An in-depth examination of the natural radiation and radioactive dangers associated with a regularly used medicinal plant in Egypt

H. A. Saudi
Al-Azhar University (Girls Branch)
H. T. Abedelkader
Zagazig Univ
Shams Issa
University of Tabuk
H. M. Diab
Atomic Energy Authority
I. I. Bashter
Zagazig Univ
Gharam A. Alharshan
Abdulrahman University
M. A.M. Uosif
Jouf University
Hesham M. H. Zakaly (h.m.zakaly@gmail.com)
Al-Azhar University

Article

Keywords: Natural radiation, radioactive risks, medical herb & High-purity Germanium

Posted Date: April 14th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1538227/v1

Abstract

Specific activity of U-238 and Th-232, as well as K-40 radionuclides in twenty-five investigated medicinal herbs used in Egypt have been measured using high purity germanium (HP Ge) detector. The measured values are ranged from the BDL to 20.71 with mean of 7.25 (Bq kg^{-1}) for uranium-238, from the BDL to 29.35 with mean of 7.78 (Bq kg^{-1}) for thorium-232, and from the 172 to 1181.2 with mean of 471.4 (Bq kg^{-1}) for Potassium-40. Individual herbs with the highest activity levels were found to be 20.71 (Bq kg^{-1}) for uranium-238 (H4, Thyme herb), 29.35 (Bq kg^{-1}) for thorium-232 (H20, Cinnamon) and 1181.2 (Bq kg^{-1}) for Potassium-40 (H24, Worm wood). Ingestion-related effective doses over the course of a year of uranium-238 and thorium-232, as well as Potassium-40 estimated from measured activity concentrations are 0.002304 (minimum), 0.50869 (maximum), and 0.0373 (average) (mSv/yr). This is the first-time natural radioactivity of therapeutic plants has been measured in Egypt. In addition, no artificial radionuclide (for example, 137Cs) was discovered in any of the samples. Therefore, the current findings are intended to serve as the foundation for establishing a standard safety and guideline for using these therapeutic plants in Egypt.

1. Introduction

All over the world, medicinal herbs have been used for a long time [1]. A growing number of people are turning to herbal medication to enhance their health in recent years because of the well-known pharmacological as well as therapeutic properties of many of them.[2]. 75% of the world's population relies on herbs for basic health care, according to WHO reports [3]. We are witnessing a global herbal "renaissance" that is taking place all over the world, with herbs with medicinal properties being used in contemporary medical therapies as well. A plant's most used organs are its leaves. Other organs include flowers, fruit, seeds, stems, wood, bark, roots, and rhizomes. These organs used as is or pulverized into a fine powder [4]. Additionally, medicinal plant ethnobotanical research is a critical step in the local development ecotourism, which includes Environmental museums and small-scale business dealing with native medicinal and edible plants, and community-based bio-conservation initiatives. However, in order to successfully complete all of these duties, the use of medicinal plants and their products must be strictly regulated in order to avoid any potentially harmful side effects to the health of consumers.

Medicinal herbs' properties and efficacy may be influenced by their environmental surroundings, and one of the most important parameters that must be monitored is the level of natural and man-made radionuclides present in them. Aside from the specific radionuclide and the level of contamination, the health risk posed by accidental radionuclide contamination of herbal medicines has been found to be dependent on the amount consumed and the length of time it was consumed. [5]. It is possible to accumulate harmful substances in the human body when using herbal remedies for a long period of time [6]. Individual annual effective dose from ingestion increases because of increased concentrations of radioactive elements, increasing the risk of radiological harm because of ingestion.

K-element is the most important nutrients for plants. Because K and Cs are members of the same chemical element family, their attitude in the plant's metabolism is very like to one another. Potassium, as well as its naturally occurring radioisotope ^{40}K, enters the plant roots through ion channels, or transporters, that are also used for the Cs^{+} ion transporter. As a result, a high K content in soil inhibits the adsorption of Cs, and the impact could be heightened by a higher mobility of the potassium ion in soil, which increases the availability of potassium to plants [7]. The purpose of this study is to provide information on:

- natural radionuclide activity concentrations in numerous medicinal plants; and
- radiation hazards related to intake of the therapeutic plants evaluated in this research.

2. Materials And Methods

2.1 Samples Preparation & Measurements

Marketplaces provided dried medicinal plant samples measuring one kilogram apiece. The samples were then rinsed in water and dried in the sun to remove any dust contamination. At CLERMIT and NRRA in Cairo, these samples were crushed into tiny bits, homogenized dried in an electric oven at 105–110°C until they reached a consistent weight. The dry components were subsequently ground into a fine powder, sieved at 0.5 mm in diameter, with a sealed joint in a beaker, as illustrated in Fig. 1. Finally, the samples were kept at room temperature for about a month before counting to allow the radionuclides ^{226}Ra, ^{222}Rn, and their daughters to approach earthly equilibrium.

The dry mass of the samples in this experiment was used to calculate the radioactive content. Table 1 lists the traditional and scientific names. The samples have been counted using a gamma-ray spectrophotometer. High purity germanium (HP Ge) detector with the efficiency of 25% and an energy resolution of 1.8 keV (FWHM) at a peak energy of 1333 keV from the $.^{60}Co$, peak share to Compton 55:1 is used. Through an Uninterrupted Power Supply, a high-voltage power supply (Model 13103) was used to deliver the bias voltage of 3000 V. (UPS). The detector was kept cooled in a 25-liter Dewar with liquid nitrogen at 196°C (77 K) and an ambient temperature of 16 to 27°C. 100 mm of lead shielding reduces the soft components of cosmic rays to a shallow level. The X-ray (73.9 keV) generated by lead as a result of its interaction with external radiation was reduced by the copper layer [8]. To facilitate radionuclide identification and quantification, the system's energy and efficiency were calibrated prior to the use of samples for analysis the IAEA's Multinuclear Reference Standard Solution, as shown in Fig. 2.

Table 1
Physical data of herbs.

herb	Code	Scientific name	Sample part
Sage herb	H1	Salvia officinalis	Leaves
Guava paper	H2	Psidium guajava	Leaves
Margoram herb	H3	Origanum majorana L.	Leaves
Thyme herb	H4	Thymus vulgaris L. (T. vulgaris)	Leaves
Stevia	H5	(Stevia rebaudiana Bert., Asteraceae)	Leaves
Senna	H6	Cassia italic	Leaves
Halfa-bar	H7	Cymbopogon schoenanthus L.	Leaves
LEMON BALM	H8	Lamiaceae	Leaves
Argel	H9	Solenostemma argel	Stems
Anise stare	H10	Illicium anisatum L.	Seed
Mustard	H11	Brassica nigra L	Seed
Agwain	H12	Trachyspermum ammi	Seed
Garden cress	H13	Lepidium sativum	Seed
Saussurea costus	H14	Saussurea lappa	Root
Flax seed	H15	Linum usitatissimum	Seed
Lavender	H16	Hyacinthus	Flower
Myrtle	H17	Myrtus Communis	Leaves
Basil	H18	Ocimum basilicum	Leaves
Barley	H19	Hordeum vulgare L	Seed
Cinnamon	H20	Cinnamomum, Cassia	Bark
Fenugreek	H21	Trigonellafoenumgm	Seed
White ginger	H22	Zingiber officinale Roscoe	Root
Quince	H23	Cydonia oblongaM	Root
Worm wood	H24	Artemisia herba-alba	Leaves
Rhubard	H25	Rheum palmatum L	Root
Spanish Broom	H26	Spartium junceum L	Seed
Turmeric	H27	Curcuma longa	Root

herb	Code	Scientific name	Sample part
Dill	H28	Anethum graveolens g	Seed
Fennel	H29	Foeniculum Vulgare	Seed

The standard and sample were computed for 8000 s to collect spectral data to improve counting and assessment, as illustrated in Fig. 3. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, as well as the background in an empty beaker under the same conditions, were estimated after normalizing for background and heterogeneity [9]. The absolute efficiency was calculated using $^{137}Cs,\ ^{152}Eu,\ and\ ^{241}Am$, with specified activities. The IAEA 154 instruction was used to calibrate the detector efficiency (IAEA,2000). Background measurement, sample counting geometry, and a standard mixed source for efficiency calibration were all kept constant. All the spectra's counting times were in the 80000s. The absolute efficiency of detector arrangement was estimated using the registered gamma-ray spectrum:

$$\epsilon(\%) = \frac{Netarea}{Act \times BR(\%) \times t \times 100} (1)$$

Where a Net-area represents net counts are those that fall under the full-energy peak identical to the Ei energy, Act represents radionuclide activity at a given date, $P_n(E_i)$ represents the eventuality of E_i Photon emission and t represent counting. The radioactivity concentration of ^{238}U, ^{232}Th, and ^{40}K in medicinal plants was assessed using quantitative analysis of gamma spectra acquired using Ortec MAESTRO-32 analytic software at specific energies. A mean of ^{214}Pb (251.9 and 295.2 keV) and ^{214}Bi (609.3 and 1764.5 keV) was used to compute ^{238}U. A mean of ^{208}Tl(2614.5 and 583.2 keV), ^{212}Pb (238.6 keV), $^{228}\mathrm{Ac}$(11.2 keV), and $^{40}\mathrm{K}$(1460.0 keV) was used to calculate $^{232}\mathrm{Th}$. After the decay has been corrected, the values for activity concentrations in decay chains are based on secular equilibrium for the various isotope activities. The measurement yielded no artificial radioactivity. Each sample's radioactivity was determined using a calibrated high purity germanium detector. The radionuclides i in the samples had their specific activity (Asp(E, i) in Bq kg^{-1}) evaluated using the following Eq. 1[0].

$$asp(E, i) = \frac{Nsam(E, i)}{\epsilon_{\gamma}(E) T_C P_{\gamma}(E, i) Msam} (2)$$

T_c is the calculation of live time (s), ***Pγ*** (E,i) is the gamma emission potential of the radionuclide i to transition at energy E; Msam is the dry weight of the samples (kg) after obtaining the values of the specific activity concentrations radionuclides that occur naturally in medicinal plants. The equations that used to calculate the radiological hazards have been discussed in detailed in previous our works [11–19].

3. Results And Discussion

Gamma-ray spectrometry was used to measure the radioactivity levels of NORMs in 29 different medicinal plants that are commonly used in Egypt. The equation used to figure out the average concentrations of ${}_{.}{}^{226}\text{R}\text{a}$, ${}_{.}{}^{232}\text{T}\text{h}$, and ${}_{.}{}^{40}\text{K}$ was used (1). Calculations were also used to figure out how much radiation these medicinal plants might cause. The risk indexes and annual effective doses were also considered. Results from our study were compared to global averages set by UNSCEAR and results from other countries. Our findings and comparisons are shown in the following logical order. Figure 4 **and** Table 2 show the average dry weight activity concentrations of ${}_{.}{}^{226}\text{R}\text{a}$, ${}_{.}{}^{232}\text{T}\text{h}$, and ${}_{.}{}^{40}\text{K}$ for the medicinal plants that were tested in this study. Each sample and isotope being looked at has a wide range of activities. Different medicinal plants may have different concentrations of NORMs because they have different amounts of radioactive minerals and can absorb certain elements [20].

Table 2

Specific activities (Bq /kg) of ^{238}U ({}_{.}{}^{226}Ra), ^{232}Th and ^{40}K in medicinal plant samples using γ-spectrometer.

Code of sample	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K(Bq/kg)
H1	4.99	10.72	478.5
H2	9.3	6.33	305.8
H3	1.064	2.84	391.5
H4	20.71	BDL	467.9
H5	1.49	BDL	520.6
H6	BDL	9.92	316.5
H7	12.92	8.49	211.7
H8	BDL	BDL	206.5
H9	BDL	BDL	623.9
H10	0.359	3.83	327.6
H11	BDL	4.26	316.5
H12	3.89	10.11	847.9
H13	13.48	BDL	418.8
H14	BDL	3.017	302.7
H15	0.105	BDL	292.8
H16	9.43	22.26	831.9
H17	22.13	0.706	230.7
H18	2.8	3.28	1074.9
H19	2.53	7.008	226.6
H20	6.5	29.35	175.4
H21	BDL	BDL	377.5
H22	18.6	BDL	425.7
H23	BDL	7.47	650.1
H24	2.55	5.61	1181.2
H25	2	4	172
H26	BDL	4.55	643.2

Code of sample	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K(Bq/kg)
H27	BDL	1.203	440.1
H28	2.95	10.78	794.5
H29	BDL	BDL	418.8
Maximum	**20.71**	**29.35**	**1181.2**
Minimum	**BDL**	**BDL**	**172**
Average	**7.25**	**7.78**	**471.4**

The current research is a case in point showed that the concentration levels of ^{238}U varied from BDL to 20.71 Bq/Kgas observed in 15 plant species more than the BDL values with an average of 7.25 Bq/Kg. Thyme herb (H4) has the highest ^{238}U concentration. ^{232}Th concentrations ranged from BDL to 29.35 Bq/Kg, as observed in 10 plant species more than BDL values with an average of 7.78 Bq/Kg. Cinnamon (H20) has the highest ^{232}Th. The ^{40}K activity concentrations were recorded between 172 Bq/Kg (turmeric) and 1181.2 Bq/Kg (cinnamon) with an average value of 471.4 Bq/Kg. Since some of the studied samples have been imported from different regions, the detected activity values of radionuclides are affected due to different levels of natural radioactivity in the soil and environment in those countries. Nevertheless, based on the findings the specific activity values of ^{238}U were in the limit of 33 Bq /Kg in all samples [21].

Furthermore, it was discovered that the specific activity levels of ^{232}Th in all samples were within the range of 45 Bq/ Kg [21]. Except for a few samples that were more extensive than the permissible value of 400 $Bqkg^{-1}$ (UNSCEAR, 2000), the values of the activity concentration of the ^{40}K are less than the allowable value of 400 $Bqkg^{-1}$. Since typical radionuclide activity heights are not regulated across the ground and the flowers' ability to absorb more basic features than others, differences in the concentrations of activity could be attributed to changes in the physical location of the plants and the radiochemical action of the lands in which these medicinal plants are developed or cultivated. The increased potassium activity in these plants might be related to the plants' effectiveness in absorbing potassium as well as other components from the soil [22]. Figure 5 shows the range, mean, median line, and outliers' radioactive elements for measured samples in the region of interest. The current study's activity concentration findings were compared to the published data in Table 3 for a selection of medicinal plants found in the literature, as shown in Fig. 6. This comparison shows that the current findings are relatively consistent with those measured in other nations using the global values indicated in the UNSCEAR 2000 report.

Table 3
The mean activity concentrations of natural radioactivity of medicinal plant samples in the present study were compared with those from similar investigations performed in other countries.

Country	U-238	Th-232	K-40	Reference
Iraq	4.953 ± 0.37	2.916 ± 0.12	219.134 ± 2.24	Kareem etal.,2016
South India	6.34 ± 0.81	5.05 ± 0.7	1895.24 ± 103.95	Chandrashekara and Somashekarappa .,2016
Iraq	38.12 ± 1.619	12.95 ± 0.896	570.70 ± 31.453	Hamza etal.,2020
Ghana	31.8 ± 2.8	56.2 ± 2.3	839.8 ± 11.9	Tettey-Larbi etal.,2013
Bangladesh	12.65 ± 5.20	7.38 ± 3.45	661.1 ± 202.6	Sultana etal.,2020
Jordan	2.63 ± 0.30	1.44 ± 0.18	593.97 ± 63.47	Okoor etal.,2019
Turkey	4.48	1.83	259.2	Kırıs .,2020
Turkey	BDL	BDL	1150.8 ± 315.2	Turhan et al. 2007
Nigeria	5.79 ± 1.51	4.13 ± 0.55	630.03 ± 52.9	Alade etal.,2020
Nigeria	25.02 ± 3.18	(35.09 ± 0.71	324.18 ± 8.69	Njinga et al. 2015
Iraq(Al-Basra)	17.42 ± 9.47	24.32 ± 13.74	225.24 ± 100.96	Mohammed etal.,2020
Serbia	2.82	0.63,	984.32	Živkovićetal.,2021
World	**33**	**45**	**420**	**UNSCEAR .,2000**
Present study	**7.25**	**7.78**	**471.4**	

In a real sense, the current results show that the amount of ^{238}U in the air is much higher than in Iraq [23], South India [24], Jordan [25], Turkey [26], Nigeria [27], Serbia [28], Turkey [29], and lower than those obtained in Iraq [30], Ghana [20], Bangladesh [31], Nigeria [32]. The results of ^{232}Th The concentrations obtained are significantly higher than those obtained in Iraq [23], South India [24] Jordan [25], Turkey [26], Turkey [29], Nigeria [27], Serbia [28], and lower than those obtained in Iraq [30], Ghana [20], Nigeria [32]. In the case of ^{40}K, Results from our study are significantly higher than those from Iraq [30], Ghana [20], Bangladesh [31], Jordan [25], Turkey [29], Nigeria [27] Serbia [28], and lower than those in Iraq [23], South India [24], Turkey [26]. The sources of the raw materials could explain the differences in natural radioactivity concentrations between countries Fig. 6.

The measured outdoor annual effective doses ($AED_{outdoor}$) values for examined herbs have been listed in Table 4. The values are ranged from 0.0108 to 0.0680 mSv/yr, with the mean value of 0.0315 mSv/yr. LEMON BALM (H8) and WORM WOOD (H24) herbs have the lowest and highest $AED_{outdoor}$ among all herb samples Fig. 7. The $AED_{outdoor}$ results are smaller than the corresponding global value of 1 mSv/yr. The measured indoor annual effective doses (AED_{indoor}) values for examined herbs have been listed in Table 4. The values are ranged from 0.0810 to 0.5053 mSv/yr, with the mean value of 0.236 mSv/yr. LEMON BALM (H8) and Quince (H23) herbs have the lowest and highest AED_{indoor} and $AED_{outdoor}$ among all herb samples Fig. 7 **and** Fig. 8. The AED_{indoor} results are smaller than the corresponding global value of 1 mSv/yr. 0.0919, 0.555, and 0.267 mSv/yr are minimum, maximum, and average total annual effective doses (AED_{tot}) values for all investigated herbs, respectively. (Lemon Balm*)* (H8) values and (Lavender)| (H16) herbs have the lowest and highest AED_{totalr}among all herb samples values for all investigated herbs, respectively. According to the NSRC and the International Atomic Energy Agency (IAEA), the annual effective dose equivalent for all tested herbs is less than the annual dose limit of 1mSv for the general population.

Table 4
The outdoor ($AED_{outdoor}$), indoor (AED_{indoor}) annual effective doses, and total annual effective doses (AED_{tot}) for different medicinal plant samples.

Code of sample	$AED_{outdoor}$ (mSv/yr)	AED_{indoor} (mSv/yr)	AED_{total} (mSv/yr)	AACDE (Ingestion of NORMs (mSv/yr)	AGDE $(\mu Sv/yr)$
H1	0.0362	0.2681	0.30441	0.01191	210.47
H2	0.0262	0.1961	0.2224	0.3357	151.21
H3	0.0234	0.1737	0.1971	0.00609	138.09
H4	0.0363	0.2770	0.3134	0.50869	210.91
H5	0.0283	0.2110	0.2391	0.00593	168.07
H6	0.0242	0.1777	0.2025	0.00924	140.84
H7	0.0249	0.187	0.212	0.00829	141.88
H8	0.0108	0.0810	0.091	0.002304	64.841
H9	0.0329	0.2448	0.277	0.006962	195.90
H10	0.0204	0.1508	0.1712	0.005891	119.98
H11	0.0138	0.1471	0.1610	0.00598	117.18
H12	0.0546	0.4048	0.4595	0.015601	320.52
H13	0.0288	0.2251	0.2540	0.005765	173.15
H14	0.0182	0.1350	0.1533	0.005115	107.65
H15	0.0155	0.1153	0.130	0.003276	92.263
H16	0.0662	0.4891	0.555	0.022869	383.40
H17	0.0252	0.1942	0.2194	0.00477	143.77
H18	0.0607	0.4521	0.512	0.014111	359.88
H19	0.0187	0.1381	0.156	0.006770	108.26
H20	0.035	0.2565	0.291	0.019389	197.84
H21	0.0199	0.1670	0.186	0.00421	118.53
H22	0.0329	0.2955	0.328	0.006257	191.14
H23	0.0399	0.5053	0.545	0.011557	235.35
H24	0.0680	0.0981	0.166	0.01662	402.22
H25	0.0132	0.2769	0.290	0.004385	76.90

Code of sample	$AED_{outdoor}$ (mSv/yr)	AED_{indoor} (mSv/yr)	AED_{total} (mSv/yr)	AACDE (Ingestion of NORMs (mSv/yr)	AGDE $(\mu Sv/yr)$
H26	0.0374	0.2589	0.296	0.009798	220.98
H27	0.0241	0.1792	0.203	0.005604	143.21
H28	0.0535	0.3832	0.436	0.015557	303.64
H29	0.0253	0.1643	0.1896	0.004673	131.50
Maximum	**0.0680**	**0.5053**	**0.555**	**0.50869**	**402.22**
Minimum	**0.0108**	**0.0810**	**0.0919**	**0.002304**	**64.841**
Average	**0.0315**	**0.2363**	**0.267**	**0.0373**	**185.1**

Table 4 **and** Fig. 9 represent the minimum, maximum, and mean annual effective doses (AACDE) values due to intake ^{238}U, ^{232}Th, and ^{40}K radionuclides through eating the medical plants (Herbs) were equal to 0.002304, 0.50869, and 0.0373 mSv/yr. LEMON BALM (H8) and WORM WOOD (H24) herbs have the lowest and highest AACDE among all herb samples. The AACDE values were lower than the global average (0.3 mSv/yr) for natural radionuclides ingestion reported in the UNSCEAR 2000 report [21]. Table 5 illustrates the contrast of our AACDE with those evaluated in Egypt [33], South India [24], Ghana [20], Iraq [30], Thailand [34], Egypt [35]. According to the comparison, our result is so smaller than the results found in Egypt [35] and The amount of AACDE higher than the result are found for Egypt [33], South India [24], Ghana [20], Iraq [30], Thailand [34] All of these values are significantly lower than the global average dose [21]. Therefore, medicinal plant samples studied here do not be harmful to human health in any way and are considered radiologically safe for adult consumption. From the results, it was found that there are no radiological health risks in the use of these samples.

Table 5
Comparison between AACED ingestion dose of the present medicial plant samples with that of other countries of the world

Country	AACED(ingestion)	Reference
Egypt	0.003 to 0.073	Harb.,2021
South India	0.0075 to 0.1067	Chandrashekara and Somashekarappa.,2016
Ghana	0.0261 to 0.042	Tettey-Larbi etal.,2013
Iraq	0.010399 to 0.002757	Hamza etal.,2020
Thailand	0.0001 to 0.0327	Kranrod et al 2016
Egyt	0.6 to 2.0	Ahmed etal.,2010
Turkey	0.3 to 9.0 0.3	Parmaksız and Ağuş, 2014
World		UNSCEAR, 2000
Present study	0.50869 to 0.002304	

The annual gonadal dose equivalent (AGDE) for medicinal plants is shown in Fig. 10 and listed in Table 4. AGDE values range from 402.2 to 64.8 μSv/yr with an average 185.1 μSv/yr. All values are less than their corresponding global value is 300 \mu Sv/yr [21], except for WORM WOOD (H24). These measurements provide information on the local drugs for these models to formulate guidelines related to radiological health care.

The outdoor absorbed dose rate ($D_{outdoor}$) values have been estimated for the medicinal plants' samples, as shown in Table 6. It was found that the values of the $D_{outdoor}$ vary from 55.46 to 8.87 nGy/h with the mean value of 22.75 nGy/h. The lowest value was found in the sample (LEMON BALM) and the highest value in the (WORM WOOD) sample. The values of the absorbed dose rate for all samples were less than the permissible level of 84 nGy h-1 according to UNSCEAR has recommended that the average exposure rate of the population should be within 84 nGy/h.While the indoor absorbed dose rate (D_{indoor}) values are ranged from 103.01 to 16.52 nGy/h, with an average value of 48.183 nGy/h. The lowest value was found in (LEMON BALM) and the highest in a sample (QUINCE). 1The values of the absorbed dose rate for all samples were less than the permissible level of 84 nGy h-1 according to UNSCEAR has recommended that the population's average exposure rate be kept within 84 nGy/h.

Table 6
Out-door, in-door absorbed dose rate, internal hazard index (H_{in}), external hazard index (H_{ex}) and radioactivity level index (I_{γ}) for different medicinal plant samples.

sample	$D_{outdoor}$ (nGy /h)	D_{indoor} (nGy/ h)	H_{in}	H_{ex}	I_{γ}
H1	29.55	54.66	0.1678	0.1558	0.459
H2	21.38	39.98	0.1382	0.1140	0.3291
H3	19.09	35.42	0.0981	0.0956	0.2965
H4	29.67	56.48	0.2092	0.1532	0.4500
H5	23.072	43.01	0.1162	0.1122	0.357
H6	19.79	36.23	0.10410	0.105	0.3102
H7	20.35	38.16	0.1466	0.1129	0.3121
H8	8.879	16.52	0.0429	0.0429	0.1376
H9	26.82	49.91	0.1297	0.1297	0.4159
H10	16.641	30.75	0.0848	0.0844	0.259
H11	11.303	30.00	0.0582	0.0588	0.176
H12	44.55	82.53	0.2419	0.2272	0.692
H13	23.55	45.90	0.1599	0.1235	0.369
H14	14.89	27.53	0.0745	0.075	0.231
H15	12.641	23.52	0.0614	0.0611	0.195
H16	53.99	99.71	0.3099	0.2874	0.840
H17	20.563	39.59	0.1703	0.11059	0.3084
H18	49.560	92.176	0.2513	0.2441	0.768
H19	15.27	28.16	0.0878	0.0819	0.2380
H20	28.83	52.29	0.184	0.1714	0.4538
H21	16.23	34.05	0.0784	0.0784	0.251
H22	26.88	60.24	0.1890	0.1387	0.407
H23	32.60	103.01	0.1639	0.1650	0.508
H24	55.46	20	0.2810	0.2749	0.860
H25	10.81	56.461	0.0620	0.0571	0.168
H26	30.49	52.77	0.1513	0.1519	0.474

sample	$D_{outdoor}$ (nGy /h)	D_{indoor} (nGy/ h)	H_{in}	H_{ex}	I_{γ}
H27	19.67	36.53	0.0961	0.0963	0.305
H28	43.62	78.13	0.2389	0.2243	0.677
H29	20.64	33.50	0.0998	0.0998	0.320
Maximum	**55.46**	**103.01**	**0.3099**	**0.2874**	**0.860**
Minimum	**8.879**	**16.52**	**0.0429**	**0.0429**	**0.137**
Average	**22.75**		**0.1448**	**0.1322**	**0.399**

According to UNSCEAR, the average indoor absorbed dose rate values for all samples are below the permissible level of 59 nGy h^{-1}. The external and internal hazard indexes are shown in Table 6, and their maximum values are 0.287 and 0.3099, respectively. At the same time, the minimum values were 0.0429 and 0.0429, respectively. The average values were 0.1322 and 0.1448. The estimated values of extrinsic and intrinsic risk indices for all types of medicinal plant samples analyzed in this work were below the recommended limit of 1 [21]. Therefore, to reduce the annual effective dose to ≤ 1.5 mSv, for the safe use of these plants. Because of the calculated radioactivity level index in Table 6. The values are ranged from 0.860 maximum value in(Worm wood) sample to 0.1376 minimum value in the (Lemon Balm) sample, with an average value of 0.399. All values of the calculated radioactivity level index (Iγ) for the samples were checked below the permissible levels [21].

Excess lifetime cancer risk (ELCR) values are ranged from the maximum value (1.7804×10^{-3}) in (Thyme herb) to the minimum value (0.00806×10^{-3}) in (Lemon Balm), with an average value (0.1307×10^{-3}). The mean value of ELCR is less than the global average of 2.9×10^{-4} based on the annual dose limit of (1mSv) for the general public by UNSCEAR, ICRP [21,36] as shown in Table 7.

Table 7
The excess lifetime cancer risk (ELCR) for the investigated samples.

Sample	ELCR×10^{-3}	Sample	ELCR×10^{-3}
H1	0.0417	H16	0.08004
H2	1.1751	H17	0.01670
H3	0.0213	H18	0.0493
H4	1.7804	H19	0.0236
H5	0.0207	H20	0.0678
H6	0.0323	H21	0.0147
H7	0.0290	H22	0.0219
H8	0.00806	H23	0.0404
H9	0.0243	H24	0.0581
H10	0.02061	H25	0.0153
H11	0.0209	H26	0.0342
H12	0.0546	H27	0.0196
H13	0.02018	H28	0.0544
H14	0.01790	H29	0.0163
H15	0.01146		
Maximum	**1.7751**		
Minimum	**0.00806**		
Average	**0.131**		

4. Conclusions

The gamma rays released by natural radionuclides, ^{238}U, ^{232}Th, and ^{40}K, were measured in 29 samples of medicinal herbs commonly used in Egypt. The concentration of naturally occurring radionuclide activity in medicinal plant samples was examined for the first time. The average activity concentrations in the examined medicinal herbs were 7.25, 7.78, and 471.4 Bq/Kg, respectively. NORMs were reported to have mean annual effective doses of 0.1579 and (0.0373) mSv/yr from both external and internal exposure (outside the residence, in the door). We also determined that the findings are within the UNSCEAR Committee's allowed limit. The computed radioactivity level index (I) for the tested samples was below the allowed limit, and the absorbed dose rate was within the world average of 84 nGy/h. Since the projected life-long excess cancer risks are globally recognised, the use of these plant samples poses no radiological health hazards. These findings were compared to their respective reference values and to results from other nations. The comparison revealed that the current study's radioactivity concentrations and annual effective doses were comparable to previous research in other countries. The levels were likewise within UNSCEAR's allowed limit. The study's plant samples had no artificial radioactivity. The radiation level of the plant samples in this investigation does not now constitute a health danger. As a result, a continual environmental monitoring program is required to detect any changes caused by artificial radioactivity produced by a nuclear site. Using these plants in herbal medicines may not be harmful to your health. The baseline data from this research may be used to estimate future radiation threats to human health.

Declarations

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data presented in this study are available on request from the

corresponding author.

Acknowledgments

This work was funded by Princess Nourah bint, Abdulrahman University, Research Supporting Project number (PNURSP2022R137) Princess Nourah bint, Abdulrahman University Riyadh, Saudi Arabia.

Author contributions: H.M.Z., S.A.I., and H.A.S.: wrote the main manuscript text, H.T.A., M.A.U., I.I.B., and H.M.D.: prepared and drown all figures, H.A.S., G.A.A., and H.M.Z.: Contributing to preparing the samples and analysis data, All authors reviewed and revised the manuscript.

Competing interests: The authors declare no competing interests

Data availability: All data generated or analysed during this study are included in this published article

Additional information: **Correspondence** and requests for materials should be addressed to H.M.Z.

References

1. Kandić, I., Kandić, A., Čeliković, I., Gavrilović, M. & Janaćković, P. Activity concentrations of 137Cs, 40K, and 210Pb radionuclides in selected medicinal herbs from Central Serbia and their effective dose due to ingestion. Sci. Total Environ. **701**, 134554 (2020).
2. Jamshidi-Kia, F., Lorigooini, Z. & Amini-Khoei, H. Medicinal plants: Past history and future perspective. J. Herbmed Pharmacol. **7**, 1–7 (2018).

3. Pan, S.-Y. *et al.* Historical Perspective of Traditional Indigenous Medical Practices: The Current Renaissance and Conservation of Herbal Resources. *Evidence-Based Complement. Altern. Med.* 2014, 1–20 (2014).
4. Mitrović, B. *et al.* Natural and anthropogenic radioactivity in the environment of Kopaonik mountain, Serbia. Environ. Pollut. **215**, 273–279 (2016).
5. HOW. *World Health Organization. (2007). WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues. World Health Organization.* (2007).
6. Cruz da Silva, R. *et al.* Radiological evaluation of Ra-226, Ra-228 and K-40 in tea samples: A comparative study of effective dose and cancer risk. Appl. Radiat. Isot. **165**, 109326 (2020).
7. Philip J. White, Kamal Swarup, Abraham J. Escobar-Gutiérrez, Helen C. Bowen, N. J. W. & M. R. B. Selecting plants to minimise radiocaesium in the food chain. Plant Soil **249**, 177–186 (2003).
8. Aziz, A. *Methods of low-Level Counting and Spectrometry Symposium*. (1981).
9. Gilmore, G. Hemingway, J.. *Practical Gamma ß Ray Spectrometry*. (John Wiley & sons Ltd., 1995).
10. Ebaid, Y. Y. & Bakr, W. F. Investigating the effect of using granite and marble as a building material on the radiation exposure of humans. Radiat. Prot. Dosimetry **151**, 556–563 (2012).
11. Zakaly, H. M. H. *et al.* An extended assessment of natural radioactivity in the sediments of the mid-region of the Egyptian Red Sea coast. Mar. Pollut. Bull. **171**, (2021).
12. Moghazy, N. M. *et al.* Natural radioactivity, radiological hazard and petrographical studies on aswan granites used as building materials in Egypt. Appl. Sci. **11**, (2021).
13. Awad, H. A., Zakaly, H. M. H., Nastavkin, A. V., El Tohamy, A. M. & El-Taher, A. Radioactive mineralizations on granitic rocks and silica veins on shear zone of El-Missikat area, Central Eastern Desert, Egypt. Appl. Radiat. Isot. **168**, (2021).
14. Awad, H. A. M., Zakaly, H. M. H., Nastavkin, A. V. & El-Taher, A. Radioactive content and radiological implication in granitic rocks by geochemical data and radiophysical factors, Central Eastern Desert, Egypt. Int. J. Environ. Anal. Chem. (2020) doi:10.1080/03067319.2020.1830987.
15. Abbasi, A., Zakaly, H. M. H. & Mirekhtiary, F. Baseline levels of natural radionuclides concentration in sediments East coastline of North Cyprus. Mar. Pollut. Bull. **161**, (2020).
16. Ghoneim, M. M. *et al.* Distribution patterns of natural radioactivity and rare earth elements in intrusive rocks (El Sela area, Eastern Desert, Egypt). Int. J. Environ. Anal. Chem. (2021) doi:10.1080/03067319.2021.1916006.
17. Abed, N. S. *et al.* Assessing the radiological risks associated with high natural radioactivity of microgranitic rocks: A case study in a northeastern desert of Egypt. Int. J. Environ. Res. Public Health **19**, (2022).
18. Tawfic, A. F. *et al.* Natural radioactivity levels and radiological implications in the high natural radiation area of Wadi El Reddah, Egypt. J. Radioanal. Nucl. Chem. **327**, 643–652 (2021).
19. El-Taher, A., Zakaly, H. M. H. & Elsaman, R. Environmental implications and spatial distribution of natural radionuclides and heavy metals in sediments from four harbours in the Egyptian Red Sea

coast. Appl. Radiat. Isot. **131**, 13–22 (2018).

20. Tettey-Larbi, L., Darko, E. O., Schandorf, C. & Appiah, A. A. Natural radioactivity levels of some medicinal plants commonly used in Ghana. Springerplus **2**, 157 (2013).
21. UNSCEAR, 2000. United Nations. Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000.Sources and Effects of Ionizing Radiation: Sources (Vol. 1). United Nations Publications, New York. (2000).
22. Bhatti, T.M., and Malik, K.. Phosphate Fertilizers a Potential Source for Uranium Recovery as by-Product., National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad, Technical Report No. PAEC/NIBGE-2. 1994.
23. Abdulhussein, A. K., Heiyam, N. H. & Ali, A. A. Measurement of natural radioactivity in selected samples of medical plants in Iraq. Int. J. Phys. Sci. **11**, 178–182 (2016).
24. Chandrashekara, K. & Somashekarappa, H. M. Estimation of radionuclides concentration and average annual committed effective dose due to ingestion for some selected medicinal plants of South India. J. Radiat. Res. Appl. Sci. **9**, 68–77 (2016).
25. Okoor.S. A. K, Abumurad.K.M, Ababneh.E. M, 2019.Manal Jamal Abdallah.M.J, T.. A.. Natural Radioactivity Concentrations And Dose Assessment In Selected Medicinal Plants Consumed In Jordan. *Fresenius Environ. Bull.* **28**, 5179–5187 (2019).
26. Kırıs, E. Radioactivity levels and radiation health hazards in medicinal plants used in Rize Province, Turkey. Int. J. Environ. Anal. Chem. 1–14 (2020) doi:10.1080/03067319.2020.1760859.
27. Alade, A.A., Igwe, C.O ., Adekunle, T.. Natural Radioactivity Levels of Some Herbal Plants With Antimalaria Potency In Ibadan South-West Local Government Area Of Oyo State, Nigeria. I.OSR J. Appl. Chem. **13**, 2278–5736 (2020).
28. Živković, M., Zlatić, N., Krstić, D. & Stanković, M. Health risk assessment of natural and artificial radionuclides in medicinal plants. Kragujev. J. Sci. 15–22 (2021) doi:10.5937/KgJSci2143015Q.
29. Turhan, Ş., Köse, A. & Varinlioğlu, A. Radioactivity levels in some wild edible mushroom species in Turkey. Isotopes Environ. Health Stud. **43**, 249–256 (2007).
30. Hamza, Z. M., Alshebly, S. A. & Hussain, H. H. A practical study to determine the percentage of radiation in medicinal herbs used in the Iraqi market. J. Phys. Conf. Ser. **1591**, 012007 (2020).
31. Sultana. S., Ferdous. J., H. M.. Natural Radioactivity and Hazards Assessment in Medicinal Plants in Bangladesh. J. Heal. Sci. **10**, 20–27 (2020).
32. Njinga, R. L., Jonah, S. A. & Gomina, M. Preliminary investigation of naturally occurring radionuclides in some traditional medicinal plants used in Nigeria. J. Radiat. Res. Appl. Sci. **8**, 208–215 (2015).
33. Harb, S. M. Natural radioactivity concentrations in some medicinal plants and annual committed effective dose from their consumption. Radiat. Prot. Environ. **38**, 35 (2015).
34. Kranrod, C. *et al.* Natural radioactivity concentration in traditional Thai herbal medicine. J. Phys. Conf. Ser. **1285**, 012010 (2019).

35. Ahmed, F., Daif, M. M., El-Masry, N. M. & Abo-Elmagd, M. External and internal radiation exposure of herbal plants used in Egypt. Radiat. Eff. Defects Solids **165**, 65–71 (2010).
36. ICRP. International Commission on Radiological Protection, (ICRP),1996.Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilations of In-gestion and Inhalation Dose Coefficients (ICRP Publica-tion 72)". Pergamon Press, Oxford. (1996).

Figures

Figure 1

Samples are inside the Marinelli beaker

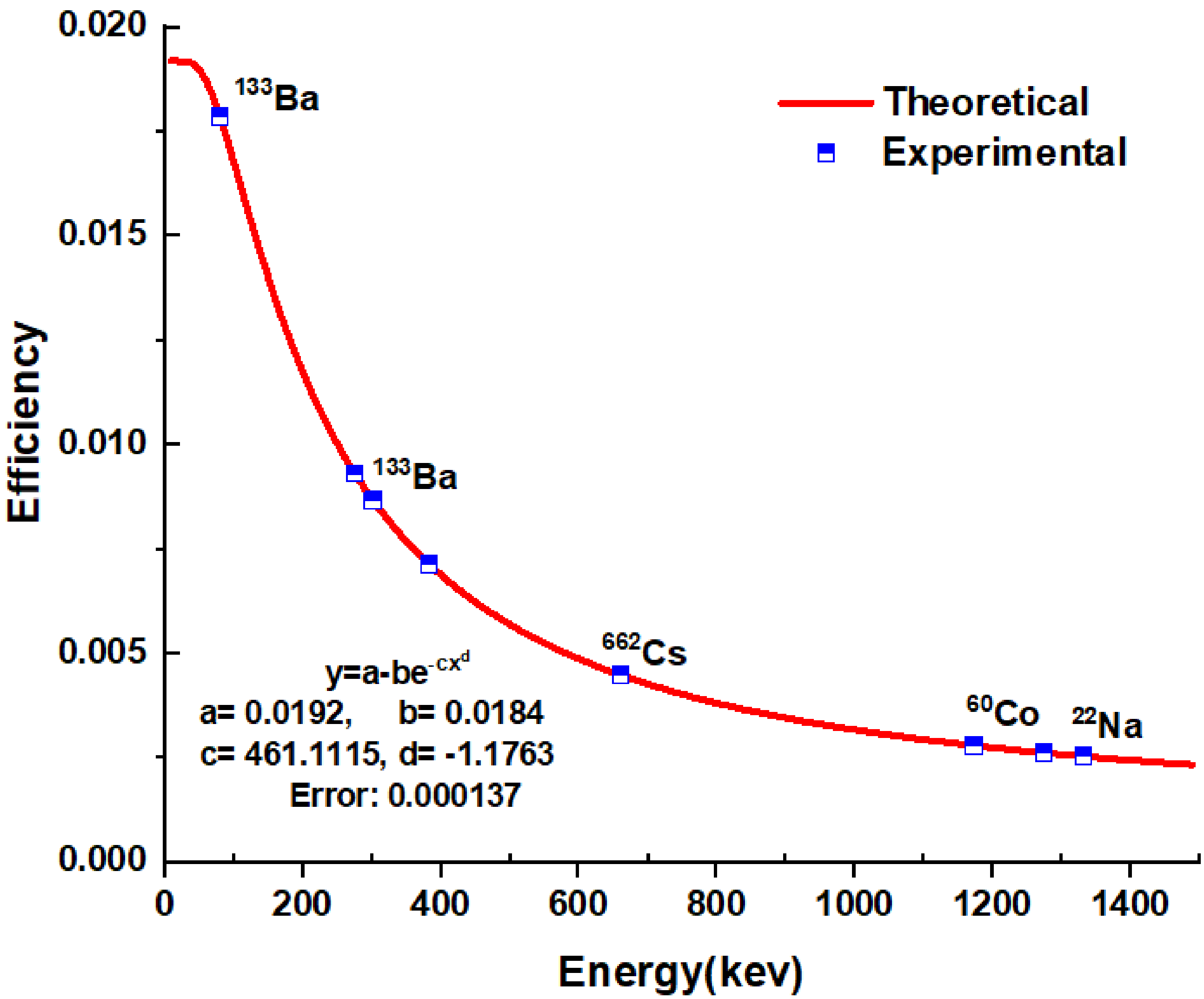

Figure 2

Standard sources are used to calibrate the detector for efficiency

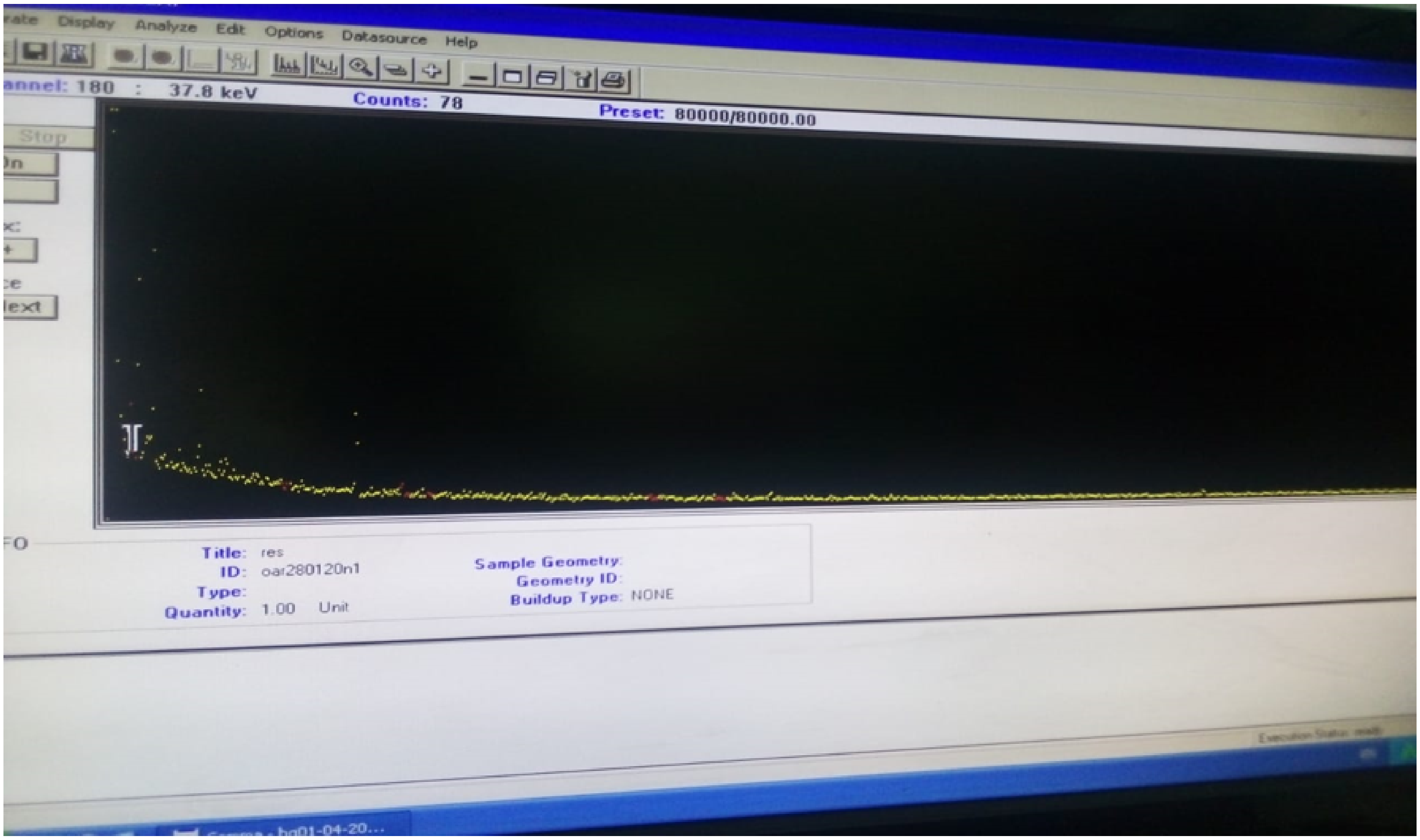

Figure 3

Spectrum of U^{238}, Th^{232} and K^{40} in one sample

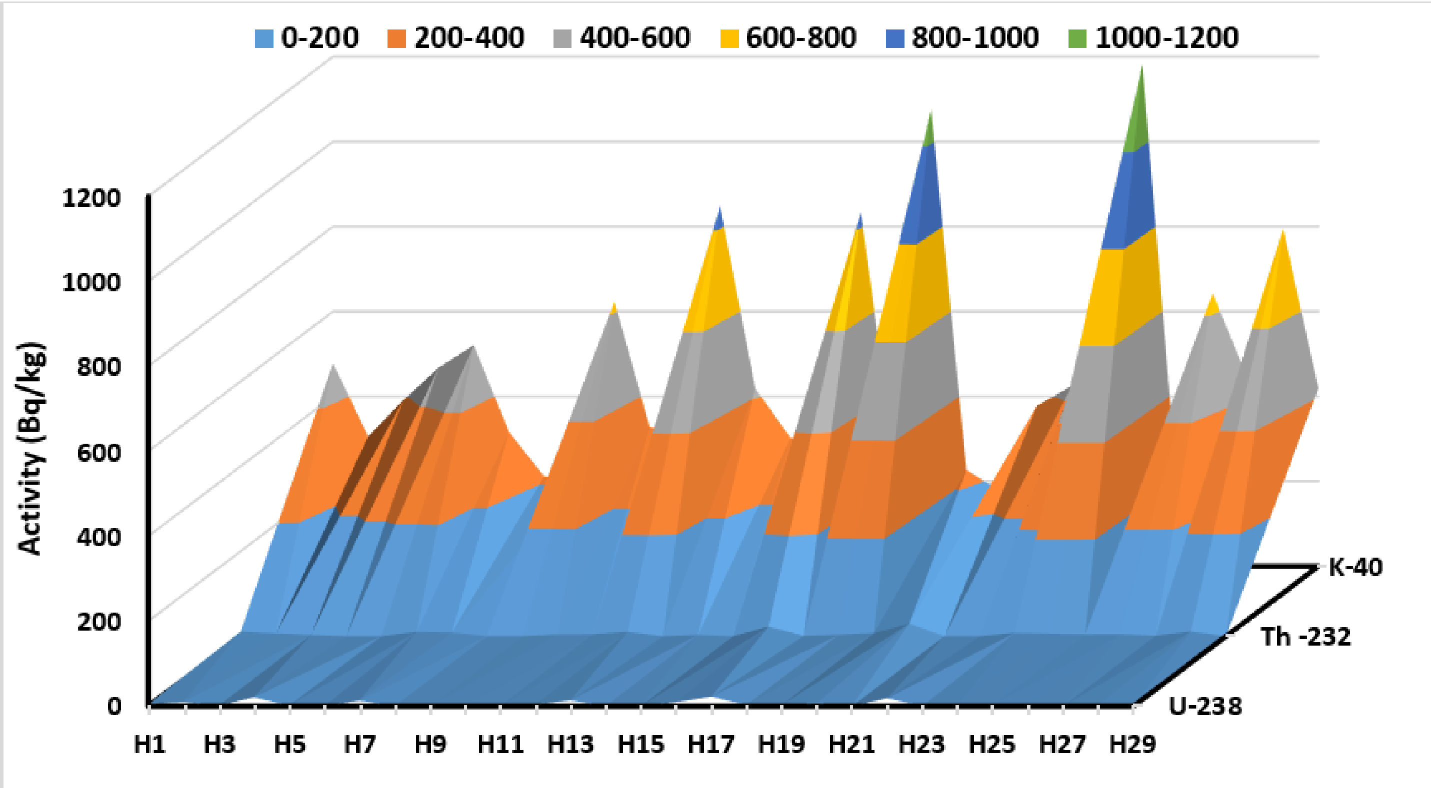

Figure 4

The activity concentration for ^{238}U, ^{232}Th, and ^{40}K in medicinal plant samples (Bq/kg).

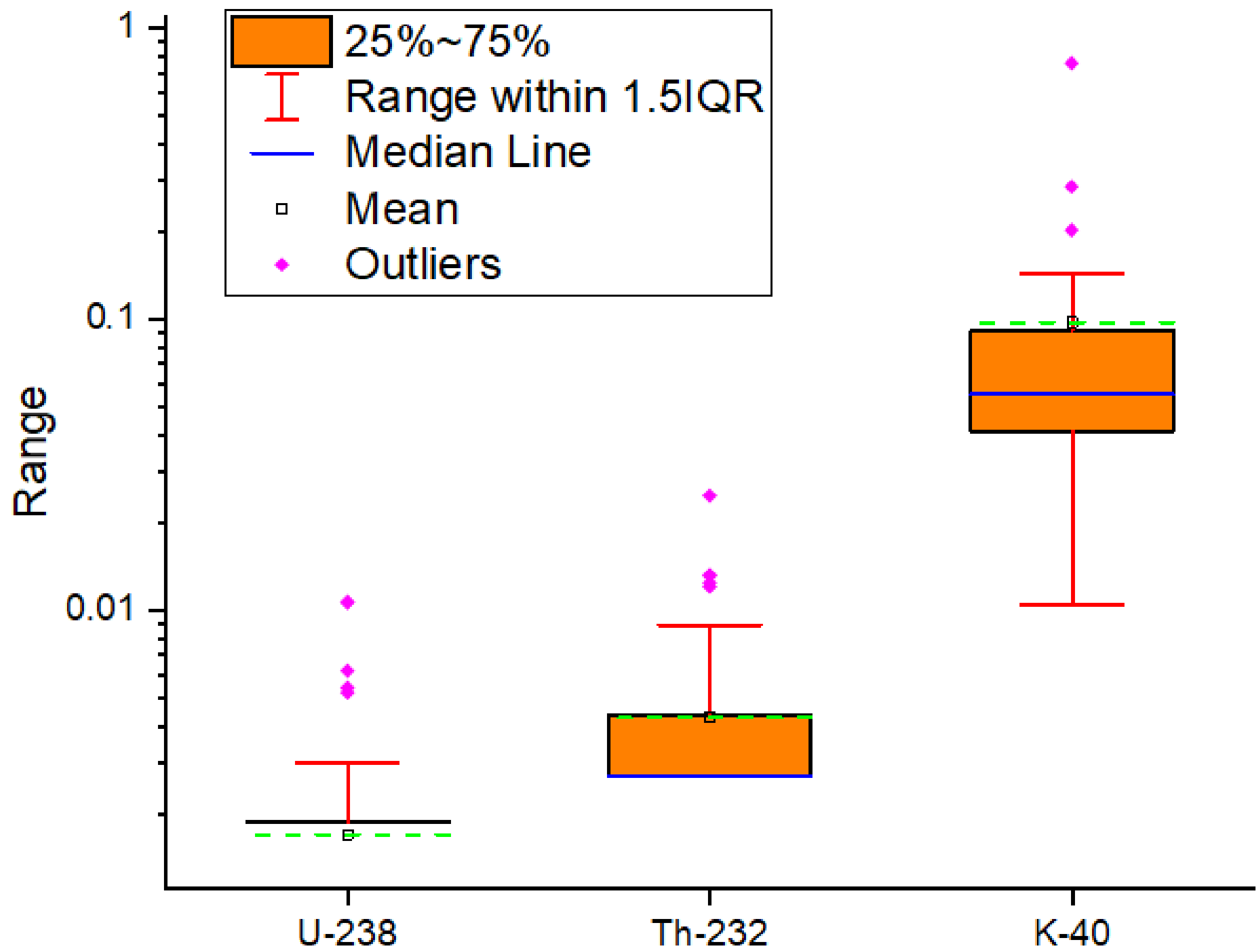

Figure 5

Range, mean, median line, and outliers radioactive elements (^{238}U, (^{226}Ra), ^{232}Th, and ^{40}K radionuclides) for measured samples in the interested area.

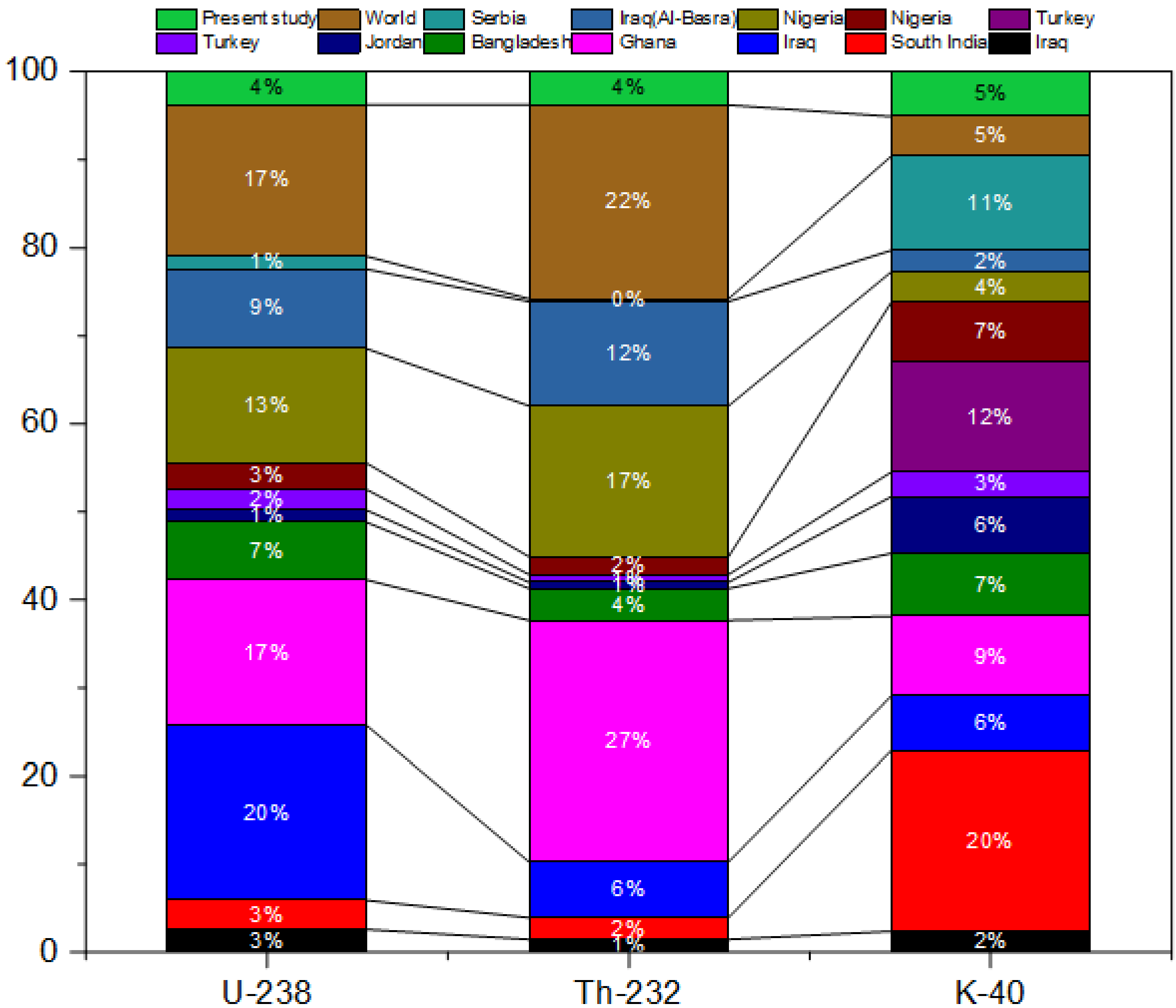

Figure 6

The mean activity concentrations of natural radioactivity of medicinal plant samples in

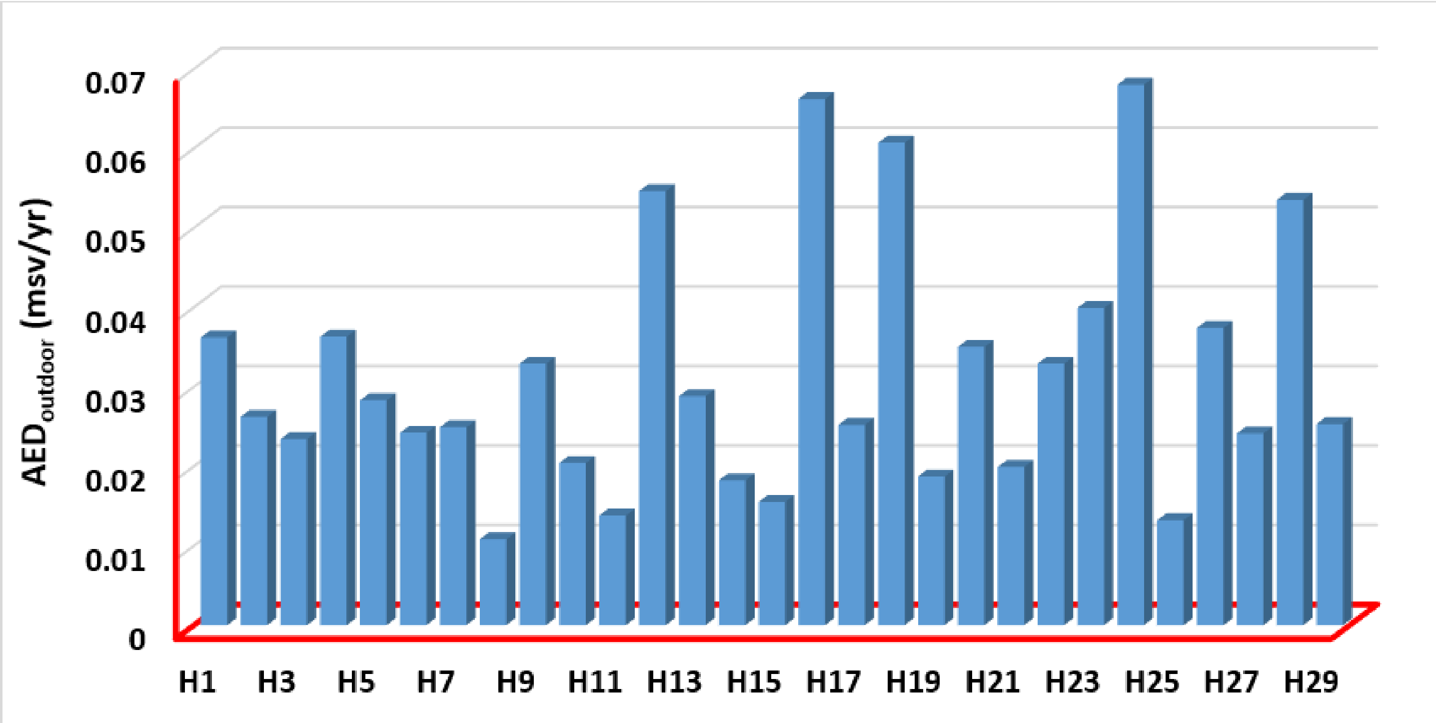

Figure 7

Outdoor annual effective doses ($AED_{outdoor}$) for all herbs.

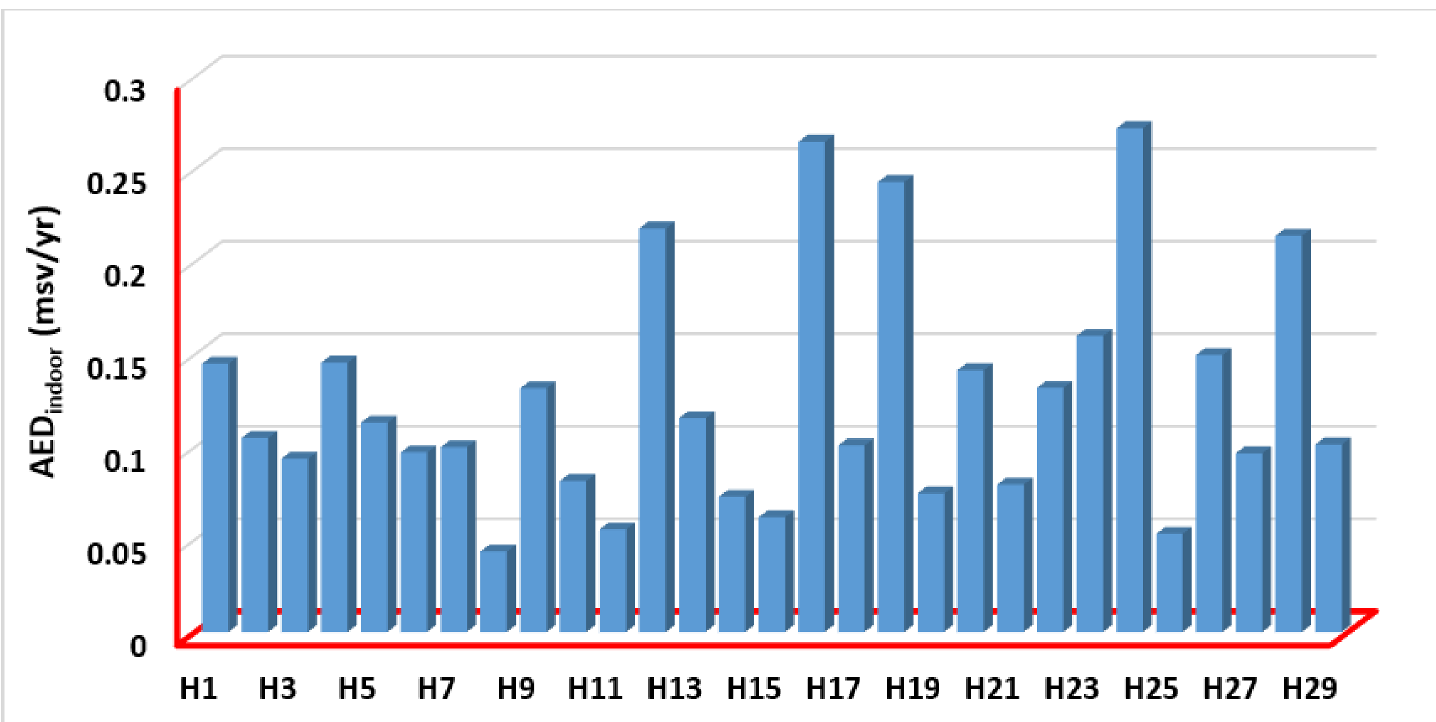

Figure 8

Indoor annual effective doses (AED_{indoor}) for all herbs.

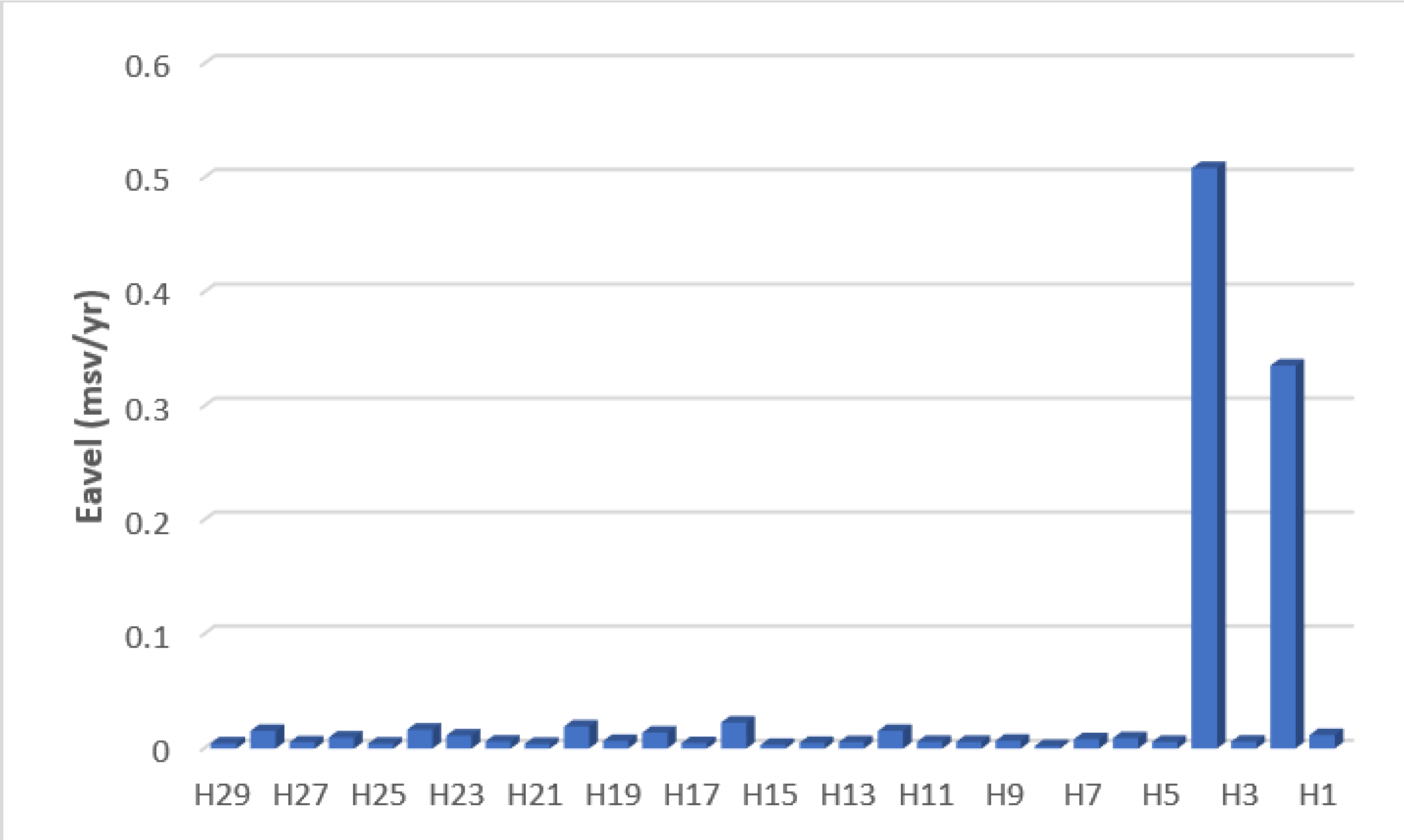

Figure 9

The average annual committed effective dose (Eave) distribution in the various species of the medicinal plant samples.

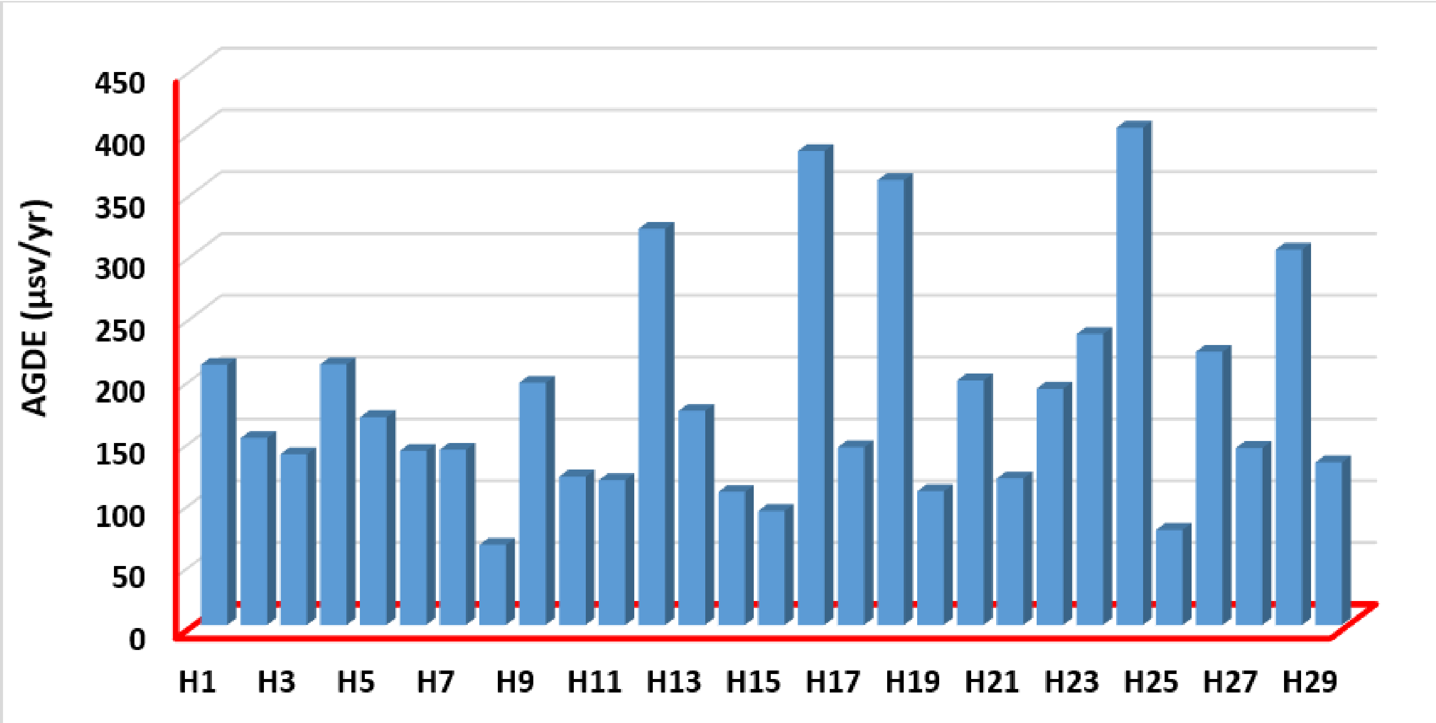

Figure 10

The annual gonadal equivalent dose (AGDA) in the various species of the medicinal plant samples.