Investigation of Radioactivity Levels for ^{137}Cs and Evaluation of Absorbed Dose Rate and Annual Effective Dose in Soil Samples Collected from different locations inside the city of Agdabya, Libya.

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Abstract: This is the first time that radiological assessment achieved in these locations inside the city of Agdabya, Libya. Twelve sites were sampled from upper 5 cm of the surface soil to be analyzed for the radioactivity of artificial radionuclide, Cesium-137(^{137}Cs),the absorbed dose rate and annual effective dose rate using gamma spectroscopy based on Hyper Pure Germanium detector (HPGe). Samples were measured at Radiological measurements and training center, Tripoli. The results showed that the radioactivity of Cesium-137(^{137}Cs) , absorbed dose rate and annual effective dose rate have average values of 0.418Bq.Kg^{-1} , 0.013nGy.$h^{-1}$and 0.015μSv.y^{-1} respectively. These values were found to be less than the world average values recommended by ICRP[1] .

Keywords: Radioactivity, Cesium137(^{137}Cs), Absorbed dose rate, Annual effect dose rate, HPGe Detector, Calibration, Efficiency, Surface soil.

Introduction:

Radioactivity levels and risk assessment are among the main problems facing ecological research since human beings are exposed to environmental radiation on a daily basis [2], [3], [4]. The levels of radioactivity in various parts of the world vary significantly, from units to hundreds of Bq/kg [5]. Long-term exposure to high level of radioactivity could cause various diseases to human beings, such as acute leukopenia, cataracts, and kidney cancer [6], [7]. The occurrence of environmental radiation is largely attributed to cosmic rays and the naturally occurring radionuclides (NORs) present in the water, soil, rock, and air, among which NORs is responsible for approximately 86% of the effective human dose [4], [8]. These radionuclides consist mainly of Uranium-238(^{238}U)series, Thorium-232(^{232}Th)series, and

Potassium-40(^{40}K) [3], [9], [10]. Among various earth surface systems, the pedosphere plays a significant role in natural background radiation. Besides, soil is a leading cause of radiation exposure for humans [11], [12]. Therefore, the monitoring of radioactive materials in soil is essential for the control of radioactivity.

Cesium-137 is an artificial or 'man-made' radionuclide with half-life of 30.17 years deposited from the atmosphere may contaminate the surface soil [13]. Because of its solubility and close physicochemical similarity to potassium, cesium can be considered one of the most hazardous radionuclides in the environment and one of the dangerous products of nuclear fission. It is a source of gamma radiation and also is a carcinogen [14], [15], [8]. With a chemical similarity to K^+, extensive investigations revealed that cesium is prone to be transferred into the human body via the food chain and substitute for potassium during transport in the cell membrane [16]. ^{137}Cs has serious damaging effects on the human body due to the gamma radiation from its daughter ^{137m}Ba. Cesium-137 is mainly accumulated in bone and muscle tissue, thereby can induce soft tissue tumors to cause cancer, such as thyroid cancer, ovarian cancer, breast cancer, bladder cancer, and bile duct cancer [17], [18]. The chronicdamage of Cesium-137 to the human body also manifests as inflammatory lesions of various tissues and organs, the most obvious of which is inflammation of the lungs, gastrointestinal tract, urinary tract, and reproductive system [19].

Cesium-137 is a fission product resulting from fallout from atmospheric nuclear weapon testing and nuclear power plant accidents like the Chernobyl and Fukushima nuclear disasters, after atmospheric deposition, radiocesium is believed to rapidly

migrate into the soil, and soon after contamination there is a high activity in the upper layers that decreases exponentially with depth (4-5) cm. Subsequent progress of Cesium-137into the deeper layers is much slower [20], [21]. Therefore, determination of activity levels of radionuclides in soil is very important to ascertain any changes in activity with time as a result of radioactive release. Also, it is necessary to monitor the radioactivity in the environment in order to assess appropriate radiological protection of living organisms [22].

Materials and Methods

Sampling Area

Libya is located in the north of Africa on the Mediterranean coast, it encompasses a geographical area estimated at ($1759540 Km^2$) between (19.30–33°N) and (9.30–25°E) and more than 90% of the country is desert [23]. It extends from the Mediterranean in the north to the borders of Niger and Chad in the south, and from the borders of the Egyptian region and Sudan in the east to the borders of Tunisia and Algeria in the west. The elevation ranges from 59 m to 2,314 m. The Libyan climate is characterized by hot, dry summers and mild winters [24]. The total population amounts to about five million in 1998. The rainfall in the northern part of the country varies between 100–500 mm/year but the southern section receives only as much as 10 mm/year and some parts are completely rainless [25]. Rainfall is generally concentrated in a short period of the year, usually from October to November on the coast and as late as March or April in the desert [23].

Samples Collection and Preparation

Twelve soil samples were taken from different locations inside the city of Agdabya, Libya on March in the year of 2023 using the template method [26] that is the usual application of this method is to scrape or shovel off layer after layer of soil within a chosen area, which could be defined by some sort of rigid frame, in some cases pressed down into the soil to a certain depth. The area sample was cut out using a template a 25cm x 25cm for guidance to a depth of 5cm [26].

Table 1. The GPS sites of the soil samples location.

Sample	Latitude	Longitude
1	46°30'01.27"N	13°20'82. 27"E
2	46°30'73.12"N	13°20'77.32"E
3	45°30'94.27"N	13°20'08.12"E
4	44°30'29.58"N	12°20'63.39"E
5	44°30'67.20"N	13°20'58.31"E
6	45°30'62.31"N	13°20'11. 26"E
7	45°30'43.45"N	12°20'70. 59"E
8	46°30'24.36"N	12°20'65. 25"E
9	45°30'23.38"N	13°20'03.51"E
10	45°30'50.20"N	13°20'75. 21"E
11	44°30'47.43"N	14°20'20.8"E
12	45°30'78.23"N	14°20'66.29"E

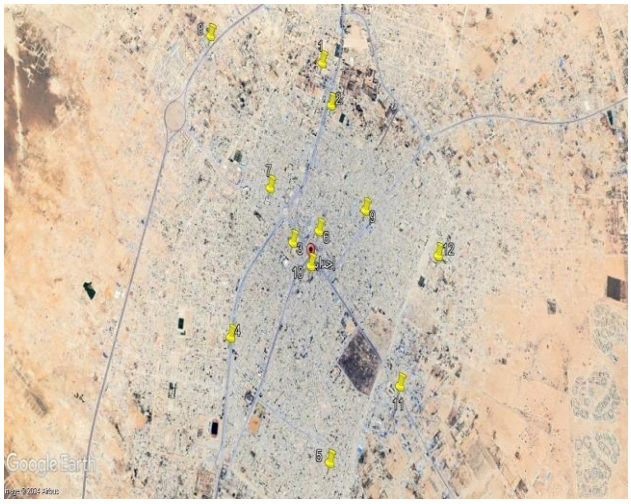

Figure 1. The geographical map for all sites of samples using google earth.

All soil samples were cleaned from stones and organic matter, they were left to dry in an oven at $80C^{\circ}$ for 24 hours. After drying they were crushed and passed through a 2-mm sieve. Their weights were measured and then kept in plastic bags. The meshed soil samples were packed in 500mL Marinelli beakers and kept sealed for four weeks to attain radioactive equilibrium before measured [27].

Samples Analysis

The activity concentrations of the radionuclides in the studied samples were measured using a gamma-ray spectrometer with a coaxial p-type HPGe detector having a relative efficiency of 50%. It has an energy resolution of 1.89 keV for the 1332.5 keV ^{60}Co gamma-ray line. The detector was shielded

using a 10-cm thick low-background lead shield. The amplified signals of the detector were acquired with a 16 K analog-to-digital converter multichannel analyzer (Genie 2000, Canberra, Australia). Each soil sample was placed on the top of the detector. The measuring times ranged from 18,000 to 100,000 s to provide adequate counts under the various gamma-ray photo peaks. Background measurements were taken under the same conditions as sample measurements and subtracted in order to get net counts for the sample. The energy and efficiency calibrations of the detector were performed using calibration sources [28].

The energy calibration of the MCA was obtained using standard point sources such as ^{22}Na, ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, etc. The efficiency of the detector for different radionuclides of interest of different energies were determined by mixing standard sources of known activities and different energies such as 122, 245, 344, 411, 444, 779, 963, 1086, 1112 and 1408 keV supplied by Health Physics Division, Atomic Energy Centre, Dhaka and following the standard method. The unknown efficiencies of different radionuclides were then calculated [29]. The efficiency calibration curve was drawn up using different energy peaks covering a range of up to 2000 keV to obtain the efficiency of the detector for the particular gamma ray energy of interest [29].

The radioactivity levels for radionuclides in the measured samples are computed using the following equation [30]:

$$A_S = \frac{A_R}{\varepsilon(E)tPW} \qquad (1)$$

where A_S is the radioactivity level of a certain radionuclide expressed in Bq.Kg^{-1} dry weight, A_R is the net counting rate of the sample after subtracting the background radiation (counts/s), ε(E) is the counting efficiency of the detector at energy (E), t is the time for the measurement of the samples, P is the absolute transition probability of γ –decay (Abundance (%)), and W is the dried sample weight expressed in kg. The absorbed dose rates were calculated using the following formula [31]:

$$D = 0.03\, A_S \qquad (2)$$

where D is the absorbed dose rate in (nGy.h^{-1}) at 1 m above the ground, and A_S is the radioactivity concentrations in (Bq.Kg^{-1}) in the soil sample. The absorbed doses in nGy.h^{-1} were converted to the annual effective dose in (μSv.y^{-1}), as proposed by (*3*). The annual effective dose rate (AEDR) was calculated using the following equation [31]:

$$AEDR = D * 8760 * 0.2 * 0.7 * 10^{-3} \qquad (3)$$

where D is the absorbed dose rate in the air (nGy.h^{-1}), 0.7 is the dose conversion factor (Sv.Gy^{-1}), 0.2 is the outdoor occupancy factor, and 8760 is the time conversion factor (h.y^{-1}).

Results

Table 2. The concentration of radioactivity, absorbed dose rate, and annual effective dose rate (AEDR) of Cesium-137(^{137}Cs) for soil samples.

Samples	Activity (Bq.Kg^{-1})	Dose rate (nGy.h^{-1})	AEDR (μSv.y^{-1})
1	1.139	0.034	0.042
2	0.356	0.011	0.013
3	0.090	0.003	0.004
4	0.249	0.007	0.009
5	1.078	0.032	0.039
6	0.831	0.025	0.031
7	0.641	0.019	0.023
8	0.106	0.003	0.004
9	0.067	0.002	0.002
10	0.058	0.002	0.002
11	0.273	0.008	0.010
12	0.129	0.004	0.005
Average	0.418	0.013	0.015
Max.	1.139	0.034	0.042
Min.	0.058	0.002	0.002

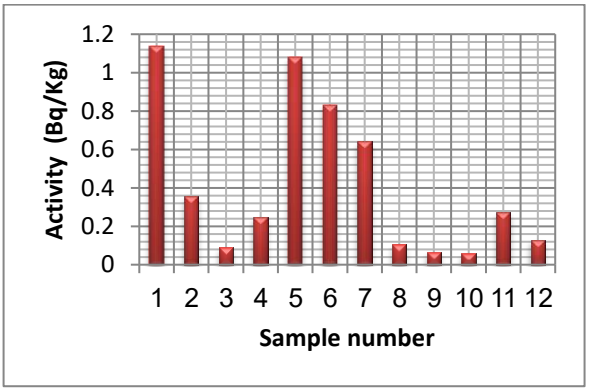

Figure 2. The radioactivity concentration of Cesium-137(^{137}Cs) in (Bq/Kg) for the soil samples.

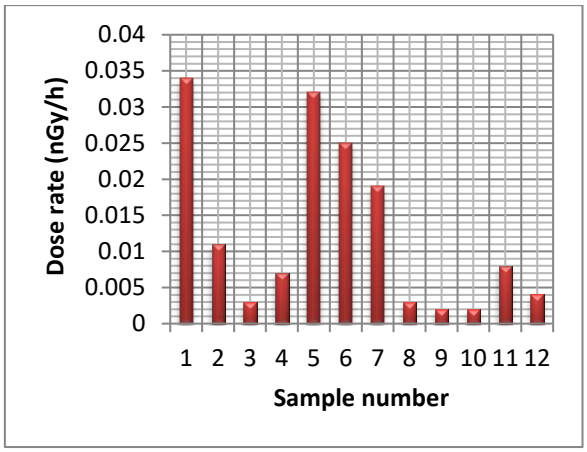

Figure3. The dose rate in nGy.$h^{-1}$for soil samples.

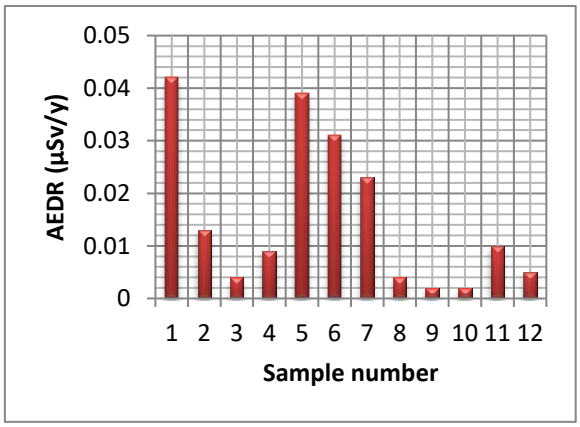

Figure4. The annual effective dose rate (AEDR) in µSv.y^{-1} for soil samples.

Conclusion

Based on the obtained data, it is concluded that:

1. Activity concentration of Cesium-137 in soil samples is found to be in the range from 0.058 to 1.139Bq. $Kg^{-1}$with average value of 0.418Bq. Kg^{-1}.
2. Absorbed dose rate in soil samples is found to be in the range from 0.002 to 0.034nGy.h^{-1} with average value of 0.013nGy.h^{-1}.
3. Annual effective dose rate (AEDR) in soil samples is found to be in the range from 0.002 to 0.042µSv.y^{-1} with average value of 0.015µSv.y^{-1}.

It was observed that the activity concentration of Cesium-137, Absorbed dose rate and the Annual effective dose rate are lower than the world average. Samples 1 and 5 showed the highest values of Cesium-137 at the level of all samples but they are still within the internationally recommended limit. Sample 1 was taken from the Maqrif Hospital, and sample 5 was taken from the Alqrfa Clinic. The reason for the high values of Cesium-137 in these sites is due to its use in medicine [32].

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