cs−137 distributes uniformly throughout the body, exposing tissues to beta and gamma radiation that can damage DNA and increase cancer risk, particularly in the thyroid, bone marrow, and muscle tissues [8–9]. Chronic exposure has also been linked to cardiovascular disease, developmental abnormalities in children, and immune dysfunction [10,11]. Consequently, monitoring Cs−137 in soil is critical for public health protection and environmental risk assessment.

Studies on Cs−137 in Libyan soils have reported wide variations across regions and time periods. In northwestern Libya, concentrations ranged from 0.975 to 1.720 Bq/kg in a 2001 study [12], while more recent measurements in the Western Mountains (2024) showed slightly higher variability, with 0.929–2.325 Bq/kg in Zintan and 0.943–2.360 Bq/kg in Al−Awiniya [13]. Strikingly, a 2018 study near Al−Bayda city detected significantly elevated levels (4–31 Bq/kg) [14], suggesting potential localized contamination.

In contrast, northeastern regions exhibited far lower concentrations: 0.0118–0.2046 Bq/kg in Gandula (2020) [15] and 0.058–1.139 Bq/kg in Agdabya (2025) [16]. These disparities underscore substantial regional differences in Cs-137 deposition and retention across Libya, highlighting the need for further investigation. This study examines the deposition levels and spatial distribution of Cs-137 in soil samples collected near fuel tanks of Al-Zawiya oil refinery that located within the administrative boundaries of Al-Zawia city (Libya) in Sep, 2024. The research aims to establish baseline data for this significant radionuclide, assess potential contamination sources, and contribute to Libya's national radiation monitoring efforts.

Materials and methods:

A total of 19 soil samples were collected from different areas within the administrative boundaries of the city of Al-Zawiya, which approximately lies 40 kilometers west of the Libyan capital, Tripoli. Table 1 represents the ID sample and the collection locations for each sample. Sampling was conducted at a depth of 15 cm to assess the vertical distribution of Cs-137. To ensure analytical accuracy, the samples underwent rigorous preparation before measurement. They were manually inspected to remove coarse impurities that could compromise homogeneity. The samples were sieved through a 1 mm mesh to standardize particle size and minimize radionuclide distribution variability. They were oven-dried at 105 °C until a constant weight was achieved, eliminating moisture that could interfere with both gravimetric analysis and detector performance. The processed samples were stored for 30 days in Marinelli beakers to allow radioactive equilibrium spectral measurement.

Table 1: Locations of measured samples.

No.	Sample ID	Sample Locations
1	AZ 1 Sand	Al-Zawiya Jadda'im
2	AZ 2 Sand	2 meters from the radiology department of Al-Zawiya Hospital
3	AZ 3 Sand	50 meters from the radiology department of Al-Zawiya Hospital.
4	AZ 4 Sand	Al-Zawiya kidney Hospital
5	AZ 5 Sand	Al-Zawiya city center.
6	AZ 6 Sand	Near the refinery's oil tanks
7	AZ 7 Sand	10 meters east of oil tanks

8	AZ 8 Sand	20 meters east of oil tanks
9	AZ 9 Sand	50 meters east of oil tanks
10	AZ 10 Sand	100 meters east of oil tanks
11	AZ 11 Sand	150 meters east of oil tanks
12	AZ 12 Sand	200 meters east of oil tanks
13	AZ 13 Sand	250 meters west of the oil tanks
14	AZ 14 Sand	1 km west of the oil tanks
15	AZ 15 Sand	1.5 west of the oil tanks
16	AZ 16 Sand	1 km south of the oil tanks
17	AZ 17 Sand	Al-Bakhnas, south of Al-Zawiya
18	AZ 18 Sand	Sayyida Zeinab, south of Al-Zawiya
19	AZ 19 Sand	Bir Hanish, south of Al-Zawiya

The gamma-ray spectroscopy measurements were conducted at the Radiation Measurements and Training Center using an n-type HPGe coaxial detector system. The detector (Model GR6022) features a germanium crystal with a 69.3 mm diameter and 69.3 mm length. The system employs a 7500SL + 4" CFE cryostat, coupled with an iPA-SL preamplifier. Operational parameters include a negative bias voltage of 3500 V_{dc} and performance characteristics measured using Co-60 and Co-57 sources. The system demonstrates an energy resolution (FWHM) of 2.2 keV at 1.33 MeV (Co-60) and 1.10 keV at 122 keV (Co-57), with a peak-to-Compton ratio of 60:1 and relative efficiency of 60% at 1.33 MeV. Radionuclide analysis was performed using the Genie2000 for spectrum processing and activity calculation, while efficiency calibration was carried out via the GEOMETY COMPOSER software, which operates with LABSOCS to enable calibration without a standard radioactive source.

The activity concentration of the Cs-137 radionuclide in the soil samples was determined by applying equation 1 [17].

$$A_C(Bq/kg) = \frac{C_S - C_B}{E\gamma \times P\gamma \times t} \qquad (1)$$

Where A_C is the radioactivity level of Cs-137, C_S and C_B are the counts per second for the sample and background, respectively, $E\gamma$ is the detector efficiency, $P\gamma$ is the emission probability, and t is the time counting.

Equation 2 was applied to estimate the absorbed dose rate (D) in outdoor air from the Cs−137 radionuclide:

$$\dot{D}_{Cs}\ (nGy/h) = 0.03(nGy\ kg/h\ Bq) \times A_{Cs} \qquad (2)$$

Where $\dot{D}_{Cs}$ is the absorbed dose rate, A_{Cs} is the specific activity, and 0.03 is the dose conversion factor for Cs−137 [18, 19].

The annual effective dose rate (E) was calculated using equation 3:

$$E(mSv\ y^{-1}) = Q \times T \times OF \times \dot{D} \times 10^{-6} \qquad (3)$$

Where: ($Q = 0.7\ \mathrm{Sv\ Gy^{-1}}$) is a conversion coefficient that converts absorbed dose in air to the effective dose, ($OF = 0.2\ and\ 0.08$) is the occupancy factor for outdoors and indoors, respectively, and ($T = 8760\ h$) is the number of hours in a year [18, 20].

Results and discussion:

In this study, Cs−137 was detected in only 9 samples out of the 19 soil samples analyzed (47.37 %). The measured activity concentrations in the 9 samples that contained the Cs−137, are listed in Table 2. The absorbed dose rate and the annual effective dose rate due to the concentration activity of Cs−137 in 9 samples are illustrates in figures 1 and 2.

Table 2: Measured concentration activity of Cs−137.

Sample ID	Activity Concentration (Bq/kg)
AZ 3 Sand	0.2982±0.0771
AZ 4 Sand	0.2979±0.0496
AZ 5 Sand	0.1369 ±0.0175
AZ 6 Sand	0.1735±0.0507
AZ 13 Sand	0.1338±0.0413
AZ 16 Sand	0.2335±0.0427
AZ 17 Sand	0.2988±0.0474
AZ 18 Sand	2.4037±0.2581
AZ 19 Sand	2.0781±0.1922
Max.	2.4037

Min.	0.1338
Mean	0.6727

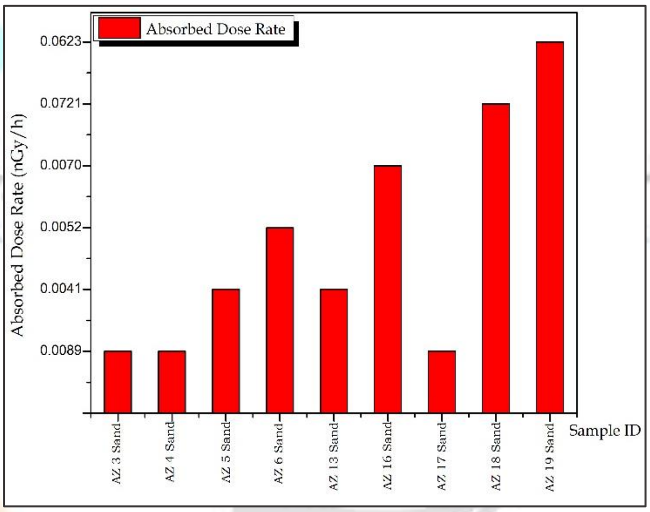

Figure 1: illustrates the absorbed dose rate across 9 samples.

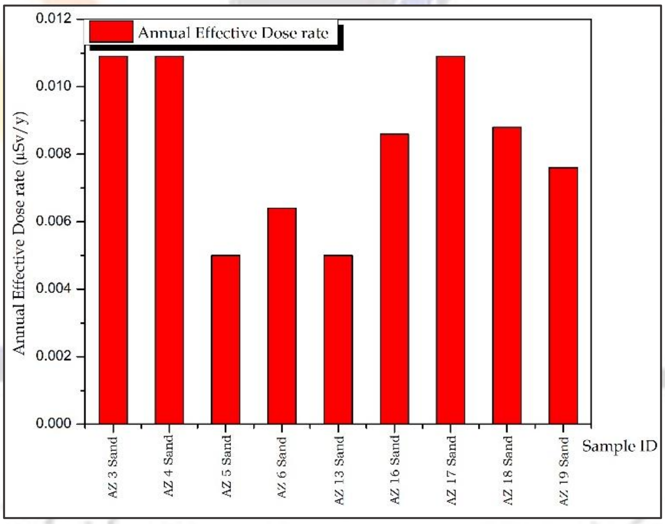

Figure 2: illustrates the annual dose rate across the 9 samples.

The results indicate the presence of detectable concentrations of Cesium−137 within the samples collected from different location within administrative boundaries of the city of Al−Zawiya, with radioactivity levels ranging between 0.1338 and 2.4037 Bq/kg (with an average value of 0.6727 Bq/kg). These levels are comparable to those recorded in the Zintan and Al−Awiniya regions in 2024, while being significantly lower than the measurements recorded near the city of Al−Bayda in eastern Libya in 2018, and higher than those recorded in the Gandula region (eastern Libya) in 2025. This regional variation demonstrates a clear disparity in Cesium-137 deposition across the country, which may be attributed to factors such as precipitation patterns or prevailing winds. It is noteworthy that the highest concentrations were not recorded near Al-Zawiya oil refinery, indicating that the primary source of contamination is not linked to local operations. Instead, it is likely attributable to global radioactive contamination resulting from atmospheric nuclear tests or historical radiological accidents.

The measured absorbed dose rates ranged from 0.0041 nGy/h to 0.0721 nGy/h, with an average absorbed dose rate of 0.0202 nGy/h. Meanwhile, the annual effective dose rates ranged from 0.0050 μSv/y to 0.0109 μSv/y. The highest measured annual effective dose rate is significantly lower than the approved regulatory limit of 1 mSv/year [21, 22], and the annual effective dose rate is very negligible compared to the typical natural background radiation, which ranges between 1 and 3 mSv/year.

Conclusion:

This study assessed Cesium-137 (Cs-137) concentrations in surface soils of Al-Zawiya, Libya. Cs-137 was detected in 47.37% of samples, with activities ranging from 0.1338 to 2.4037 Bq/kg (mean 0.6727 Bq/kg). These levels align with background measurements in western Libya but are lower than elevated readings near Al-Bayda. The spatial variation reflects heterogeneous global fallout deposition, influenced by environmental factors rather than local refinery operations. The highest concentrations were not near industrial sites, confirming that contamination originates from historical atmospheric nuclear testing and accidents. Radiological risk assessment indicates absorbed dose rates (0.0041 – 0.0721 nGy/h) and annual effective doses (0.0050 – 0.0109 μSv/y) are negligible—far below the public limit of 1 mSv/year and natural background radiation. The findings provide baseline data for Libya's environmental monitoring and confirm no current public health hazard. Future studies should expand spatial-temporal sampling and include other radionuclides to better understand deposition and migration dynamics.

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