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# Yearly effective dose due to consumption of wild black fungus grow in southern Iraq assessed by measuring of radionuclide concentrations

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# Yearly effective dose due to consumption of wild black fungus grow in southern Iraq assessed by measuring of radionuclide concentrations

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**Abstract**. Wide range of studies have been conducted around the word focusing on the evaluation of radionuclide concentrations in foodstuff. This work focusing on the estimation of the annual effective dose due to radionuclide activity in Iraqi wild fungus, specifically black desert truffles. The fungus have been collected from the desert of As Samawah governorate in the south of Iraq as it is grow in a large amount. The average activity concentrations for $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs were 3.95, 2.53, 260.36 and 1.78 $Bqkg^{-1}$ respectively in all 10 collected truffle samples. The average annual effective doses from $^{238}$U ingestion were 0.36 and 0.54, from $^{232}$Th ingestion were 1.16 and 1.47, from $^{40}$K ingestion were found to be 3.23 and 319.20 and from $^{137}$Cs were 0.05 and 0.04 $\mu$Sv year$^{-1}$ in adults and children respectively. The measured values were less than the assessed world mean value from the exposure caused by natural radionuclide ingestion that documented in the literature (0.29 mSv year$^{-1}$).

**Keywords.** fungi; radionuclide concentration; annual dose; Iraq; truffles; high purity germanium detector

## 1. Introduction

Since decades, contamination levels measurement in food stuff have been spread widely around the word. The scientists focus on this field as a result of the wide prevalence of radiological pollution in the air, soil, water, animals and plants [1-7]. The reasons for the elevated levels of contamination in some regions in the world can be probably natural or man-made. The natural radionuclides are exist in the environment without human intervention depending on the structure of i.e soil and rocks, such as potassium, thorium and uranium in addition to their decay products. The man-made contamination can be due to several causes, such as the pollution caused by the radionuclides employed in nuclear medicine, the radioactive materials in the reprocessing of nuclear fuel, and the contamination caused by wars and nuclear accident like Chernobyl [8]. For example, 137Cs isotope was released to the environment due to Chernobyl accident with a radioactivity of $9 \times 10^{16}\ Bq$ [9]. The existence of anthropogenic radionuclides in the examined environmental samples give an indication of previously occurred contaminated event. The man-made and natural occurring radionuclides are transfer from soil by roots to the plant and then consumed by humans through ingestion. Thus, there is a wide attention in estimation of individual radiation exposure due to the radioactive nuclei intake from plants, meat, water and other foodstuff [10-12].

Wild fungus or desert truffles or also called thunder plant as it grows after the thunder storms, is a seasonal mushroom that grows in the desert after rain falls 5 to 15 centimeters deep underground and is used as food. It is considered one of the tastiest and most valuable desert fungi in Iraq and around the world. It grows near the roots of huge trees. Its spherical shape is fleshy, soft, and its color varies from white to black, and it is in sizes that vary and it grows to reach the size of an orange [13]. During the mushroom harvest, Iraqis consume large quantities of it in cooking different types of food. This plant grows inside the soil and is surrounded by it from all sides. It is possible for the radioactive nuclei to be transmitted from the soil to this plant, which poses a great risk to human health.

The most known radionuclides that measured by the scientist to evaluate the radioactive contamination in food and other environmental samples are 238U, 232Th, 40K and 137Cs [14-17]. There are many methods that are used to measure the concentrations of radioactive nuclei utilizing several types of detectors (i.e high purity germanium detector HPGD, Cr-39, Sodium Iodide NaI) [18-20]. In this work HPGD has been chosen due to the accuracy of its work and its results are somewhat error free. The aim of this study is to calculate the 238U, 232Th, 40K and 137Cs radionuclides concentration in black wild truffle collected from As Samawah desert in the south of Iraq to assess the annual effective dose due to consumption of it by adults and children for the purpose of ensuring that this fungus is free from contamination and is considered as edible.

## 2. Methodology

### *2.1. Samples preparation and collection*

As Samawah is one of the Iraqi governorates that located in the south east of Iraq (30°12′N, 45°21′E), 15.1 m above the sea with an area of 51.8 km$^2$. There is a suspicion that the lands of this province are polluted as a result of the wars that took place on it [21]. The black wild truffle (locally called chema aj-jubbah) were harvest from As Samawah desert during January 2018. A total of 10 samples (1 kg each) were collected from the sites indicated in figure (1), the location of the samples was identified by the global positioning system (GPS) and then affixed on the map according to its latitude and longitude degrees.

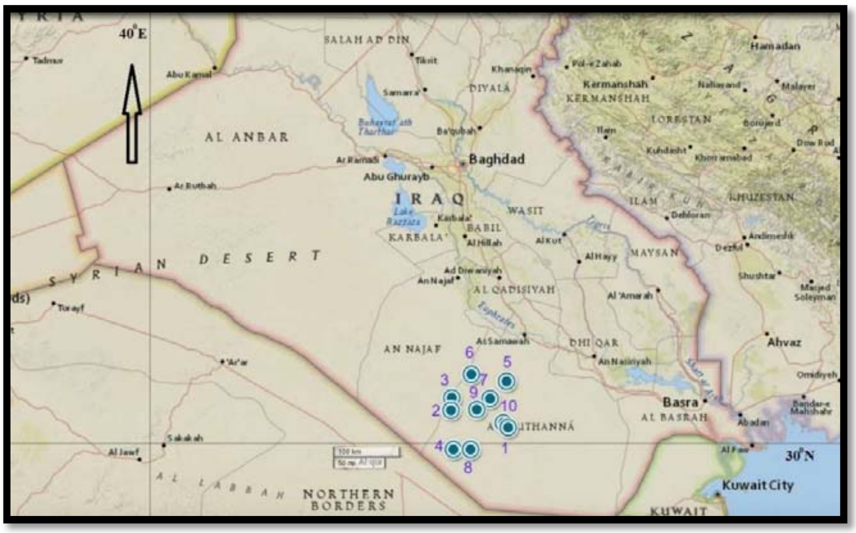


**Figure 1.** The map of Iraq includes the samples sites affixed using GPS.

The truffle skin has been cleaned from the mud and soil using dry clean toothbrush. The samples are then cut into slices using disposable knife and let to air dry at $30^0$C. Thereafter, the samples were grinded by a clean electric grinder, homogenized using 2-mm mesh, weighed, and stored in coded plastic bags for 1 month to reach equilibrium between $^{238}$U and $^{232}$Th isotopes and their decay products (figure 2). The gathered truffles mass was in the range of 220~351 g dry mass.

**Figure 2.** The stored truffle samples in a codded plastic bags inside Marinelli beakers.

*2.2. Gamma ray spectroscopy*

After 1 month of storage, samples were sent for gamma ray spectroscopy to estimate the activity concentrations of $^{238}$U, $^{232}$Th, $^{40}$K, $^{137}$Cs radionuclides using HPGD system with efficiency of 42% and energy resolution of 2.59 keV at energy of 1332.7 keV for $^{60}$Co. The detector is surrounded by lead shield to get rid of the effect of radiation in the background (figure 3). The following relation has been used to assess the radionuclide activity concentration from the samples in 0.5 litter Marinelli beaker [22],

$$\boldsymbol{A = (area\ under\ the\ photopeak\ at\ energy\ E - P.A)/(mI_\gamma \varepsilon T)} \quad \textbf{(1)}$$

where, $A$ is the radionuclides activity concentrations in $Bqkg^{-1}$.
$P.A$ is the total peak area below the peak of background includes shielding.
$m$ is the sample mass in kg.
$I_\gamma$ is the abundance at specific energy.
$\varepsilon$ is the detector efficiency at specific energy.
$T$ is the time (7200 s).
It is worth noting that the gamma spectroscopy lab was routinely subject to examination to reach high standards of analytical quality and control, and to emphasize the accuracy and reliability of the process [23].

**Figure 3.** The HPG detector shielded with lead to prevent the background radiation from reaching the samples.

## 3. Results and Discussions

The Canberra HPG detector that used to evaluate the radionuclide concentrations is connected to a computer system with Genie 2k Canberra software installed to display the gamma ray spectra. The illustrated gamma peaks of 295.2, 351.9, and 609.3 keV from $^{214}$Pb, $^{214}$Pb and $^{214}$Bi respectively, represent the uranium daughter series. The gamma peaks of 238.6, 583.2 and 911.2 keV from $^{212}$Pb, $^{208}$Tl and $^{228}$Ac is the thorium daughter series. Figure 4 illustrates the activity concentrations for each detected radionuclide in the truffle samples under examination. It is clear that the activity concentration of $^{214}$Pb (295.2 keV), $^{214}$Pb (351.9 keV), $^{214}$Bi, $^{212}$Pb, $^{208}$Tl, $^{228}$Ac, $^{40}$K and $^{137}$Cs radionuclides are ranging from 2.68 to 6.4, 0.66 to 6.52, 2.07 to 6.54, 0.48 to 3.43, 0.28 to 4.44, 1.07 to 4.60, 76.51 to 423.32 and from 0.11 to 3.37 $Bqkg^{-1}$dry biomass (db) respectively. Consequently, the activity concentration for $^{238}$U and $^{232}$Th was calculated from their progeny photopeaks [24] and found to range from 2.31 to 5.88, and from 1.76 to 3.71 $Bqkg^{-1}db$ respectively as illustrated in figure 5; The data in figures 4 and 5 were plotted using Matlab programming language.

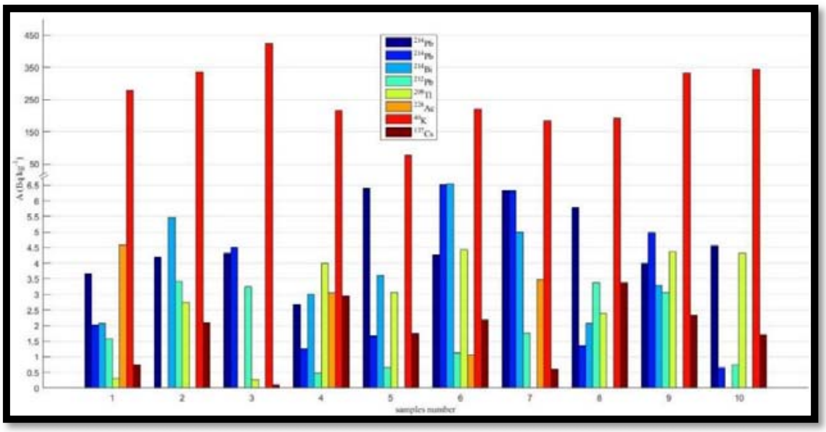

**Figure 4.** The $^{214}$Pb (295.2 keV), $^{214}$Pb (351.9), $^{214}$Bi, $^{212}$Pb, $^{208}$Tl, $^{228}$Ac, $^{40}$K and $^{137}$Cs radionuclides activity concentrations in 10 truffle samples.

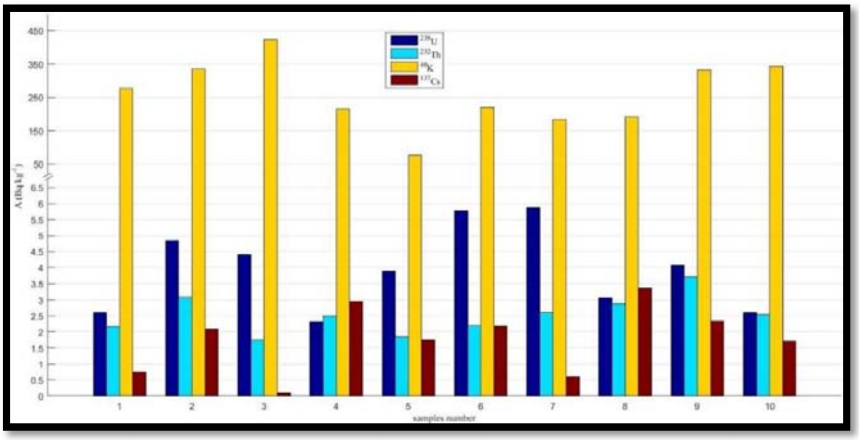


**Figure 5.** The $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs radionuclides activity concentrations.

The obtained outcomes show that $^{137}$Cs has been recorded in nine out of ten samples, this gives the impression that this area has been subjected to environmental pollution resulting from military operations and this radionuclide is still being uptake by truffles. The absence of cesium in sample 9 is not considered as a conclusive evidence of its absence, it is well known that system detection and background grade may hide minor photo-peaks [25]. The maximum acceptable limit of $^{137}$Cs in fresh foodstuff is 1250, and 12500 $Bqkg^{-1}$ for dry mass as recommended by the international atomic energy agency (IAEA) [26]. The concentration of $^{137}$Cs in the examined site was three order of value lower than the recommended one.

The $^{238}$U, $^{232}$Th, $^{40}$K radionuclides were detected in all samples, the presence of these radionuclides in truffle samples was expected, especially for $^{40}$K due to its natural abundance. The obtained results in this study were compared to the outcomes reported in the literature that estimate the radionuclides concentration in mushroom (Table 1). In this table, the results in this study show that the values of activity concentration in Iraqi truffles is very low compared to those documented in the literature.

**Table 1.** The activity concentrations of radionuclides in mushroom evaluated in the selected regions around the globe compared to the results obtained in this work in black truffle.

| Country | 238U $Bqkg^{-1}$ | 232Th $Bqkg^{-1}$ | 40K $Bqkg^{-1}$ | 137Cs $Bqkg^{-1}$ | References |
|---|---|---|---|---|---|
| Nigeria | 2.7 ± 0.8-21.6 ± 7.2 | 8.6 ± 3.3-14.3 ± 6 | 254.2 ± 46.8-416.1 ± 68.4 | *WD | [27] |
| Turkey/ Mersin | WD | 7.2± 3.6 | 784.0 ± 26.9 | 23.7 ± 1.1 | [28] |
| Canada/ Manitoba | WD | WD | 1300±57 | 2256±690 | [29] |
| Japan | WD | WD | 12 ± 0.8- 1800 ± 160 | 1.9 ± 0.06 –20 ± 0.79 | [30] |
| Italy/ Venezia Giulia | WD | WD | 700-2100 | 95-27626 | [31] |
| Czech Republic | WD | WD | 1800 ± 100-2400±200 | 161±7-1500 ± 200 | [32] |
| Belgium | WD | WD | 800-1120 | 370-1350 | [33] |
| Russia | WD | WD | 1760 | 9.6 | [33] |
| Iraq | 3.95 | 2.53 | 260.36 | 1.78 | This study |

*without data

The yearly effective dose due to the consumption of truffle was estimated using the following expression [34]

$$\boldsymbol{D = AIE} \quad \textbf{(1)}$$

where $D$ is the yearly effective dose in $Sv\ year^{-1}$, $A$ is the radionuclide activity concentration in $Bqkg^{-1}$, $I$ is the yearly intake of truffle and taken to be 2 $kg$ , and $E$ is the dose conversion factor in $Sv\ year^{-1}$. The dose conversion factor is age dependent and has different values depends on the radionuclide that might be consumed. Based on the International Commission on Radiological Protection (ICRP) recommendations [35], the dose conversion factor for $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs is 0.045, 0.23, 0.0062, 0.013 in adults and 0.068, 0.29, 0.613 and 0.01 $nSv\ Bq^{-1}$ in children respectively. The results of the annual effective dose for each age group due to consumption of 2 kg of truffles yearly are represented in Table 3. As recommended by UNSCEAR [34], the exposure from ingestion of uranium and thorium must be less than 0.12, from potassium ingestion should be less than 0.17 $mSv\ year^{-1}$ and the total ingestion exposure from all radionuclides should not exceed 0.29 $mSv\ year^{-1}$. It is noteworthy that the yearly effective dose from uranium, thorium, potassium and cesium existent in truffle are low compared to the internationally permitted values. The average total annual effective dose in both adults and children are 4.80 and 321.25 $\mu Sv\ year^{-1}$ which seems very low compared to the allowed annual dose, thus making the consumption of truffle is safe and does not pose any risk during consumption.

**Table 2.** Yearly effective dose due to truffle consumption by both adults and children age group

| samples no. | $D\ (\mu Sv\ year^{-1})$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **238U** | | **232Th** | | **40K** | | **137Cs** | |
| | **adult** | **child** | **adult** | **child** | **adult** | **child** | **adult** | **child** |
| 1 | 0.23 | 0.35 | 1.00 | 1.26 | 3.45 | 341.58 | 0.02 | 0.01 |
| 2 | 0.44 | 0.66 | 1.42 | 1.79 | 4.17 | 412.56 | 0.05 | 0.04 |
| 3 | 0.40 | 0.60 | 0.81 | 1.02 | 5.25 | 518.99 | WD | WD |
| 4 | 0.21 | 0.31 | 1.15 | 1.45 | 2.68 | 265.39 | 0.08 | 0.06 |
| 5 | 0.35 | 0.53 | 0.85 | 1.08 | 0.95 | 93.80 | 0.05 | 0.04 |
| 6 | 0.52 | 0.79 | 1.02 | 1.28 | 2.73 | 270.05 | 0.06 | 0.04 |
| 7 | 0.53 | 0.80 | 1.20 | 1.51 | 2.28 | 225.23 | 0.02 | 0.01 |
| 8 | 0.28 | 0.42 | 1.33 | 1.67 | 2.38 | 235.27 | 0.09 | 0.07 |
| 9 | 0.37 | 0.56 | 1.71 | 2.15 | 4.13 | 408.22 | 0.06 | 0.05 |
| 10 | 0.24 | 0.36 | 1.16 | 1.47 | 4.26 | 420.94 | 0.04 | 0.03 |
| Min. | 0.21 | 0.31 | 0.81 | 1.02 | 0.95 | 93.80 | 0.02 | 0.01 |
| Max. | 0.53 | 0.80 | 1.71 | 2.15 | 5.25 | 518.99 | 0.09 | 0.07 |
| Ave. | 0.36 | 0.54 | 1.16 | 1.47 | 3.23 | 319.20 | 0.05 | 0.04 |

## 4. Conclusion and Recommendations

The radionuclide activity concentration and the annual effective dose due to consumption of wild black truffle in Iraq were investigated. The truffle samples were collected from 10 different locations in As Samawah desert. The study focused on four gamma emitters, precisely $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs radionuclides. These radionuclides were detected in all samples with varying values. Interestingly enough, $^{137}$Cs was discovered in all samples except one, which is a conclusive evidence of pollution from man-made sources that occurred with human intervention. Additionally, the yearly effective dose due to consumption of truffle in Iraq was calculated in both adults and children groups. It was clear that truffle consumption in Iraq is save and free from the risks resulting from radiation.

The present work is the first at the domestic level that estimate the radionuclide concentrations and the annual effective dose caused by the consumption of black truffle. The outcomes of the present work will assist in incorporation a baseline of radioactivity from consuming of the foodstuff. To establish a solid baseline, there is a necessity to examine more kinds of foodstuff, in addition to the targeting on beta emitter radionuclides.

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