Determination of Radionuclides and Heavy Elements in the Rising Dust in the Small Side of Diwaniyah City due to the Movement of Wheels and Cars

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Abstract. This research aims to determine the concentration of radionuclides in dust samples on the public streets of the small side of Diwaniyah city in Iraq as a result of movements of wheels and cars using the gamma spectra and high purity germanium detector (HPGe) with resolution of (2.3 keV) for energy (1.332 MeV) of cobalt ⁶⁰⁶⁰Co. Dust samples were collected from the streets Diwaniyah city with (26) samples prepared for measurement. The results of the specific activity concentration of Uranium-238, Thorium-232, Potassium-40 and Cesium-137 were (14.66±0.950, 26.29±2.431, 219.04±15.150 and 11.49±0.876) Bq/kg respectively. The radiation parameters Ra eq, absorbed dose rate, annual effective external exposure rate and annual effective dose rate of internal exposure were (69.122 Bq/kg, 31.787 nGy/h, 0.0389 mSv/y, 0.155 mSv/y) respectively. The value of the external risk index (H ex), the internal risk index (H In) and the risk index for gamma radiation was (0.186, 0.226 and 0.506) respectively. The results obtained from granular volumetric analysis of dust patterns as a result of movement of cars and vehicles indicate that most of dust for some samples of the study area was sandy-silt with a little clay (Sandy Silt Clayey). These components of dust depend on the energy and speed of the transport wind, Volumetric granules.

Key word: High purity Germanium Detector, Gamma Ray, Heavy Elements, Radioactivity.
1. Introduction

In many areas of the world, soils are exposed to pollution of toxic heavy metals as a result of human activity in many fields, especially industry and agriculture, the addition of phosphate fertilizers, manufacturing, mining and waste disposal. These activities are a major source of air pollution in minutes loaded with heavy elements. On the other surfaces washed by rain and transferred by water dissolved or suspended and eventually to the soil [1] and can be said that the pollution of these heavy elements is one of the biggest problems for the time of the soil and water sources. There is another form of air pollution associated with environmental pollution is an increase of radioactive isotopes in the environment as a result of the atomic dust falling from dust emissions from the industrial use of nuclear energy and nuclear bombs [2].

Radioactivity is defined as the automatic transformation of an element's radioactive nuclei into other, more stable elements through the emission of a particular type of radiation, the emitted radiation is the alpha, beta and gamma rays. Many radioisotopes such as Ra-226, U-235, U-238, Th-232 and K-40 are found naturally in rocks and in soil. Other radioactive isotopes such as Cs, Co, I, Kr, Pu and Sr are mainly produced as fission products from the atomic dust of atomic bombs, nuclear reactors or other sources of radiation [3].

Radiation, whether solid, liquid or gaseous, is combined with elements of the environment such as water, air and soil. The speed of gas diffusion is often greater in air than in liquid or solid, resulting in widespread pollution in large areas where wind plays a distinctive role. Radiated dust leads to contamination of soil and water [4]. Thus human are exposed to a low level of radiation background, since radiation has an effect on the environment, which may remain for many years to affect the genetic makeup of humans and animals, leading to a genetic defect that affects the future generations. Moreover, the effect of this pollution reaches water and soil and enters the food chain of both humans and animals [5]. Thus, the need to study the effect of radiation and detection and the extent of pollution of the environment using several techniques for the detection of radioactive materials such as gamma ray spectroscopy.

2. Location of studied area

The province of Diwaniyah occupies the southern part of the middle of the Mesopotamian plain, which is one of the provinces of the Middle Euphrates bordered to the north by Babil province and to the south by Al-Muthanna province and from the east by Wasit and Dhi Qar provinces. The direction of wind mostly north-west. The Diwaniyah River divided the Diwaniyah province into areas which included several residential neighborhoods. (26) samples of rising dust by cars and vehicles were collected from streets in small side of Diwaniyah city in order to calculating the concentrations of radionuclides using a gamma ray spectrometry, in addition to four samples of them were selected to calculating the concentration of heavy elements using a special device. Figure (1) shows the map of the districts of Qadisiyah Governorate (Diwaniyah province) showing the collection sites.
Figure 1. Map of the districts of (Diwaniyah province).
3. Experimental

Dust samples were collected from the streets of Diwaniyah (26) samples using an electric device for dust extraction. They were prepared for measurement by drying them at 100°C for two hours, grinding them and then were sieved with a (75μm) sieve kept in petri dish with a Radius of 4.25 cm and height of 1 cm for one month to get radiation equilibrium. Gamma spectrometer system, which consists of "3x3" (CANBEERA) high purity germanium detector, that operates with voltage of (3500 Volts), with efficiency of (40%) and resolution of (2.3 keV) at (1.332 MeV) for the cobalt-60. The detector is surrounded by a lead shield to protect it from the radioactive background. This system were at the College of Education for Pure Sciences / Ibn al- Haytham at Baghdad University. Figure (2) illustrates the measurement system which calibrated as in reference [6].

![Figure 2. The measurement system.](image)

Then (15g) of dust samples from 4 areas that selected from the city limits with the desert region and carefully placed in bags. These samples were transferred to the Geochemistry Laboratory at the Geology Department, University of Baghdad for analysis by XRD and XRF methods to determine clay minerals and heavy elements (iron, zinc, copper, cobalt, lead, nickel and cadmium). These systems shown in figures (3). These samples were prepared by drying in oven at 60 °C and then were grinded into a powder.

![Figure 3. XRD and XRF device.](image)
4. Results and discussion

4.1. Specific activity concentration of samples

The specific activity concentration of the dust samples were obtained as a result of the movement of cars and vehicles in the small side of Diwaniyah city in Bq/kg units using the high purity germanium detector (HPGe). The specific activity was obtained using the following equation [7]:

\[ A = \frac{\text{Area under peak}}{I_\gamma \times E_{ff} \times m \times t} \pm \sqrt{\frac{\text{Area under peak}}{I_\gamma \times E_{ff} \times m \times t}} \quad \ldots \quad (1) \]

Where:

\( A \): represents the specific activity concentration measured in units of (Bq / kg)

\( \text{Area under peak} \) : Area under peak represents the net area below the peak

\( t \): represents the measuring time in second (10800 s)

\( I_\gamma \) : represents the energy intensity of Gamma rays

\( E_{ff} \) : The efficiency of the detector

\( m \) : represents the mass of the sample.

Table (1) shows the gamma energies for isotopes used in the present work.

| Series | Equivalent isotope | Half–life | E (keV) | \( I_\gamma \) (\( E_\gamma \)) |
|--------|--------------------|-----------|--------|------------------|
| 232 Th  | 212 Pb             | 10.64 h   | 238.63 | 43.50            |
| 238 U   | 214 Pb             | 26.80 m   | 351.92 | 35.10            |
| 232 Th  | 208 Tl             | 3.07 m    | 583.19 | 30.58            |
| 238 U   | 214 Bi             | 19.90 m   | 609.32 | 44.60            |
| ......   | 137 Cs             | 30 y      | 661.61 | 87.50            |
| 232 Th  | 228 Ac             | 6.13 h    | 911.16 | 26.60            |
| ......   | 40 K               | 1.2 \times 10^9 y | 1460.80 | 10.67 |

The specific activity concentration of the bismuth-214 and lead-214 at energies of (609.32, 351.92) keV were adopted as an equivalent for the specific activity concentration of uranium-238 by selecting the most highest activity, and the specific activity concentration of actinium-228, lead-212 and thallium-208 at energies of (583.19, 238.63, 911.16 ) keV as an equivalent of the specific activity of thorium-232, the specific activity concentration of potassium-40 was at (1460.8) keV and the specific activity concentration of cesium-137 was at (661.61) keV, Figures (4) to (7) show the specific activity concentration in samples.
Table (2) shows the overall results of the specific activity for $^{238}\text{U}$, $^{232}\text{Th}$, $^{40}\text{K}$ and $^{137}\text{Cs}$ in 26 samples of dust street from different locations the Small Side of Diwaniyah City in Iraq. It is clear from this table that average value of specific activity for $^{238}\text{U}$ was found (14.66±0.950 Bq/kg), While the average value of specific activity for $^{232}\text{Th}$ of (26.29±2.431 Bq/kg), the average value of specific activity for $^{40}\text{K}$ was found (219.04±15.150 Bq/kg) and the average value of specific activity for of $^{137}\text{Cs}$ of (11.49±0.876 Bq/kg).

Table 2. Specific activity concentration of different nuclides in dust samples of the small sides in Diwaniyah city.

| Sample Code | Location                        | U-238 (Bq/kg) | Th-232 (Bq/kg) | K-40 (Bq/kg) | Cs-137 (Bq/kg) |
|-------------|---------------------------------|--------------|---------------|-------------|--------------|
| S1          | University Site / first Location| 15.59±0.925  | 25.29±2.382   | 296.63±16.338 | 4.76±0.665   |
| S2          | University Site / Second Location| 22.04±1.083  | 30.15±2.573   | 311.43±16.640 | 2.10±0.573   |
| S3          | Cultural Site / first Location  | 25.21±1.1763 | 31.88±2.692   | 324.47±17.290 | 5.70±0.714   |
| S4          | Hakim Site / first Location     | 13.35±0.839  | 26.94±2.377   | 227.81±14.354 | 5.50±0.662   |
| S5          | Hakim Site / Second Location    | 11.56±1.064  | 16.28±1.910   | 168.94±12.905 | 6.06±0.675   |
| S6          | Professors Site / first Location| 18.60±1.028  | 16.29±2.037   | 243.00±15.655 | 3.64±0.651   |
| S7          | Towards Shamia Site / first Location| 11.08±0.822 | 22.82±2.353   | 116.61±12.580 | 3.99±0.669   |
| S8          | Towards Shamia Site / Second Location| 2.94±0.521  | 15.33±2.037   | 226.22±15.873 | 6.24±0.768   |
| S9          | Karar Site / first Location     | 6.70±1.004   | 17.70±2.180   | 119.46±13.124 | 2.43±0.639   |
| S10         | Karar Site / Second Location    | 10.21±0.817  | 40.16±3.099   | 329.26±18.135 | 16.49±1.039  |
| S11         | Karar Site / Third Location     | 11.52±0.860  | 17.31±0.738   | 235.93±16.100 | 11.25±0.911  |
| S12         | Green Site / first Location     | 17.86±0.984  | 29.76±2.558   | 199.77±14.205 | 17.91±1.003  |
| S13         | Green Site / Second Location    | 15.82±0.909  | 24.94±2.31    | 247.16±14.859 | 9.16±0.771   |
| S14         | Green Site / Third Location     | 12.86±1.222  | 27.36±2.601   | 357.05±18.584 | 17.98±1.066  |
| S15         | Industrial Site / first Location| 9.39±0.789   | 16.84±2.137   | 206.07±15.392 | 18.64±1.087  |
| S16         | Industrial Site / Second Location| 9.72±0.800  | 21.16±2.345   | 212.78±15.554 | 18.78±1.090  |
| S17         | Ramadan Site / first Location   | 19.04±1.420  | 39.30±3.069   | 194.12±15.099 | 17.93±1.071  |
| S18         | Ramadan Site / Second Location  | 19.12±1.422  | 39.94±3.091   | 210.55±15.500 | 16.54±1.019  |
| S19         | Algeria Site / first Location   | 15.23±0.970  | 26.34±2.573   | 240.41±16.203 | 9.87±0.874   |
| S20         | Algeria Site / Second Location  | 23.59±1.182  | 37.35±2.999   | 266.54±16.795 | 17.93±1.071  |
| S21         | Teachers Site / Site / first Location| 24.63±1.193 | 29.63±2.677   | 161.03±14.061 | 15.10±0.993  |
| S22         | Teachers Site / Second Location | 24.65±1.141  | 22.37±2.260   | 216.59±14.598 | 16.28±0.968  |
| S23         | Heritage Site / first Location  | 4.53±0.598   | 26.12±2.564   | 158.28±14.185 | 16.40±0.990  |
| S24         | Heritage Site / Second Location| 10.11±1.127  | 30.78±2.738   | 121.23±13.078 | 15.95±1.020  |
| S25         | Heritage Site / Third Location  | 12.98±0.840  | 31.06±2.56    | 123.12±12.023 | 17.44±0.977  |
| S26         | Virginity Site / first Location| 12.72±0.897  | 20.29±2.305   | 180.68±14.763 | 7.58±0.809   |
|             | the average                     | 14.66±0.950  | 26.29±2.431   | 219.04±15.150 | 11.49±0.876  |

World average | 35       | 30       | 400      | 14.8
Figure 4. Specific activity concentration levels of U-238 in dust samples.

Figure 5. Specific activity concentration levels of Th-232 in dust samples.
4.2. Calculation of Radiation hazard parameters (indices) for dust samples:
The following radiation hazard indices were determined for the dust samples in the present work
A. Radium Equivalent
B. Absorbed Dose
C. The Annual Effective Dose Equivalent
D. External Hazard Index
E. Internal Hazard Index
F. Activity Concentration Index
Using the following equations[9][10][11]:
\[ R_{eq}(Bq.kg^{-1}) = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \]  \hspace{1cm} \text{... (2)}
\[ D_Y(nGy.h^{-1}) = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K \]  \hspace{1cm} \text{... (3)}
The average value of (\(\text{Ra}_{\text{eq}}\)) was equal to (0.186) , Current results show that (\(H_{\text{ex}}\)) in the studied areas is less than the accepted average which is equal to (1) , Where the results showed that (\(\text{AEDE}_{\text{in}}\)) in the studied areas is less than the accepted average which is equal to (55 nGy/h) , The average value of (\(\text{AEDE}_{\text{out}}\)) was found (69.122 Bq/kg) , Results show that (\(\text{Ra}_{\text{eq}}\)) in the studied areas is less than the accepted average which is equal to (370 Bq/kg), while the average value of (\(D_{\gamma}\)) was (31.787 nGy/h) , Results show that (\(D_{\gamma}\)) in the studied areas is less than the accepted average which is equal to (55 nGy/h) , the average value of (\(\text{AEDE}_{\text{out}}\)) was found (0.155 mSv/y) , Where the results showed that (\(\text{AEDE}_{\text{in}}\)) in the studied areas is less than the accepted average which is equal to (1 mSv/y) , While the results showed that the average value of (\(\text{AEDE}_{\text{out}}\)) (0.0389 mSv/y) less than the accepted average which is equal to (1 mSv/y). The average value of (\(H_{\text{in}}\)) was equal to (0.226) which is less than the accepted average which is equal to (1), While the average value of (\(H_{\text{ex}}\)) was found(0.186) , Current results show that (\(H_{\gamma}\)) in the studied areas is less than the accepted average which is equal to (1). The average value of (\(I_{\gamma}\)) which is equal to (0.506) which is less than the accepted average which is equal to (1).

**Table 3.** The radiation hazard indices in dust samples of the small side in Diwaniyah city.

| Sample Code | Location                        | Ra\(_{\text{eq}}\) (Bq/Kg) | \(D_{\gamma}\) (nGy/h) | \(\text{AEDE}_{\text{out}}\) (mSv/y) | \(\text{AEDE}_{\text{in}}\) (mSv/y) | \(H_{\text{ex}}\) | \(H_{\text{in}}\) | \(I_{\gamma}\) |
|-------------|---------------------------------|-----------------------------|-------------------------|-----------------------------------|----------------------------------|----------------|--------------|-------------|
| S\(_{1}\)   | University Site / first Location| 74.606                      | 34.852                  | 0.0427                            | 0.170                            | 0.201          | 0.243        | 0.554       |
| S\(_{2}\)   | University Site / Second Location| 89.146                      | 41.385                  | 0.0507                            | 0.203                            | 0.230          | 0.300        | 0.656       |
| S\(_{3}\)   | Cultural Site / first Location  | 95.801                      | 44.441                  | 0.0545                            | 0.218                            | 0.258          | 0.326        | 0.703       |
| S\(_{4}\)   | Hakim Site / first Location     | 69.428                      | 31.944                  | 0.0391                            | 0.156                            | 0.187          | 0.223        | 0.510       |
| S\(_{5}\)   | Hakim Site / Second Location    | 47.867                      | 22.227                  | 0.0272                            | 0.109                            | 0.129          | 0.160        | 0.352       |
| S\(_{6}\)   | Professors Site / first Location| 60.619                      | 28.571                  | 0.0350                            | 0.140                            | 0.163          | 0.214        | 0.448       |
| S\(_{7}\)   | Towards Shamiya Site / first Location| 52.704                  | 23.770                  | 0.0291                            | 0.116                            | 0.142          | 0.172        | 0.379       |
| S\(_{8}\)   | Towards Shamiya Site / Second Location| 42.294                  | 20.057                  | 0.0246                            | 0.098                            | 0.114          | 0.122        | 0.323       |
| S\(_{9}\)   | Karar Site / first Location     | 41.222                      | 18.773                  | 0.0230                            | 0.092                            | 0.111          | 0.129        | 0.301       |
| S\(_{10}\)  | Karar Site / Second Location    | 93.004                      | 42.709                  | 0.0523                            | 0.209                            | 0.251          | 0.278        | 0.689       |
| S\(_{11}\)  | Karar Site / Third Location     | 54.448                      | 25.619                  | 0.0314                            | 0.125                            | 0.147          | 0.178        | 0.407       |
| S\(_{12}\)  | Green Site / first Location     | 75.809                      | 34.561                  | 0.0423                            | 0.169                            | 0.204          | 0.253        | 0.549       |
| S\(_{13}\)  | Green Site / Second Location    | 70.524                      | 32.683                  | 0.0400                            | 0.160                            | 0.190          | 0.233        | 0.519       |
| S\(_{14}\)  | Green Site / Third Location     | 79.496                      | 37.364                  | 0.0458                            | 0.183                            | 0.214          | 0.249        | 0.597       |
| S\(_{15}\)  | Industrial Site / first Location| 49.348                      | 23.107                  | 0.0283                            | 0.113                            | 0.133          | 0.158        | 0.368       |
| S\(_{16}\)  | Industrial Site / Second Location| 56.370                     | 26.147                  | 0.0320                            | 0.128                            | 0.152          | 0.178        | 0.418       |
| S\(_{17}\)  | Ramadan Site / first Location    | 90.195                      | 40.632                  | 0.0498                            | 0.199                            | 0.243          | 0.295        | 0.649       |
| S\(_{18}\)  | Ramadan Site / Second Location   | 92.467                      | 41.746                  | 0.0512                            | 0.204                            | 0.249          | 0.301        | 0.667       |
| S\(_{19}\)  | Algeria Site / first Location    | 71.425                      | 32.978                  | 0.0404                            | 0.161                            | 0.192          | 0.234        | 0.525       |
| S\(_{20}\)  | Algeria Site / Second Location   | 97.543                      | 44.581                  | 0.0546                            | 0.218                            | 0.263          | 0.327        | 0.708       |
| S\(_{21}\)  | Teachers Site / first Location   | 79.417                      | 35.998                  | 0.0441                            | 0.176                            | 0.214          | 0.281        | 0.567       |
| S\(_{22}\)  | Teachers Site / Second Location  | 73.324                      | 33.935                  | 0.0416                            | 0.166                            | 0.198          | 0.264        | 0.332       |
4.3. Calculation of Clay Metal Concentrations and Heavy Elements of Samples:

The results were obtained for (4) samples by particle size analysis. The results were based on the energy and speed of the winds of the dust storms, which carry the mixture of the different grains in dry seasons, including sand, silt and clay. Table 4 shows the results of the volumetric analysis and classification[5].

**Table 4.** The results of the volumetric analysis and classification.

| Sample Code | Location       | Sand% | Silt% | Clay% | Classification |
|-------------|----------------|-------|-------|-------|----------------|
| S1          | University Site| 45    | 50    | 5     | Sandy Silt     |
| S2          | Karar Site     | 72    | 24    | 4     | Silty Sand     |
| S3          | Green Site     | 56    | 36    | 8     | Silty Sand     |
| S4          | Virginity Site | 66    | 32    | 12    | Silty Sand     |
| Min         |                | 45    | 24    | 4     |                |
| Mix         |                | 72    | 50    | 12    |                |
| Average     |                | 59.75 | 35.5  | 7.25  |                |

Figure (8) The XRD pattern of the non-clay elements for samples (S2). Figure (9) shows the XRD pattern of the identification of clay elements for samples (S2).

The results of the analysis were determined by X-ray diffraction method (XRD). The non-clay minerals of 4 samples selected from the studied areas were examined in the range of 20° (2-50 ) (jibs, quartz, calcite, feldspar and dolomite, respectively) Shown in Figure (8) . Clay minerals were also identified and diagnosed in the dust patterns of the selected areas, depending on the basal reflections characteristic of each mineral (Palygorskite , Kaolinite , Montmorillonite , Chlorite , Illite and Chlorites – Montmorillonite Mixed Layers) Shown in Figure (9).

![Figure 8. XRD pattern of sample (S2) (non-clay elements).](image-url)
Figure 9. XRD pattern of sample (S₂) (clay elements).

The concentrations of heavy metals (Fe, Ni, Cu, Zn, Cd, Pb, Co) were performed using an XRF device. These elements were selected for their effect on the environment and on humans, animals and plants. Table (5) illustrates the concentrations of these elements in dust samples.

Table 5. The concentrations of the elements in the dust of the studied streets.

| Samples | Pb (ppm) | Fe (ppm) | Co (ppm) | Ni (ppm) | Cu (ppm) | Zn (ppm) | Cd (ppm) |
|---------|----------|----------|----------|----------|----------|----------|----------|
| S₁      | 41.864   | 7924.0   | 2.448    | 49.000   | 16.111   | 84.782   | 2        |
| S₂      | 37.037   | 9772.0   | 2.448    | 59.500   | 23.973   | 75.978   | 2        |
| S₃      | 98.116   | 11952.5  | 2.448    | 67.645   | 51.813   | 119.739  | 2        |
| S₄      | 50.496   | 9877.0   | 2.448    | 56.063   | 17.722   | 57.000   | 2        |
| Average | 56.878   | 9881.25  | 2.448    | 58.052   | 27.404   | 84.374   | 2        |
| Accepted limit | 10  | 38000   | 8        | 40       | 30       | 50       | 0.06     |

Conclusions

1- The results obtained showed that most of the specific Activity concentration rates of the different nuclides were lower than the global average as indicated in tables (2). However, the S₁₀ and some other samples a higher level of specific activity concentrations than the global average for Th-232.

2- As for the results of radioactive effects, they were all less than the rate allowed globally, but although the rates are lower than the global average, we believe that the accumulation may have a negative impact on the public health.

3- The results obtained by X-ray analysis have shown that the sources of these minerals were different, either from the weathering process of the source rocks in the geological formations of Western Sahara or their sources which were transported from distant places with the wheels of the vehicles which supply these materials as they pass on the outskirts of the street.

4- We propose that the process should be sprinkled with water to reduce the environmental damage while conducting regular monitoring of aerosol pollutants and also support to this study with geological surveys and geochemical studies of the region.
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