Radionuclides Concentrations in Soils of Al-Hawija Technical Institute-Kirkuk Governate, Iraq

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Abstract: The aim of this study is to evaluate the level of natural and industrial radiation activity for soil samples of Al-Hawija Technical Institute which by using the High Purity Germanium detector (HPGe). It has been taken nine soil samples from Al-Hawija Technical Institute which located in Al-Hawija District-Kirkuk governate. The result showed that the specific activity concentration values (Bq.kg⁻¹ unite) for radium ²³²Ra, lead ²¹⁴Pb, lead ²¹⁹Pb, Actinium ²²⁴Ac, Cesium ¹³⁷Cs and potassium ⁴⁰K and the calculation of the risk rates for radium equivalent 67.487 Bq.kg⁻¹, effect concentration factor 0.496, internal risk factor 0.256, external risk factor 0.182, absorbing values dose in air 32.215 mGy. kg⁻¹, internal annual effective dose values 0.158 mSv.y⁻¹ annual effective external dose 0.040 mSv.y⁻¹, increased risk of cancer 0.139×10⁻², annual effective external dose 0.301 mSv.y⁻¹ in all soil samples are lower than the average international value, so, the soils in these locals have no negative effect in human health or the environment.

Key words: Radium, radiation concentrations, High-Purity Germanium (HPGe) detector, Al-Hawija Technical Institute-Kirkuk Governate, human health (Bq.kg⁻¹ unite)

INTRODUCTION

Radiation is an effective part of our environment in which we live, since, all people will exposure to it through soil, water, air and food. The radiation sources divided to two important sources, natural (cosmic radiation) and artificial radiation source that is man-made. Radiation is a natural part of the environment in which we live and everyone will exposure to radiation through soil, water, air and food (Green et al., 1992). The radiation sources which can be divided into two important sources. The first form is the natural radiation source were found in the free nature such as the cosmic radiation coming from the stars, sun, galaxies and radiation that have existed, since, the origin of the universe. This type known radiological background radiation that includes radiation in rocks, water, soil and our bodies. The second type is the artificial radiation source which is man-made. This includes X-rays which generated by the X-ray tube or in the medical and industrial accelerators, gamma, alpha and beta rays which are all generated by nuclear reactions, neutron or photon activation and activation by charged particles, nuclear accidents, nuclear reactors, etc. (UNSCEAR, 1988). Soil pollution is generally, happened when adding or losing some or all its components which cause an imbalance, change its natural, for either the chemical or biological properties and affects directly or indirectly in those live in its surface such us humans, plants or animals. The scientific and technological progress in the manufacture of radioactive materials and their application in many field became the most risk threatens the elements of environment including the soil, so, it became necessary to know the nature and dangers of these materials and how to be protect from them and circulate them safely (Selvaskarapadian et al., 2000). The main concept of soil pollution mainly depends on the information about transitions and accumulation away from the site of contamination. The accumulation and movement of radioactive materials depends on the interaction of materials and compounds with the solid part of the soil. This interaction reflects the soil's ability to retain and reacivate radioactive material. The physical, chemical and biological properties of the solid components can determine their ability to retain radioactive materials. On the other hand, rainfall, irrigation
water quantity, cultivated plant species and soil
management processes largely determine the type and
amount of radioactive contaminants into groundwater
or their transmission to plants or other media such as air
and water. In the soil, the radiation content is on the
surface within 1-2 cm and 90% of the radioactive
material is removed by wind and rain in the first few
months of soil contamination as well as the natural
degradation of radioactive material (UNEP, 2000). The
aim of this study is to evaluate level of natural
and industrial radiation activity for soil samples from
Al-Hawija Technical Institute using the spectroscopy
 technique that has a high purity germanium detector.
All of these process has been done, to be take the
samples from the site after finishing all the military
operations. As a result, this study has contributed in
accounted the level of radiation in the soil taken
samples from a polluted location, Al-Hawija Technical
Institute. Eventually, it recorded values lower than
danger numbers which allowed values as compared to
the international limits.

**MATERIALS AND METHODS**

**The theoretical side:** Specific Activity concentration (A) is defined as the radiation effectiveness of the unit of mass the radioactive material. Specific activity concentration is calculated by using Eq. 1:

\[
A \text{ (Bq/kg)} = \frac{N}{\epsilon \text{(E)} \cdot I \text{(E)} \cdot M \cdot t}
\]

(1)

Where:

- \(N\) = The Net count under the top
- \(\epsilon \text{(E)}\) = The Efficiency of the gamma ray detector
- \(M\) = The Mass of the model in kg and t is the
counting time in the second unit
- \(I \text{(E)}\) = The percentage of the potential Emission of
gamma from the radionuclides under study

Radium equivalent activity (Ra\(_a\)) is defined as a radiation factor used to ensure the uniform distribution of
natural radionuclides represented by \(^{226}\text{Ra}, ^{222}\text{Th}\) and \(^{40}\text{K}\). It is measured in Bq kg\(^{-1}\) and can be calculated by Eq. 2 (Badawy et al., 2015; Ramola et al., 2011):

\[
\text{Ra}_a \text{ (Bq kg}^{-1}\text{)} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K
\]

(2)

The \(A_{Ra}, A_{Th}\) and \(A_K\) are the radioactive effects of
\(^{226}\text{Ra}, ^{222}\text{Th}\) and \(^{40}\text{K}\) in Bq kg\(^{-1}\), respectively. The maximum
allowable value of radium equivalent is 370 Bq kg\(^{-1}\)
(Tawfiq et al., 2015). Absorbed dose rate in air for gamma
ray (D) at mL above ground level can be calculated by
using efficacy quality of \(^{226}\text{Ra}, ^{222}\text{Th}\) and \(^{40}\text{K}\) as in Eq. 3 (Ramola et al., 2011):

\[
D_T (\text{nGy} h^{-1}) = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K
\]

(3)

\(D_T\) = The rate of Dose absorbed in A\(_{Ra}\), A\(_{Th}\), A\(_K\)
\(A_K\) = The efficacy quality of \(^{226}\text{Ra}, ^{222}\text{Th}\) and \(^{40}\text{K}\) 40 in
Bq kg\(^{-1}\)

The Hazard guide (H) is defined as a radiation factor
used to determine external and internal radiation risks. The
external risk index (H\(_e\)) and the internal risk index (H\(_i\)) are
calculated by using Eq. 4 and 5 (Badawy et al., 2015;
Tawfiq et al., 2015):

\[
H_e = A_{Ra} / 370 + A_{Th} / 259 + A_K / 4810
\]

(4)

\[
H_i = A_{Ra} / 185 + A_{Th} / 259 + A_K / 4810
\]

(5)

The \(A_{Ra}, A_{Th}\) and \(A_K\) are the efficacy of radium-226
and thorium-232 and potassium-40 in Bq kg\(^{-1}\). The
external risk index (H\(_e\)) and internal risk index (H\(_i\)) must also be
<1. Annual Effective Dose Equivalent (AEDE) is defined as
a radiation factor used to know the health effects of the
absorbed dose and measured in mSv y\(^{-1}\). The annual
effective dose equivalent is estimated by using the
conversion factor 0.7 Sv. The Gy\(^{-1}\) which converts the
absorbed dose in air to the effective dose as well as using
indoor occupancy factor 0.8 and outdoor occupancy
factor 0.2 as in Eq. 6 and 7 (Tawfiq et al., 2015;
Mehra et al., 2009):

\[
\text{AEDE}_{ae} (\text{mSv y}^{-1}) = D (\text{nGy h}^{-1}) \times 10^{-4} \times 8760 \times 365 \times 0.7\text{Sv.Gy}^{-1} \times 0.8
\]

(6)

\[
\text{AEDE}_{ae} (\text{mSv y}^{-1}) = D (\text{nGy h}^{-1}) \times 10^{-4} \times 8760 \times \frac{1}{y} \times 0.7\text{Sv.Gy}^{-1} \times 0.2
\]

(7)

Activity concentration index is an irradiation factor
that estimate the risk levels of gamma-ray associated with
natural radionuclides in samples and can be calculated by
Eq. 8 (Hossain et al., 2010; Tawfiq et al., 2015):

\[
I = \frac{A_{Ra} + A_{Th} + A_K}{150 + 100 + 1500}
\]

(8)
Table 1: Demonstrate the number, symbol and the name of area which the soil sample collect (Al-Hawija Technical Institute)

<table>
<thead>
<tr>
<th>No and symbol of sample</th>
<th>Name of area</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>The new chancellory building</td>
</tr>
<tr>
<td>S2</td>
<td>The site of chicken house inside the institute</td>
</tr>
<tr>
<td>S3</td>
<td>The first campus</td>
</tr>
<tr>
<td>S4</td>
<td>Department of Electrical Technique</td>
</tr>
<tr>
<td>S5</td>
<td>The second campus</td>
</tr>
<tr>
<td>S6</td>
<td>The workshop building</td>
</tr>
<tr>
<td>S7</td>
<td>The sport building</td>
</tr>
<tr>
<td>S8</td>
<td>The first student campus</td>
</tr>
<tr>
<td>S9</td>
<td>The second student campus</td>
</tr>
</tbody>
</table>

Table 2: Specific activity concentration for all radionuclides in soil samples

<table>
<thead>
<tr>
<th>No of samples</th>
<th>$^{210}$Pb (Bq kg$^{-1}$)</th>
<th>$^{210}$Po (Bq kg$^{-1}$)</th>
<th>$^{226}$Ra (Bq kg$^{-1}$)</th>
<th>$^{228}$Th (Bq kg$^{-1}$)</th>
<th>$^{232}$Th (Bq kg$^{-1}$)</th>
<th>$^{232}$U (Bq kg$^{-1}$)</th>
<th>$^{40}$K (Bq kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>23.6±4.4</td>
<td>11.6±0.6</td>
<td>11±0.6</td>
<td>13.6±0.8</td>
<td>1.4±0.1</td>
<td>225±6.6</td>
<td>292±9.1</td>
</tr>
<tr>
<td>S2</td>
<td>21.3±4.9</td>
<td>15.1±1.1</td>
<td>16.6±1.1</td>
<td>16±1.2</td>
<td>0.6±0.2</td>
<td>284±6.1</td>
<td>313±6.9</td>
</tr>
<tr>
<td>S3</td>
<td>31.6±4.4</td>
<td>14.1±1.1</td>
<td>16.1±0.9</td>
<td>16.6±0.9</td>
<td>0.6±0.1</td>
<td>242±5.4</td>
<td>284±6.1</td>
</tr>
<tr>
<td>S4</td>
<td>28.4±4.8</td>
<td>16.5±1.2</td>
<td>17.2±4.3</td>
<td>18.4±7.1</td>
<td>0.8±0.2</td>
<td>242±5.4</td>
<td>313±6.9</td>
</tr>
<tr>
<td>S5</td>
<td>23.6±6.1</td>
<td>11.4±0.7</td>
<td>14.4±0.6</td>
<td>12.4±0.8</td>
<td>0.8±0.2</td>
<td>242±5.4</td>
<td>284±6.1</td>
</tr>
<tr>
<td>S6</td>
<td>32±6.1</td>
<td>10.8±0.9</td>
<td>10±0.7</td>
<td>10.4±0.6</td>
<td>B.D.L</td>
<td>221±7.5</td>
<td>284±6.1</td>
</tr>
<tr>
<td>S7</td>
<td>25.3±9</td>
<td>13.4±0.7</td>
<td>12.2±0.6</td>
<td>11.8±0.9</td>
<td>2.6±0.2</td>
<td>265±6.9</td>
<td>313±6.9</td>
</tr>
<tr>
<td>S8</td>
<td>21.3±7</td>
<td>11.6±0.6</td>
<td>12.2±0.6</td>
<td>13.6±0.8</td>
<td>2.6±0.2</td>
<td>265±6.9</td>
<td>313±6.9</td>
</tr>
<tr>
<td>S9</td>
<td>38.2±6.7</td>
<td>15.6±1.2</td>
<td>16.2±0.9</td>
<td>16.4±1.2</td>
<td>0.8±0.2</td>
<td>252±9.1</td>
<td>313±6.9</td>
</tr>
<tr>
<td>Max</td>
<td>38.2±6.7</td>
<td>15.6±1.2</td>
<td>17.2±4.3</td>
<td>18.4±7.1</td>
<td>0.8±0.2</td>
<td>252±9.1</td>
<td>313±6.9</td>
</tr>
<tr>
<td>Min</td>
<td>21.3±7</td>
<td>10.8±0.9</td>
<td>10±0.7</td>
<td>10.4±0.6</td>
<td>B.D.L</td>
<td>221±7.5</td>
<td>284±6.1</td>
</tr>
<tr>
<td>Ave</td>
<td>27.1±4.9</td>
<td>13.3±0.9</td>
<td>14.0±1.4</td>
<td>14.1±0.93</td>
<td>1.25±0.14</td>
<td>260.7±4.7</td>
<td>313±6.9</td>
</tr>
<tr>
<td>Global limit</td>
<td>35</td>
<td>30</td>
<td>14.8</td>
<td>420</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(UNSCEAR, 2000a, b; Cottens, 1999)

Fig. 1: Diagram for radioactive measurement system

Increasing the time or number of exposing to the radiation lead to increase the chance of happing the cancer for a specific level. This represented in the number of cancer cases happened for number of people when they expose to material for a specific level. Also ELCR can be determined form Eq. 9 if supposed the human old around 70 years (Taskin et al., 2009):

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF}$$  \hspace{1cm} (9)

Since, AEDE is the annual equivalent active sample which determined from Eq. 10:

$$\text{AEDE} = \text{AD} \times 1.23 \times 10^3$$  \hspace{1cm} (10)

DL is average old of human (approximately 70 years old). RF is the dangers factor (UNSCEAR, 1993) which calculated by Sv$^{-1}$ and probability dangers of happing of died cancer for each unit (Sv$^{-1}$). The back ground radiation with a low level will be generate a random effects. Since, the International Committee (ICRP 60) depends the value of 0.05 as a safe value for the general people Eq. 11:

$$\text{EAD} = (0.92\text{A}_{\text{u}} + 1.1\text{A}_{\text{r}} + 0.08\text{A}_{\text{k}}) \times 10^{-6} \text{Gy} \cdot \text{h}^{-1} \times 0.7 \text{Sv} \cdot \text{Gy}^{-1} \cdot \text{y}^{-1} \times 0.8$$  \hspace{1cm} (11)

Sample preparation: It has been collected nine samples of soil from nine different sites at Al-Hawija Technical Institute which all were under the occupation of ISIS and after that exposed to military operations with different types of weapons. Each sample dried then sifted, grinded well and become powder in average 0.5 kg Table 1. Sample analyzed by a high purity germanium detector (Canberra Model) in Ministry of Environment (radiation protection center) (Fig. 1, Table 2), this detector is semiconductors (p-type) which needs to reduce the temperature to -196°C by nitrogen liquid. The operating voltage is applied as a high approximately 4000 V. The
detector was shield with lead of thickness of 10 cm and internally lined with cadmium and copper to reduce the X-ray radiation that resulted from interaction between gamma ray and lead (IAEA., 2000). The gamma radiation spectrum soil Sample (S9) explained in Fig. 2.

RESULTS AND DISCUSSION

The specific activity concentration: In Table 2 the specific activity concentration for soil samples data are summarized, the result showed highest value of specific activity for Radium $^{226}$Ra 38.2±6.7 Bq.kg$^{-1}$ in Sample (S9), this value is higher than the average international value for radium (35) Bq.kg$^{-1}$ and the lowest value showed in (S8) sample 21±3.7 Bq.kg$^{-1}$. The general average was 27.19±4.9Bq.kg$^{-1}$ (Fig. 2) (UNSCEAR., 2000a, b; Cottens, 1990).

The lowest value of specific activity for $^{214}$Pb in Sample (S6) was 10.8±0.9 Bq.kg$^{-1}$ while the lowest value in Sample (S4) was 16.5±1.2 Bq.kg$^{-1}$ and the average value 13.33±0.9, this value in each sample is lower than the average international value for radium 35 Bq.kg$^{-1}$ (UNSCEAR., 2000a, b; Cottens, 1990).

In Fig. 3 it can be seen that the higher and lower specific activity concentration value for Thorium series $^{232}$Th in Bq.kg$^{-1}$ unite for ($^{222}$Pb, $^{228}$Ac) in range 17.2±4.3-18.47±1.2 in Sample S4 and 10.6±0.7-10.4±0.6 in Sample S6, respectively and the average value for Thorium series $^{228}$Th was 14.05±1.4-14.14±0.93, respectively, these results were lower than the average international value 30 Bq.kg$^{-1}$ (IAEA., 2000; UNSCEAR., 2000a, b). The specific activity concentration value for Cesium $^{137}$Cs in soil samples were lower than the average international value 14.8 Bq.kg$^{-1}$ (UNSCEAR., 2000a, b; Cottens, 1990).
The internal annual effective dose equivalent values: The internal annual effective dose equivalent values was (0.414-0.188) for (S5-S9), respectively, in value (0.158), so, this value is lower than average international value (0.45) Table 3 (UNSCEAR., 2000a, b; Cottens, 1990). The result showed that the external annual effective dose equivalent average value 0.040 mSv.y⁻¹ was lower than average international value (0.07) Table 3, mSv.y⁻¹. The average absorbed dose rate value in air for soil samples was 32.215 mGy.h⁻¹ this average value was lower than average international value (55) mGy.h⁻¹ Table 3 (UNSCEAR., 2000a, b; Cottens, 1990). The average value of increased incidence of lung cancer (0.139) in soil samples was lower than average international value (0.29) Table 3 (IAEA., 2000; UNSCEAR., 2000a, b). The external annual effective dose in all soil samples will be calculated, the average value was (0.301 mSv.y⁻¹) which is lower than average international value 1.5 mSv.y⁻¹, Table 3 (UNSCEAR., 2000a, b; Cottens, 1990).

CONCLUSION

In this study, the activity of the radiation has been measured both of the natural and industrial radiation in a different samples collected from the site of Al-Hawija Technical Institute. This study has been investigated by using HPGe detector have been obtained different points of conclusion.

The specific activity concentration values for (¹⁵⁷Cs, ¹³⁷Ba, ²¹⁰Po, ²¹⁰Pb, ²²⁸Ra) in all the soil samples from Al-Hawija Technical Institute-Kirkuk Governorate were lower than the average international value. The average effects of the dangerous values which represented by the activity of the equivalent Radium (Ra eq) (67.487 Bq.Kg⁻¹). While the dangerous guide of gamma ray (I) (0.469). And the guide of the internal dangerous (H₂) and external (Hₐ) (0.182), (0.256), respectively. Whenever, the annual
active injection for the internal exposing (AEDE\textsubscript{in}) (0.040) mSv y\textsuperscript{-1} while the annual active injection for the outer exposing (AEDE\textsubscript{ou}) (0.158 mSv y\textsuperscript{-1}) and the average injection absorbed by air (D\textsubscript{a}) (32.215 nGy n\textsuperscript{-1}). Also, increasing the time of exposing for radiation leads to happening the cancer (ELCR) (0.139). Since, the annual external active injection (EAD) (0.301 mSv y\textsuperscript{-1}). In the sample of the soil is lower than the international limits.

REFERENCES


