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Assessing the Radioactivity of Samples Taken during a Dust Storm in the Iraqi City of Hilla

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Keywords: Specific Activity, Dust Storm, Absorbed Dose, Gamma Radiation, Nai (Tl) Detector.

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Abstract:

The research aims to investigate the distinguishing behaviors and risk indicators in samples of dust storms in Hilla city, Iraq. NaI (Tl) detector was used for the measurements, along with spectrum analysis. The findings of the measurements of elements ^{238}U, ^{232}Th, and ^{40}K's specific activities in samples from dust storms ranged for ^{238}U from 9.2 ± 0.5 to 22.9 ± 0.8 (Bq/kg) at an average 16.92 ± 0.7 (Bq/kg), the range of ^{232}Th's specific activity was between 2.7 ± 0.2 to 11.41 ± 0.5 at the average6.5 ± 0.3 (Bq/kg), whereas the range for ^{40}K was 119.43 ± 2.2 to 174.92 ± 2.6 (Bq/kg) with mean150.34 ± 2.4 (Bq/kg). Furthermore, it is shown that the radium equivalent activity and absorbed dose in dust storm samples average 37.774 Bq/kg and 34.881(nGy/h), respectively, and the external hazard index was 0.102. In contrast, the average of the effective dose of samples was 0.022 mSv/y. The findings of the present study were compared with the global average, the levels were discovered to be within the advised limit according to UNSCEAR.

Keywords: Specific Activity, Dust Storm, Absorbed Dose, Gamma Radiation, Nai (Tl) Detector.

تقييم النشاط الإشعاعي للعينات المأخوذة أثناء العاصفة الغبارية في مدينة الحلة العراقية

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الخلاصة:

يهدف البحث إلى دراسة السلوكيات المميزة ومؤشرات الخطورة في عينات العواصف الغبارية في مدينة الحلة بالعراق، وقد تم استخدام كاشف *NaI(Tl)* للقياسات، إلى جانب تحليل الطيف. وقد تراوحت نتائج قياسات النشاط النوعي للعناصر ^{40}Kو ^{232}Th و^{238}U في عينات العواصف الغبارية لليورانيوم- ٢٣٨ من ٩,٢ ± ٠,٥ إلى ٢٢,٩ ± ٠,٨ (بيكريل/كجم) بمتوسط ١٦,٩٢ ± ٠,٧ (بيكريل/كجم)، وكان نطاق النشاط النوعي للثوريوم- ٢٣٢ بين ٢,٧ ± ٠,٢ إلى ١١,٤١ ± ٠,٥ بمتوسط ٦,٥ ± ٠,٣ (بيكريل/كجم)، في حين كان نطاق النشاط النوعي للعنصر للبوتاسيوم-٤٠ من ١١٩,٤٣ ± ٢,٢ إلى ١٧٤,٩٢ ± ٢,٦ (بيكريل/كجم) بمتوسط ١٥٠,٣٤ ± ٢,٤ (بيكريل/كجم). علاوة على ذلك، تبين أن متوسط نشاط مكافئ الراديوم والجرعة الممتصة في عينات العواصف الغبارية يبلغ ٣٧,٧٧٤ بيكريل/كجم و ٣٤,٨٨١(*nGy/h*) على التوالي، وكان مؤشر الخطر الخارجي ٠,١٠٢. وعلى النقيض من ذلك، كان متوسط الجرعة الفعالة للعينات ٠,٠٢٢ ميكروسيفرت/سنة. تمت مقارنة نتائج الدراسة الحالية بالمتوسط العالمي، وتبين أن المستويات تقع ضمن الحد الموصى به وفقًا للجنة العلمية التابعة للأمم المتحدة لآثار الإشعاع الذري.

الكلمات المفتاحية: الفعالية النوعية، العاصفة الغبارية، الجرعة الممتصة، إشعاع جاما، كاشف *NaI(Tl)* .

1. Introduction:

The German Association for the Building and Construction Sector has warned that small dust particles in construction sites pose a great risk to health. Sand and dust storms are an important element of Earth's natural biogeochemical cycles, but they are also influenced by human activities such as climate change, inappropriate land management, and water waste. Thus, sand and dust storms contribute to climate change and air pollution [1]. The radiation originates from a variety of sources, both natural and artificial. These include both cosmic radiation and environmental radioactivity from naturally occurring radioactive materials. Naturally, radioactivity is widespread in the Earth's environment, mainly in various geological formations and their disintegration products [2]. The major natural radioactivity sources are the nuclides of very long half-lives that have existed since the Earth's formation, and these nuclides are produced via cosmic rays [3]. The natural radionuclides of concern are mainly uranium(^{238}U), thorium (^{232}Th), or their progenies and potassium (^{40}K) [4]. Long-term exposure to radioactivity and inhalation of radioactive nuclides have serious health effects, such as cancerous disease. Nuclides' radioactive exposure can cause lung diseases, pancreatic, hepatic, bone, and kidney cancers, and leukemia. These diseases are caused by gamma-radiation, which is capable of traveling long distances through air to affect human beings [5].

The distribution of radionuclides in the environment and their typical concentration levels in soil are of interest to many international studies to determine the levels of radioactivity in soil samples [6-10]. Numerous methods exist for uranium to enter the body, including drinking uranium-containing water, inhaling uranium-containing dust particles, or indirectly from nutrient-rich soil layers through the food chain [11]. The NaI(Tl) detectors have exceptional absorption efficiency because of the density of the crystal, whilst the detection systems based on these scintillators show high absorption efficiency for low-energy gamma ray detection due to the relatively high atomic number of iodine (Z = 53)[12].

There are currently no known baselines for the concentration of naturally occurring radioisotopes, and only a small number of studies on the radioactivity of soil samples in the areas under inquiry have been published. Furthermore, there have been reports of a few people of different ages who have died from cancer instances that have been documented in these areas. Therefore, the goal of this research is to examine the radioactive content of dust storm samples collected from various locations inside Hilla city during the storm. The purpose of the study was to determine whether radioactivity in the storm's dust was dangerous to people or not.

2. Area of Study

Hillah is the Babel provincial capital, which is located in central Iraq between latitudes 32° 28' 59.99" N and longitudes 44° 25' 59.99" E [13]. 5119 km^2 is that amount. Located on the Euphrates River, close to the historic city of Babel [13]. The physical arrangement of the states comprising the Babel Province is shown in Figure 1, along with the sites of sample research.

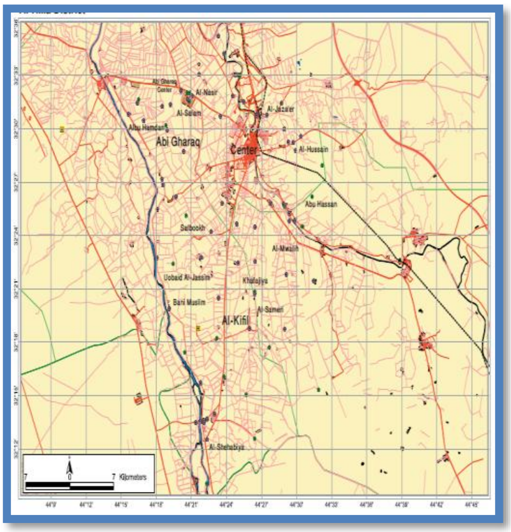

Figure 1: Study area's location on a map [13].

3. Nuclear Detection System:

Nine samples were taken from the dust storm that hit the city of Hillah in May 2022, where a deep container was placed from the beginning of the storm until its end on the roofs of the houses selected for the studied samples. After collecting the samples, they were transferred to the Advanced Nuclear Laboratory of the Physics Department at the College of Education for Pure Sciences at the University of Babylon, and were used. Natural radionuclide activity concentrations were measured using a NaI(Tl) detector comprising a "3 x 3" crystal and a Multi-Channel Analyzer (MCA) at 1024 channels. Gamma-ray spectroscopy observations were analyzed by the MAESTRO-32 software [14]. The lead and stainless steel outside section of the ORTEC cylindrical chamber is split into two pieces. These portions measured 20 cm and 5 cm in breadth, respectively. The evaluation of the whole radiation environment was made easier by the chamber's design. This detector has several advantages, including the ability to easily calibrate the power and its exceptional gamma ray capture capabilities, as **Figure 2.** An energy efficiency calibration using ^{60}Co, ^{133}Ba,^{137}Cs, and ^{22}Na was the first step in the process, which allowed for precise energy values to be obtained.

Figure 2: Detection system

3.1 Sample Measurements: The activity concentration is calculated using the following formulae and hazard indices after determining the radiation background and calibrating the detector's energy and effectiveness.

3.2 Specific Activity (A): Calculations were made to determine the radiologic efficacy of ^{238}U using the energy of ^{214}Bi (1764 keV), the energy of ^{208}Tl (2614 keV) for ^{232}Th, and the energy of ^{40}K (2614 keV) (1460 keV). For computing radionuclide specific activity (A) in soil samples, the following equation was utilized [15]:

$$A = \frac{N.a}{I_{\gamma}.\varepsilon.m.t.} \pm \frac{\sqrt{N.a}}{I_{\gamma}.\varepsilon.m.t.} \left[\frac{\text{Bq}}{\text{kg}}\right] \quad (1)$$

,where:

N.a: refers to the area beneath each spectrum's curve after removing background radiation

Iγ: The probabilities of the transition to gamma rays.

m: The specimen's mass

t: Counting time (14400 sec)

ε: The detector's efficiency

3.3 Radium Equivalent (Ra_{eq}): The levels of activity have been described by a radiological index. The formula computes the (Raeq) index of (^{238}U, ^{232}Th, and ^{40}K) [16]:

$$(Ra_{eq}\ Bq/kg). = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

where: A_U, A_{Th}, and AK stand for the respective activity concentration of (^{238}U.,^{232}Th. and ^{40}K.) in (Bq/kg).

3.4 Absorbed Dose (D_r): The following equation can be used to determine the D_r in air given the abundance of terrestrial cores [17]:

$$Dr(\frac{nGy}{h.}) = 0.462A_{.U} + 0.604A_{.Th} + 0.047A_{.K} \qquad (3)$$

3.5 Annual Effective Dose (AED): The predicted value was calculated using a conversion factor AED that one person of this (0.7sv/Gy) received. This was then used to determine the comparable effective dosage for a 20% outdoor occupancy and an interior occupancy of (80%) [18]:

$$AED\ (mSv/y) = AD(\frac{nGy}{h}) \times 10^{-6} \times 8760\ h \times 0.2 \times 0.7(\frac{sv}{Gy}) \qquad (4)$$

3.6 External Hazard Indices (Hex): For the purpose of assessing the radiation risk from gamma rays and other sources, (H_{ex}) may be computed. Depending on the level of specific radiation activity, the following two equations were obtained [17,18]:

$$H_{ex} = \frac{Au}{370} + \frac{ATh}{259} + \frac{Ak}{4810} \qquad (5)$$

4. Results and Discussion:

Table 1 displays the specific activity for nine dust storm collecting samples from various zones in Babel.

Table 1: Specific activity values for ^{238}U, ^{232}Th, and ^{40}K

Sample No.	Specific Activity (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
D1	22.91±0.8	11.41±0.5	174.92±2.6
D2	9.27+0.5	3.86±0.3	147.93±2.4
D3	16.34±0.7	10.48±05	169.68±2.6
D4	15.52±0.6	4.94±0.3	125.34±2.6
D5	19.67±0.7	10.31±.4	168.94±2.6
D6	16.12±0.7	6.45±0.3	123.04±2.2
D7	16.84±0.7	2.72±0.2	151.71±+2.4
D8	20.61±0.8	5.91±0.3	172.15±2.6
D9	15.11±0.6	3.54±0.2	119.43±2.2
Ave± SD	16.93±0.7	6.53±0.3	150.34±2.5
Max± SD	22.91±0. 8	11.41±0. 5	174.92±2.6
Min± SD	9.27±0.5	2.72±0.2	117.43±2.2
UNSCEAR 2008	30	35	400

Table1. shows that the maximum and minimum values of a specific activity for 238U ranged from 9.2 ± 0.5 to 22.91 ± 0.8 (Bq/kg). Sample D2 contained the lowest value, while sample D1 contained the highest value, with a mean of 16.93 ± 0.7 (Bq/kg), as **Figure 3** depicts values of activity level for ^{238}U. The current work's mean is less than 30 (Bq/kg) UNSCEAR calculated global average value is 30 (Bq/kg). Conversely, the max. and min. values of ^{232}Th a specific activity, which range from 2.72 ± 0.26 to 11.41 ± 0.5 (Bq/kg) to an average of 6.5 ± 0.3 (Bq/kg), as **Figure 4**. The current work's mean value of ^{232}Th is smaller than the mean of 35 (Bq/kg). While the maximum and minimum values of a specific activity of ^{40}K range from 119.43 2.2 to 174.92 2.7 (Bq/kg), with a mean is 150.34 2.5 (Bq/kg), as **Figure 5**.

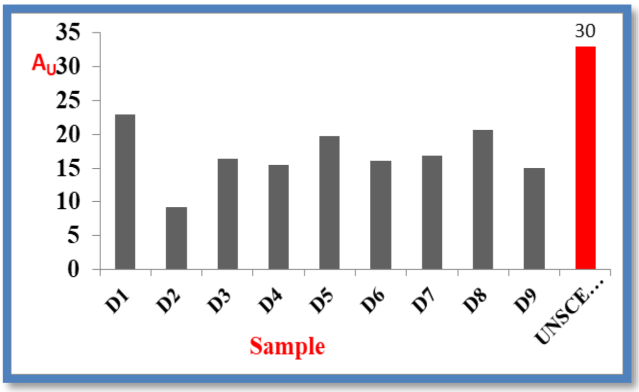

Figure 3: The specific activity of the samples' ^{238}U

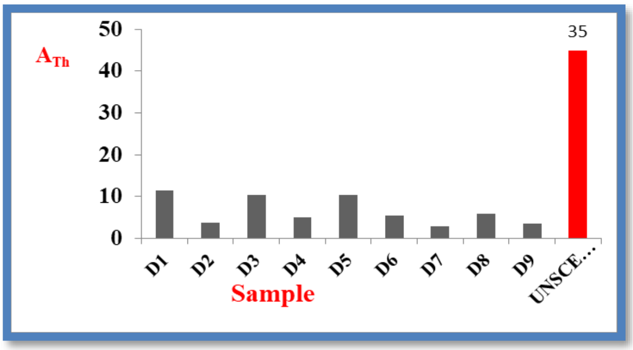

Figure 4: The specific activity of the sample' ^{232}Th

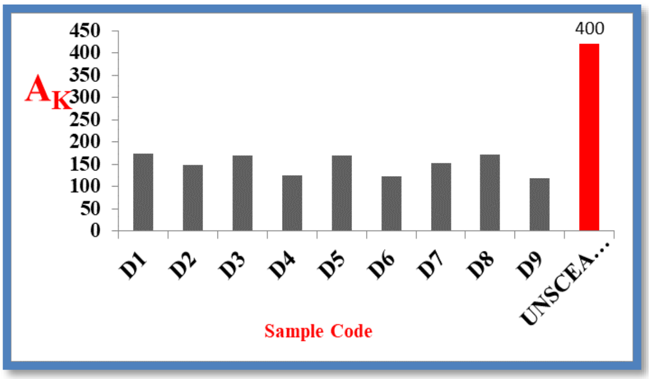

Figure 5: The specific activity of the samples' ^{40}K

Table 2 displays the Radiation Hazard Indices values, while **Figures 6** and **7** depict the Ra_{eq} and D_r, which representative level hazard indices in dust storm samples. In this study.

Table 2: Indicators of risk measured in the current work

Sample No.	Ra_{eq} Bq/kg	D_r(nGy/h)	H_{ex}	AED(mSv/y)
D1	52.685	47.789	0.142	0.029
D2	26.074	24.675	0.070	0.015
D3	44.232	40.182	0.119	0.025
D4	32.173	29.817	0.086	0.018
D5	47.368	43.080	0.127	0.026
D6	33.386	30.7911	0.090	0.018
D7	32.420	30.780	0.087	0.018
D8	42.309	39.399	0.114	0.024
D9	29.317	27.421	0.079	0.016
Ave.	37.774	34.881	0.102	0.022
Max	52.685	47.789	0.142	0.029
Min	26.074	24.675	0.070	0.015
UNSCEAR 2008	370	55	≤ 1	1

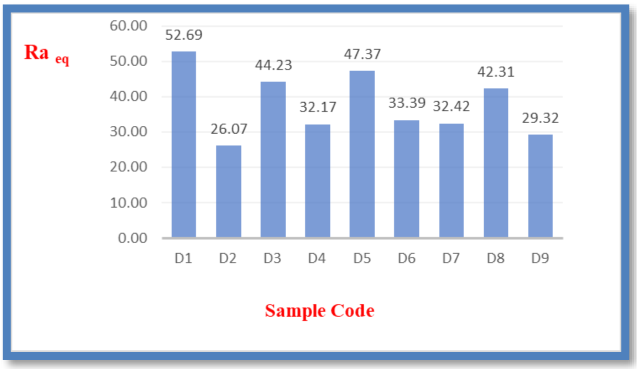

Figure 6: Radium equivalent in dust storm samples

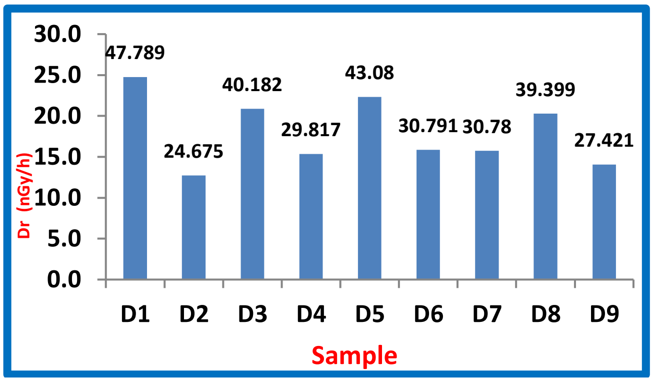

Figure 7: The absorbed dose rate in dust storm samples

It had been noticed from **Table (2)** that the Ra_{eq} values varied from 26.074 to 52.685 (Bq/kg) with an average of 37.774 (Bq/kg), as shown in **Figures (6)** and **(7)**. All dust storm samples had Raeq. values that were fewer than the high value that was advised, 370 (Bq/kg), the D_r value varied between 24.675 (nGy/h) to 47.789 (n.Gy/h). The levels of H_{ex} differed by 0.07 - 0.142 to 0.095 - 0.204, AED values varied by 0.015 to 0.029 (mSv/y), at the average was 0.022

(mSv/y). According to the most recent data, dust storm sample readings for (Ra_{eq}, Dr, H_{ex}, and AED) were below the UNSCEAR and ICRP recommended value [19,20].

5. Conclusions

In the dust storm samples from the Iraqi city of Hillah, the specific activity of ^{238}U, ^{232}Th, and ^{40}K is lower than the global average values. The radiation safety publications UNSCEAR (2008) and ICRP (1993) found that the majority of the radioactive effects, including Ra_{eq}, D_r, H_{ex}, and AED, were below the global average. Thus, dust storms do not pose a radiation risk.

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