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Assessment of the Natural Radioactivity and Concentrations of Some Heavy Elements in the Dust of Some Schools in Karbala, Iraq

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ABSTRACT

Introduction: This study covered the assessment of the natural radioactivity levels and heavy metals concentration in dust samples collected from selected schools in the holy Governorate of Karbala. The purpose of this study was to assess the radiological health and safety impact of dust pollution on the children going to school.

Material and Methods: Sodium Iodide system (NaI [TI]) from BICRON and the Atomic Absorption Spectrometer from SHIMADZU were used to measure the natural radioactivity in terms of ^{238}U, ^{232}Th, and ^{40}K, as well as the concentrations of some heavy metals in the dust samples.

Results: The specific activity of ^{238}U, Th^{232}, and ^{40}K in dust samples were 5.59± 0.1679 to 71.91±1.6561 Bq/kg, 1.36±0.0963 to 43.35±1.0434 Bq/kg, 66.94±1.638 to 417.91±13.721 Bq/kg, respectively. The external and internal hazard indices were 0.047 ± 0.001 to 0.449±0.011 and 0.062±0.00169 to 0.643±0.01583 respectively. The absorbed dose rate and radium equivalent values ranged from 8.21±0.215 to 76.83±1.968nGy/h and 17.45±0.458to 166.08±4.205 Bq/kg, respectively. The concentration of lead was within the range of 8.839-2.689 mg kg^{-1} and the concentration of Cd ranged from 0.141 mg kg^{-1} to less than the lower limit of detection of the Atomic Absorption Spectrometer.

Conclusion: The absorbed dose rate, effective dose (indoor and outdoor), hazard indices, and radium equivalent values were within the range of values indicated in the UNSCEAR 2008 report. The levels of lead and cadmium concentration detected in some schools were due to dust pollution in the Schools environment.

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Introduction

Environmental pollution, in particular air pollution, is one of the most important problems of our time, which leads to the death of 7 million people yearly in the world [1]. Approximately 82% of human-absorbed radiation doses, which are out of human control, arise from natural sources of radiation, including cosmic, terrestrial, and exposure through inhalation or ingestion [2]. The industrial activities and the increase in vehicle emissions are the most important sources of air pollution in cities. Many pollutants are emitted into the air, such as heavy metals and hydrocarbons. Dust is one of the main air pollutants, especially particles below 100 microns, which can infect the upper and lower respiratory tract, as with 2.5 microns. These pollutants become more dangerous because of their physical properties and chemical contents [3, 4]. Radionuclides, such as ^{3}H, ^{39}Cl, ^{10}Be, ^{14}C, ^{33}P, and ^{22}Na, are the main sources of radioactive dust in the atmosphere and cosmic ray. The natural radiation sources are responsible for most of the radiation exposure, and radon typically constitutes up to 50% of the background radiation [5]. The ^{222}Rn is the most abundant radioactive element in nature and radioactive dust has a negative and dangerous impact on human health. Free radicals, which cause significant damage in DNA and chromosomes as well as cells and tissues, lead to cancerous cells [6]. The combustion of coal, nuclear plants, radioactive waste, and nuclear weapons are the most important sources of radioactive dust in the atmosphere, which are deposited depending on the size and weight of the particles. Dust, particularly urban dust, is associated with heavy metals [7] and is known to have adverse effects on human health because of its bioaccumulation capacity in vital tissues. The inhalation of heavy metals in the dust causes serious damage to the respiratory tract and reaches the pulmonary vesicles and can transport these minerals to the rest of the organs through the bloodstream [8].

In recent decades, the urban environment has been of utmost importance as a result of the steady

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increase in pollutant concentration. The study of the school environment is very important because the buildings occupy a large number of students and are the most affected age groups, thus making them susceptible to many diseases affects their health. Therefore, it is essential to the assessment of the radioactivity and concentrations of some heavy metals in school dust.

Materials and Methods

This study was an investigation of specific activities resulting from natural radioactivity and the concentrations of some heavy metals in dust samples collected from the selected schools in Karbala Governorate.

Twelve samples were collected from selected schools of Karbala governorate, out of which nine samples were selected from the city center and its outskirts and the rest from the rural areas. These samples were coded as Sam 1 to Sam 12 as shown in Table 1. The dust samples were collected from that of the shelves, floors of the classrooms, and school corridors with plastic brushes. The samples were filtered and cleaned from plankton and sieved with a sieve with a diameter of 500 μm to obtain homogeneous powder. The prepared samples were stored in Marinelli beakers and sealed tightly for about one month to allow ^{226}Ra and ^{222}Rn to reach secular equilibrium [9].

After the completion of the storage period, the gamma-ray spectroscopy system was used for 24 h to obtain the best spectrum for the studied samples. This system consists of the detector (NaI [Tl]) from BICRON with the dimensions of the crystal (1.5×2 1024 channels) surrounded by a shield consisting of two layers. The first layer consists of lead (Pb) and the second layer was made of copper with a thickness of 4 cm and 6 mm, respectively. The shield was used to minimize the background radiation surrounding the detector to the extent possible.

In order to calculate heavy metal concentrations, the samples containing dust particles less than 63 microns were taken, and dried by oven at 110 ° C, then weighed 1 gram of each sample and three replicates as in the method described by Harrison, RM, and Perry[9], (HNO3) by 3:1, respectively, and heated on a hot plate. After complete digestion, the volume was completed to 50 ml with distilled water. Next, there was an evaluation of the concentration of minerals extracted by the Atomic Absorption Spectrometer from SHIMADZU (Japanese public KK Company, Japan).

Specific Activity

The Specific Activity of the natural radionuclides in the dust samples was estimated using Equation 1 as indicated in the reference section table10.

$$A(Bqkg^{-1}) = \frac{(N-B)}{T \times \varepsilon \times I_{\gamma} \times M} \quad (1)$$

Where A refers to Specific Activity, B denotes the count of background radiation, N signals totally count (sample+ background) T is count time, ε suggests the possibility of emitting gamma-rays for each energy, I_{γ} refers to the efficiency of the detector for each energy, and *M* is the mass sample.

Table 1. Data about the study samples

Sample No.	Code Sample	School	Location
1	Sam1	Al Thuraa	Urban
2	Sam2	Othman bin Said	Urban
3	Sam3	Masar	Urban
4	Sam4	AL Mufeed	Urban
5	Sam5	Cortoba	Urban
6	Sam6	Al Abrar	Urban
7	Sam7	Al – Haydariyah	Urban
8	Sam8	Hassan Shehata	Urban
9	Sam9	Ghadir	Urban
10	Sam10	Shahad	Countryside
11	Sam11	Hudhayfah ibn al-Yaman	Countryside
12	Sam12	Warka	Countryside

External Hazard Index

The external hazard index (H_{ex}) is a measure of the risk of gamma ray exposure due to natural radionuclides, including ^{226}Ra, ^{232}Th, and ^{40}K. The H_{ex} can be calculated by *Equation 2* [11].

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (2)$$

Where, A_{Ra}, $A_{Th,}$ and A_k are the specific activity of ^{226}Ra, ^{232}Th, and ^{40}K. The normal range equal to or below unity [12, 13]. This model takes into consideration that the H_{ex} which is caused by gamma rays corresponds to a max radium-equivalent activity of 370 Bq.kg-1 for the material [11].

Internal Hazard Index

The internal hazard index expresses the radiation risk due to the inhalation of radon gas or its daughter. The H_{in} is calculated using Equation 3 [12-14]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (3)$$

The A_{Ra}, $A_{Th,}$ and A_K are the Specific Activity of ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

Absorbed Dose Rate in Air

The main contribution of the absorbed dose into the air comes from terrestrial radioactive sources in the earth. The specific activity of ^{238}U, ^{232}Th^{232}, and 40K can be used to calculate the absorbed dose in the air at a height of one meter from the surface of the earth using Equation 4.

$$AD = 0.4299\, A_U + 0.666\, A_{Th} + 0.042\, A_K \quad (4)$$

Where, 0.4299, 0.666, and 0.042 nGy h^{-1}/Bq kg^{-1} are the dose conversion factors for ^{238}U, ^{232}Th, and ^{40}K, respectively. [15]

The A_U, $A_{Th,}$ and A_K are the Specific Activity of ^{238}U, ^{232}Th, and ^{40}K, respectively

Radium Equivalent

The radium equivalent can be calculated from the following equation.

$$Ra_{eq}(\text{Bq/Kg}) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad (5)$$

A_{Ra}, A_{Th}, and A_K are the Specific Activity of ^{226}Ra, ^{232}Th, and ^{40}K respectively. Where, it is assumed that 370 Bq.kg-1 of ^{226}Ra, 259 Bq.kg-1 of ^{232}Th, and 4810 Bq.kg-1 of ^{40}K produce the same gamma dose rate [13].

The Annual Effective Dose (E)

The annual effective dose (indoor and outdoor) were calculated using the Equations 6 and 7, respectively:

$$E_{indoor} = AD_{indoor}\left(\frac{nGy}{h}\right) \times 8760(h) \times 0.8 \times 0.7\left(\frac{Sv}{Gy}\right) \times 10^{-3} \quad (6)$$

$$E_{outdoor} = D\left(\frac{nGy}{h}\right) \times 8760(h) \times 0.2 \times 0.7 \times \left(\frac{Sv}{Gy}\right) \times 10^{-3} \quad (7)$$

Where 0.7 Sv/Gy is the dose conversion coefficient from absorbed dose into the air to the effective annual dose. The 0.8 is the indoor occupancy factor, 0.2 is the outdoor occupancy factor, and 8760 is the number of h of the year. The global average effective annual dose is 0.48 mSv [16].

Results

Table 2 shows the Specific Activity for ^{238}U, ^{232}Th, and ^{40} K in the dust at the schools selected from Karbala as well as the external and internal hazard indices. The minimum and maximum values of these parameters occurred at Othman bin Said, Al asar, and Warka schools, respectively.

Table 2. Specific Activity of (U^{238}, Th^{232} series, and K^{40}), External Hazard Index, and Internal Hazard Index of the investigated samples

Sample No.	Sample Code	Specific Activity (Bq/kg)			H_{ex}	H_{in}
		^{238}U	^{232}Th	^{40}K		
1	Sam1	15.61±0.2919	15.08±0.2085	101.66±2.43	0.1215±0.0021	0.164±0.00289
2	Sam2	17.63±0.2366	1.36±0.0963	158.02±2.1206	0.0858±0.00145	0.133±0.00209
3	Sam3	5.59±0.1679	4.69±0.1146	66.94±1.638	0.0471±0.00124	0.062±0.00169
4	Sam4	14.21±0.2175	8.01±0.1315	96.94±1.8036	0.0895±0.00147	0.128±0.00206
5	Sam5	14.1±0.2872	5.04±0.1608	143.47±2.6952	0.0874±0.00196	0.126±0.00273
6	Sam6	17.59±0.3473	12.28±0.2255	128.66±2.9861	0.1217±0.00243	0.169±0.00337
7	Sam7	30.75±0.6317	26.48±0.435	253.72±5.6083	0.2381±0.00455	0.321±0.00626
8	Sam8	24.45±0.4001	11.29±0.2306	170.21±3.3542	0.1451±0.00267	0.211±0.00375
9	Sam9	11.69±0.3182	7.2±0.2031	113.88±2.9613	0.0831±0.00226	0.115±0.00312
10	Sam10	25.17±0.2763	11.93±0.1543	149.92±2.1372	0.1453±0.00179	0.213±0.00253
11	Sam11	29.52±0.3619	9.57±0.1832	203.87±2.964	0.1591±0.0023	0.239±0.00328
12	Sam12	71.91±1.6561	43.35±1.0434	417.91±13.721	0.4486±0.01136	0.643±0.01583
Min		5.59±0.1679	1.36±0.0963	66.94±1.638	0.047±0.001	0.062±0.00169
Max		71.91±1.6561	43.35±1.0434	417.91±13.721	0.449±0.011	0.643±0.01583
Average		23.185±0.433	13.023±0.266	167.1±3.702	0.148±0.003	0.21±0.004

$H_{ex:}$ external hazard index
$H_{in:}$ internal hazard index

Table3. Values of absorbed dose rate and annual effective dose (indoor and outdoor)

Sample No.	Sample Code	Absorbed Dose Rate in Air (nGy/h)	Outdoor	Indoor	Radium Equivalent Activity (Bq/Kg)
			Annual Effective Doses Equivalent (μSv/y)	Annual Effective Doses Equivalent (μSv/y)	
1	Sam1	20.56±0.36212	25.21±0.4441	100.86±1.78	45±0.77717
2	Sam2	15.56±0.2559	19.08±0.31384	76.33±1.26	31.74±0.5376
3	Sam3	8.21±0.21509	10.07±0.26379	40.27±1.06	17.45±0.4579
4	Sam4	15.45±0.25512	18.95±0.31288	75.79±1.25	33.13±0.54442
5	Sam5	15.54±0.3422	19.06±0.41967	76.23±1.68	32.35±0.72467
6	Sam6	20.91±0.42117	25.64±0.51652	102.58±2.07	45.06±0.89969
7	Sam7	40.78±0.78845	50.01±0.96696	200.05±3.87	88.15±1.68559
8	Sam8	25.21±0.464	30.92±0.56905	123.67±2.28	53.7±0.98813
9	Sam9	14.5±0.39317	17.78±0.48218	71.13±1.93	30.75±0.83665
10	Sam10	25.09±0.30997	30.77±0.38015	123.08±1.52	53.77±0.66151
11	Sam11	27.92±0.40145	34.24±0.49234	136.96±1.97	58.9±0.8521
12	Sam12	76.83±1.9675	94.22±2.41294	376.9±9.65	166.08±4.20469
Min		8.21±0.215	10.07±0.264	40.27±1.06	17.45±0.458
Max		76.83±1.968	94.22±2.413	376.9±9.65	166.08±4.205
Average		25.547±0.515	31.329±0.631	125.321±2.527	54.673±1.098

Table 4. Concentrations of lead and cadmium elements

Sample No.	Sample Code	Cd (mg/kg)				Pb (mg/kg)			
		Min	Max	Stde.v.	Average	Min	Max	Stdev.	Average
1	Sam1	0.008	0.032	0.012	0.018	2.252	2.944	0.38	2.689
2	Sam2	0.092	0.211	0.062	0.141	6.882	11.712	2.542	8.839
3	Sam3	0.005	0.028	0.012	0.017	2.098	4.32	1.196	2.953
4	Sam4	0.033	0.039	0.003	0.036	2.782	6.321	1.828	4.815
5	Sam5	0.002	0.041	0.022	0.027	2.793	5.005	1.108	3.937
6	Sam6	0.004	0.015	0.006	0.009	1.983	4.21	1.122	3.175
7	Sam7	LLD	0.011	0.006	0.005	1.872	7.162	2.647	4.455
8	Sam8	0.012	0.128	0.058	0.073	4.44	10.102	2.962	7.774
9	Sam9	0.008	0.018	0.005	0.012	3.443	5.342	0.95	4.369
10	Sam10	0.011	0.027	0.008	0.019	2.781	4.102	0.703	3.581
11	Sam11	0.028	0.062	0.017	0.045	4.44	7.221	1.391	5.847
12	Sam12	LLD	LLD	LLD	LLD	1.022	6.211	2.603	3.738

LLD: lower limit of detection
CD: cadmium
PB: lead

Table 3 shows the absorbed dose sate in the air, the annual effective dose (indoor and outdoor) and the radium equivalent at the selected Schools. Table 4 shows the variations concentrations of heavy elements of Pb and Cd in mg kg^{-1} expressed as min, max, average, and standard deviation.

Discussion

The minimum activity concentration of ^{238}U and ^{40}K were found in sample 3 and ^{232}Th in sample 2. The maximum concentrations of the ^{238}U, ^{232}Th, and ^{40}K were in sample 12. As shown in Table 2, all the specific activities were within the average value reported in the UNSCEAR 2008 Report [16].

Table 2 shows that the highest values of external and internal hazard index were observed in sample 12, and the lowest value was in sample 3, which was within the reference values [16].

Table 3 shows that the highest values for both the absorbed dose rate, the annual effective dose (internal and external), and radium equivalent were in sample 12; however, these values were within the reference level.The results showed that the highest concentration of lead was in sample 3 followed by sample 8as shown in Table 4. However, the lowest concentrations were recorded for sample 3 and sample 1, respectively, compared to the rest of the schools. The reason for the high concentration of lead may be due to the quality of school waste, such as pencils, dyes, and books, in addition to the quality of paint in the classrooms, which falls on the floors [17].

Table 4 shows that the highest concentration of cadmium element was in sample 2 and sample 8 while the concentration of cadmium in sample 12 was below the lower limit of detection of the Atomic Absorption Spectrometer. High traffic density and vehicle emissions also play a role in the increase of metal concentration [18].

Conclusion

The absorbed dose rate, effective dose (indoor and outdoor), hazard indices, and radium equivalent values are within the range of values reported in the UNSCEAR 2008 report [16]. The levels of lead and cadmium concentration detected in some schools are due to dust pollution in the school environment.

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