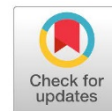


Research Article

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Estimation of Natural Radioactivity and Radiation Hazards Indices of Some Organic Fertilizers Used in Al-Gable Al-Akhdar, Libya

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Abstract

In the present work, an assessment of the following levels of natural radioactivity in 5 samples of organic fertilizers collected from the market in Al Bayda City, Libya. Sodium iodide (NaI) gamma spectroscopy was used. The activity concentrations of radionuclides in the ^{238}U and ^{232}Th natural decay chain as well as ^{40}K were determined. The average activity concentrations in ^{226}Ra , ^{238}U , ^{232}Th and ^{40}K in the samples studied were found to be (± 62.74 , ± 64.42 , ± 63.63 and ± 70.88 Bq Kg⁻¹) (for samples. The results of this study have been compared with the world recommended values of (1550, 1500, (7-50) and (100-700)) Bq kg⁻¹, respectively as specified by the [UNSCEAR, 2016]. The results showed that all samples had lower levels of radioactivity than the recommended limits for ^{226}Ra , ^{238}U , ^{40}K for organic fertilizers and the activity concentrations were below the thorium (7-50 Bq kg⁻¹) except for 1, 4 and 5 were higher than the recommended limits. The radium equivalent, absorbed dose rate in air, annual effective dose equivalent for indoor and outdoor exposure, excess lifetime cancer risk, internal and external hazard indicators were calculated. The results of most samples were within the global average recommended by [UNSCEAR, 2016]. So, it is safe to consume and does not pose a threat to the general public.

Keywords: Organic Fertilizers; Sodium Iodide; The Activity Concentration; Exposure; Cancer Risk.

INTRODUCTION

Each year, the absorbed doses of radiation that humans receive vary depending on a number of variables, including climate, geological location, and the use of radioactive material and nuclear energy by humans. Energy manifested as particles or waves is called radiation. Radiation can be categorized as either ionizing or non-ionizing. Ionizing radiation, such as alpha, beta, neutrons, and gamma radiation, has sufficient energy to cause electrons in their orbits to be released, forming positive ions in the atoms. Non-ionizing radiation, which includes radio waves, infrared light, and visible light, is less energetic than ionizing radiation and cannot produce ions. Natural radioactivity permeates the terrestrial environment and can be found in a variety of geological formations, including soils, phosphate rocks, air, plants, and animals. Around the world, the use of fertilizers in agriculture has become crucial. In addition to improving soil qualities and nutrient deficiencies, fertilizers are crucial for raising crop yields. Different ferti-



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lizers have different effects on a plant's physiology and metabolism, affecting how different elements and radionuclides are absorbed. aFertilizer application has the potential to raise radionuclide content inasoil, resulting in increasedaradionuclide uptake.(Hallenburg, 2020).More than 30 million tons ofaphosphate fertilizers areaannually consumed worldwide, which increases cropaproduction and landareclamation. However, a possibleanegative effect of fertilizers is theacontamination ofacultivated lands by asome naturallyaoccurring radioactiveamaterials the natural radionuclide of fertilizersaconsists mainly ofauranium and thorium series radioisotopes and natural ^{40}K .(KeleÅŸ & Atik, 2018).

MATERIALS AND METHODS

To assess the levels of natural radioactivity in some fertilizers, 5 samples of organic fertilizers were collectedafrom Al-Bayda city market (Libya) Theaccollected samples, are locally sourced Table (1) shows the details of the collected samples. They were cleaned, ground as shown in Fig. (1), and dried inathe electric oven in the laboratory for one hour per sample to get rid of moisture in samples asashown in Fig. (2), and weighed then stored in polymer containers of 250 Cm^3 volume oraat least 30 days; toallow radioactive equilibrium to be reached. This step isanecessary to ensure that radon gas is confinedawithin theavolume and that theadaughters will also remain inathe sample. The measurement time foraboth activity and radiologicalahazards measurement was 3600 seconds. The radionuclides activity concentrations were measured using NaI (TI) detector-based gamma spectrometric system where the digiBASE system that combines a miniaturized preamplifier and detector with a powerful digital multichannel analyzer and special features for fine time-resolution measurements. The digiBASE incorporated into the NaI (TI) detector provides a gain stabilizer to significantly reduce the sensitivity of the detector to changes in ambient temperature and magnetic fields. Three gamma-ray lines of interest were (1460, 1764 and 2615) keV (Baqir, Y.et al., 2020)

Table: (1). Description of the fertilizer samples

Samples No	Description
Fo1	Derna sheep
Fo2	AL-Bayda sheep
Fo3	AL-Bayda cows
Fo4	Derna cows
Fo5	AL hisha horses



Figure: (1). Grind some samples



Figure: (2). The electric oven device

Theoretical Calculations

1. Calculation the Activity Concentrations

The activity of an radioactive source is defined as the rate at which the isotope decays. Radioactivity may be thought of as the volume of radiation produced in a given amount of time. The radioactivity concentration of the different identified radionuclides was determined by gamma-ray spectrometry with the measured for each peak, and the associated activity (A) was computed by using the formula (Al-Mousawi et al., 2020).

$$A = \frac{\text{Net area (cps)}}{I_{\gamma} \times \xi \cdot M} \quad (1)$$

Where A is the Activity concentration of the gamma spectral line in Bq/Kg, **Net area (cps)** is the net detected counts per second corresponding to the energy, ξ is the Counting system efficiency of the energy, M is the Mass of sample in Kg and I_{γ} is the Intensity of the gamma spectral.

2. Radium Equivalent Activity (Bq/kg).

The concentration and distribution of ^{226}Ra , ^{232}Th and ^{40}K in the studied samples are not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent Ra_{eq} in (Bq kg⁻¹) is the most extensively used radiation danger index, to represent the activity levels of ^{226}Ra , ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with each component. The radium equivalent for the samples was calculated from the following relation: (Geremew, 2023; Mwalongo et al., 2023).

$$Ra_{eq} = A_{Ra} + 1.34 A_{Th} + 0.77 A_K \quad (2)$$

Where A_{Ra} , A_{Th} and A_K are the activity concentrations (Bq/Kg) for ^{226}Ra , ^{232}Th and ^{40}K respectively. The maximum value of (Ra_{eq}) must be less than 370 Bq.kg⁻¹.

3. Gamma Absorbed Dose Rate (Dr).

The absorbed dose rates DR (nGy h⁻¹) due to terrestrial gamma rays at 1m above ground level can be calculated by using activity concentrations of ²²⁶Ra, ²³²Th, and ⁴⁰K were calculated by using the equation (AL-abrdi, 2023).

$$D_r = 0.427A_U + 0.662A_{Th} + 0.043A_K \quad (3)$$

Where A_U, A_{Th} and A_K are the activity concentrations (Bq/Kg) for ²³⁸U, ²³²Th and ⁴⁰K respectively. (Najam et al., 2022), 0.427, 0.662 and 0.043 nGy.h⁻¹/BqKg⁻¹ are the conversion factors of ²³⁸U, ²³²Th and ⁴⁰K respectively

4. Internal Hazard Index (H_{in}).

The widely used hazard indices that reflect both internal and external exposure are called internal hazard and external hazard respectively. The internal exposure to ²²²Rn and its daughter products are controlled by an internal hazard index, H_{in} which is defined as (UNSCEAR, 2000).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

5. External Hazard Index (H_{ex}).

The external hazard index resulting from samples gamma-ray emissions and radiological danger was computed using the relation

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (5)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations (Bq/Kg) for ²²⁶Ra, ²³²Th and ⁴⁰K respectively (Isinkaye & Emelue, 2015).

6. Excess Lifetime Cancer Risk (ELCR).

People who are exposed to radiation for an extended period of time are thought to be at risk of developing cancer. The ELCR is the increased of acquiring cancer as a result of exposure to a radiation during a person's lifetime. It is determined using the following equation

$$ELCR = E_{out} \times DL \times RF \quad (6)$$

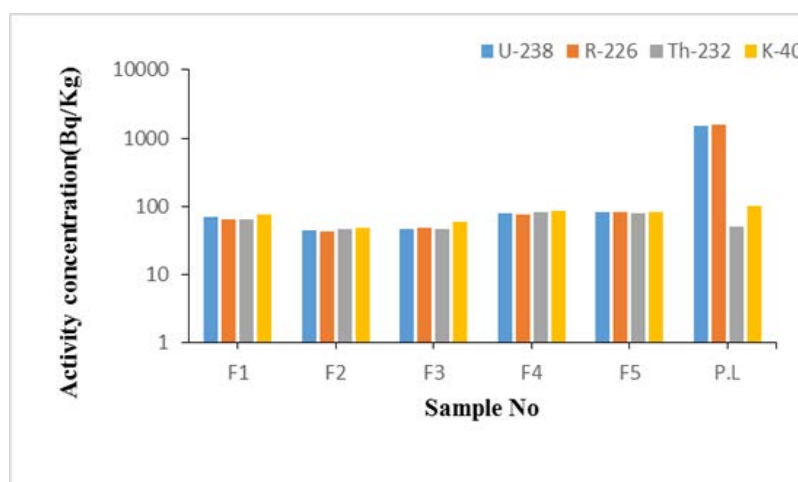
Where E_{out} means the annual effective dose equivalent (outdoor), DL denotes life expectancy (70 years), and RF denotes the risk factor (Sv⁻¹), which is Sievert's fatal cancer risk (Yalcin et al., 2020).

RESULTS AND DISCUSSION

The values of activity concentrations for organic fertilizer samples the recorded values of radionuclides were varied from (44.92 to 81.24), (43.51 to 81.79), (45.79 to 82.23) and (48.62 to 85.72) Bq kg⁻¹ for ²³⁸U, ²²⁶Ra, ²³²Th and ⁴⁰K respectively, with an average (64.42, 62.74, 63.63 and 70.88) Bq kg⁻¹ respectively Table (2), The outcomes of radioactive activity concentrations for organic fertilizer samples, including ²³⁸U, ²²⁶Ra, ²³²Th, and ⁴⁰K The samples analyzed in this investigation had activity concentrations less the allowable level for uranium (1500 Bq kg⁻¹) (UNSCEAR, 2017), the activity concentrations are below the radium (1550 Bq kg⁻¹), the activity concentrations are below the thorium (7-50 Bq kg⁻¹) except for samples (fo1, fo4 and fo5) were higher than the recommended limits. The activity concentration is below the potassium suggested ranges (100–700). Figure (3) show the activity concentrations of radium, uranium, thorium, and potassium in organic fertilizers.

Table (2): The average activity concentrations (Bq kg⁻¹) of the radioactive elements (²³⁸U, ²²⁶Ra, ²³²Th and ⁴⁰K) of the investigated samples.

Samples	²³⁸ U	Error	²²⁶ Ra	Error	²³² Th	Error	⁴⁰ K	Error
F o1	70.98	± 2.19	65.27	± 3.90	64.65	± 2.84	76.77	± 7.55
Fo2	44.92*	± 1.32	43.51*	± 4.50	45.79*	± 3.61	48.62*	± 9.12
Fo3	47.18	± 1.19	47.86	± 4.13	45.85	± 3.00	60.13	± 8.30
Fo4	78.79	± 1.49	75.27	± 3.87	82.23**	± 2.99	85.72**	± 8.85
F05	81.24**	± 1.63	81.79**	± 4.76	79.65	± 2.76	83.17	± 9.40
Average	64.42	± 1.56	62.74	± 4.23	63.63	± 3.04	70.88	± 8.64
P.L	1500		1550		7-50		100-700	

**Figure: (3).** The activity concentration of organic fertilizers.

The Radium equivalent activity (Ra_{eq}) is a single quantity that compares the activity concentrations of ²³⁸U, ²²⁶Ra, ²³²Th and ⁴⁰K in fertilizer samples to obtain a total activity concentration. The results of the calculated (Ra_{eq}) values for organic fertilizer samples range from (112.74 to 202.11 Bq kg⁻¹), with an average value of 159.20 Bq/kg as shown in Fig. (4). In Table (3), the (Ra_{eq}) values for all fertilizer samples in the present study are lower than the world recommended value 370 Bq kg⁻¹. The estimated absorbed dose rate values for the investigated organic fertilizer samples range from (49.80 to 80.03 nGy h⁻¹), but the average value of the absorbed dose rate for the organic fertilizer samples was 64.98 nGy h⁻¹, Fig. (5) Shows these results the studied organic fertilizer samples, they were within the recommended limits (UNSCEAR, 2017).

Table (3): The value of radium equivalent.

Samples code	Ra_{eq} Bq/Kg
Fo1	163.63
Fo2	112.74
Fo3	118.06
Fo4	199.47
Fo5	202.11
Average	159.20
P.L	370

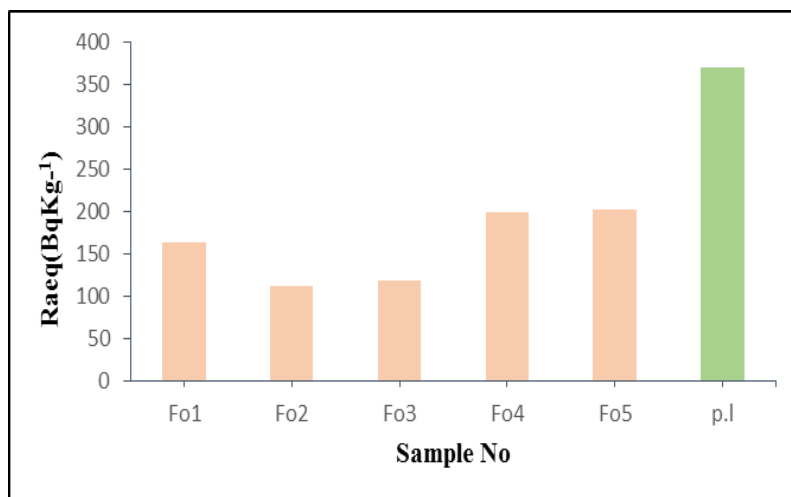


Figure: (4). Radium Equivalent of organic fertilizer samples

Table (4): The value of absorbed dose rate.

Samples code	Dose rate Dr(nGyh ⁻¹)
Fo1	72.42
Fo2	49.80
Fo3	52.33
Fo4	70.05
Fo5	80.3
Average	64.98
P.L	84

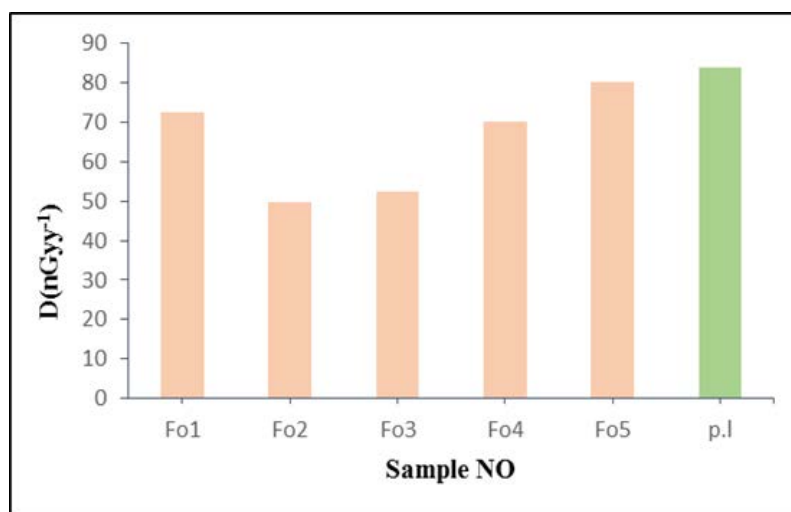
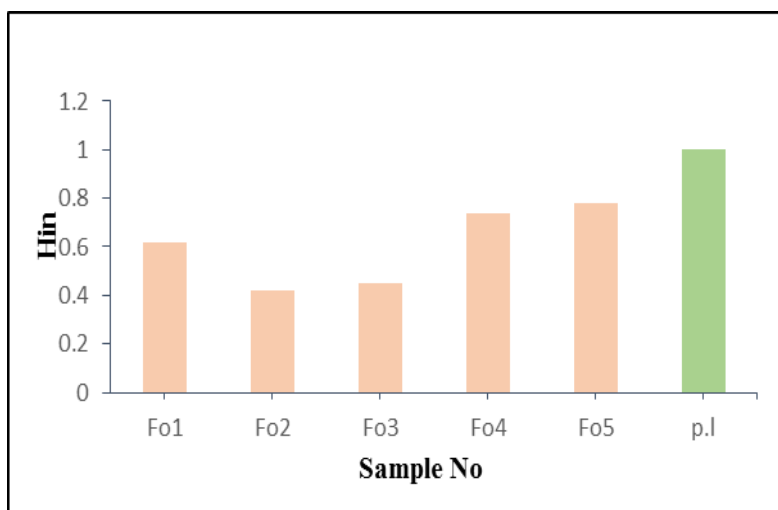
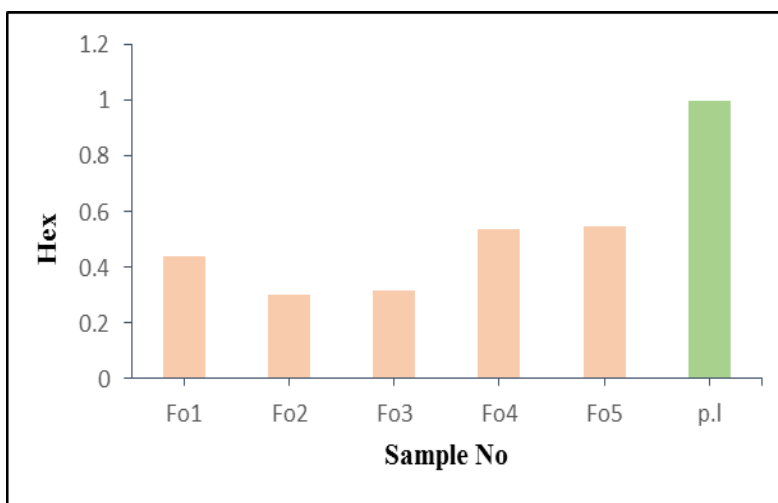


Figure: (5). The absorbed dose rate of organic fertilizer samples

The internal and external hazard results were obtained and shown in Table (5). The results value of organic fertilizer samples ranged from (0.42 to 0.78), with an average value 0.60, as shown in Fig. (6). In the results, all internal hazard values for the fertilizer samples under study were lower than the (UNSCEAR, 2017) recommended values. The external hazard for organic fertilizer samples the results ranged from (0.30 to 0.54), with an average of 0.43, as shown in Fig. (7).

Table (5): The value of internal and external hazards

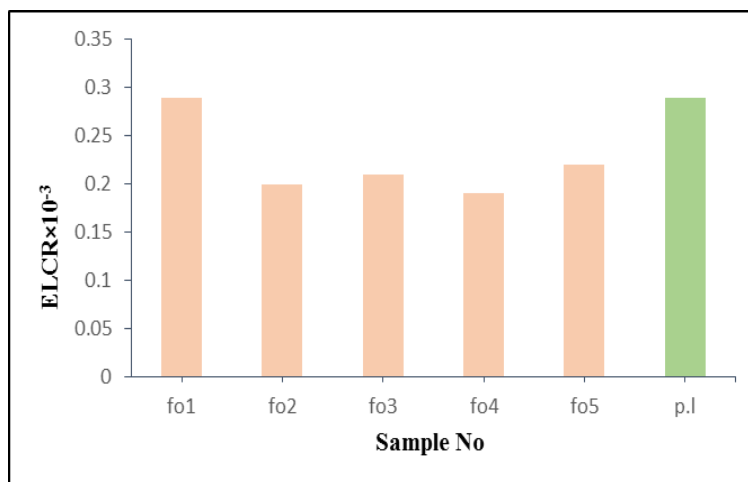
Samples code	H _{in}	H _{ex}
Fo1	0.62	0.44
Fo2	0.42*	0.30*
Fo3	0.45	0.32
Fo4	0.74	0.54**
Fo5	0.78**	0.55
Average	0.60	0.43
P.L	1	1

**Figure: (6).** Internal hazard index of organic fertilizer samples**Figure: (7).** External hazard index of organic fertilizer samples

Equation (6) has been calculated of ELCR where the equation dependent of life expectancy (70 years) and risk factor (0.05 sv^{-1}). Table (6) shows the excess lifetime cancer risk factor ELCR for all samples, the recorded values of ELCR range from (0.19 to 0.22) with an average value 0.22. The results of the ELCR values for all the organic fertilizer samples studied were within the recommended limits of 0.29×10^{-3} (UNSCEAR, 2017), as shown in Fig. (8).

Table (6): The value of Excess Lifetime Cancer Risk (ELCR).

Samples code	Cancer risk factor ELCR $\times 10^{-3}$
Fo1	0.29
Fo2	0.20
Fo3	0.21
Fo4	0.19*
Fo5	0.22**
Average	0.22
P.L	0.29

**Figure: (8).** The cancer risk factor of the organic fertilizer samples.

CONCLUSION

The study on natural radioactivity levels in organic fertilizers in Al-Bayda city, Libya, produced the following conclusions:

- Use of simple NaI gamma spectrometer showed potential in the assessment of radioactivity concentration.
- In this study, the activity concentrations of radionuclide ^{226}Ra , ^{238}U , ^{232}Th , and ^{40}K were determined to be lower than the world-recommended value for all organic fertilizer samples.
- Furthermore, the activity concentrations were used to estimate various radiological features in the samples.
- The studied organic fertilizer samples had radium equivalent activity below the world recommended value of 370 Bq kg^{-1} .
- The absorbed dose rate values of the studied samples for organic fertilizers, it was less than the recommended limits.
- The obtained values of internal hazard index H_{in} , and external hazard index H_{ex} for all the studied sample were lower than the recommended value.
- The Excess lifetime cancer risk (ELCR) values are found to be much lower than the permissible level (0.29) for organic samples (UNSCEAR, 2017).

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Author contributions: A and B. developed the theoretical formalism, performed the analytic calculations and performed the numerical simulations. Both A and B. authors contributed to the final version of the manuscript. A. supervised the project.

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