Assessment of Radiation Hazard Indices and Excess Life time Cancer Risk due to Dust Storm for Al-Najaf, Iraq

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Abstract: - Dust storm is a meteorological phenomenon common in Al-Najaf city of Iraq. This study investigates the presence of long-lived gamma emitters in dust storms samples, and estimates radiation hazed indices. Dust storm samples were collected from the Iraqi weather of 2013. After proper lab treatment, the samples underwent gamma spectroscopy, where the targeted radionuclides were ^{228}U, ^{232}Th, and ^{40}K. The average of specific activity in the collected dust storms samples was found the range from (237.166±5.834) to (368.689±17.697) Bq/Kg with an average value of (308.168±46.124) Bq/Kg for ^{40}K, ^{238}U specific activity range from (11.531±2.080) to (34.997±2.683) Bq/Kg with an average value of (21.4775±8.406) Bq/Kg and ^{232}Th specific activities range from (2.805±0.370) to (11.162±1.638) Bq/Kg with an average of (5.446±2.738) Bq/Kg and. The average value of the radium equivalent was found (52.994±13.041) Bg/Kg, while the average value of the external hazard index, internal hazard index , representative level index, absorbed dose in air and annual effective dose in outdoor were found (0.224±0.0569), (0.201±0.057) , (0.202±0.048), (26.384±6.263) nGy/h and (0.0324±0.007185) mSv/y respectively. The range value of the Excess Lifetime Cancer Risk was found from(0.0762194) to (0.144037637) with an average (0.1132494±0.025147). The obtained the Radiation Hazard Indices and Excess Lifetime Cancer Risk are found to agree with those reported in the international level.

Key-Words: - dust storms , Al-Najaf, Natural radioactivity, Gamma-ray spectroscopy.

1 Introduction

Dust storm (sand storm) is a metrological phenomenon that is common in deserts and arid areas. It can also be defined as a draft of air carrying dust and flying at up to hundreds of kilometers. In such storms, the visional level usually comes down, the dust particles rise up and moves to another place according to the air's speed and direction [1].Iraq is considered one of the region’s most vulnerable countries to climate change and it faces a unique set of environmental challenges. Rising environmental degradation and increasing frequency and intensity of extreme weather events, especially sand and dust Storms, take an enormous toll on socioeconomic life and human development across the region [2].Dust and sand storms are persistent problem in Iraq and middle East Region. The regional dust storms had bad effects on health of human life which can cause asthma, bronchitis and lung diseases as well as the effects of natural radioactivity that contain of dust storms. In Iraq no surveys of natural radioactivity in dust storm have been carried out and no baselines of concentration of natural and anthropogenic radioisotopes have been reported. Therefore, the establishment of radio-isotope concentrations will prove meaningful information that can contribute to knowledge of population exposure and to the setting up of original baseline. The aim of this work was measured natural radioactivity due to ^{238}U, ^{232}Th and ^{40}K in Al-Najaf area for some samples of dust storm in different data time 2013 using gamma ray spectroscope and determined the radiation hazard(the absorbed dose rate, radium equivalent activities, external hazard index and Internal hazard) have been calculated based on guidelines provided by UNSCEAR (2008)[3,4].

2 Area of Study

Al-Najaf is located on the edge of western plateau of Iraq, at southwest of Baghdad the capital city of Iraq, at 160 km far from the capital. It is 70 meters above sea level and is situated on longitude of 44 degree and 19 minutes, latitude of 31 degree and 59 minutes . It is boarded from north and northwest by Karbalaa city (which is 80 km far from it), and from the south and west by low sea of Al-Najaf, and Abi Sukhair (which is 18 km far from the city) and from the east by Al- Kufa city (which is 10 km far from the city). The area of Al-Najaf Province is 28824 km² except the Badeh region (3424 km²), that is 1269600 dunam with the exception of Badeh. It is distinguished by its strategic proximity to the Baghdad Province and accessibility to other provinces and Saudi Arabia [5].

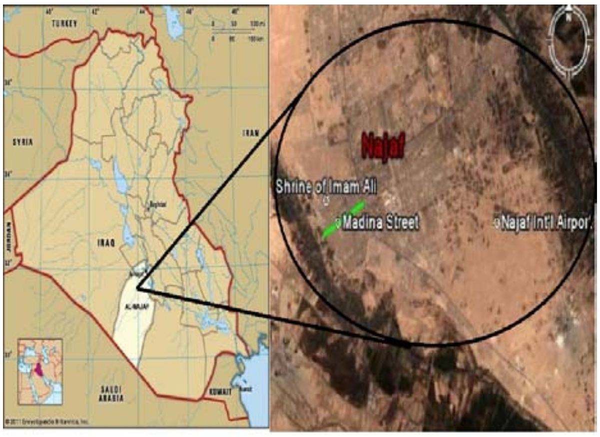


Fig.1: Map of Al-Najaf Al-Ashraf Province

3 Materials and Methods

3.1 Sampling and sample preparation

Eight dust storm samples were collected in different locations at Al-Najaf during several dust/sand storm events from January to July 2013, measurement of radioactivity concentration in different dust storms samples which that shown in Table(1).

Table (1): Sample data and sample code of dust storms samples in this study.

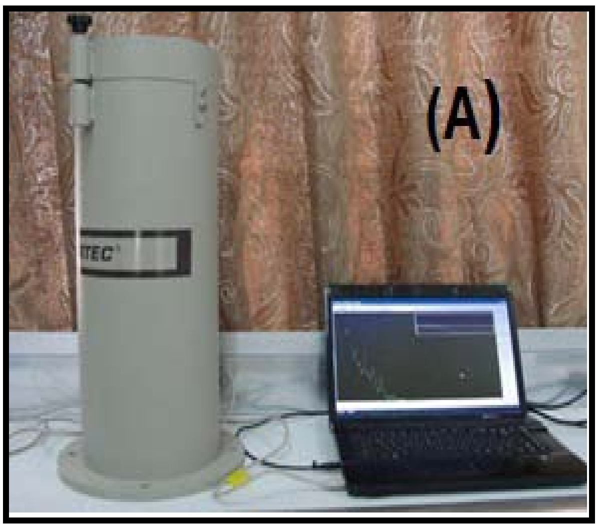
No.	Samples Data	Samples Code
1	23/02/2013	D1
2	06/03/2013	D2
3	17/03/2013	D3
4	05/04/2013	D4
5	16/04/2013	D5
6	02/06/2013	D6
7	09/06/2013	D7
8	20/06/2013	D8

After collection , each soil sample was kept in a plastic bag and labelled according to its time of dust storms . Sample preparation was then carried to dry under the heat of sun in order to remove excess moisture. In order to get homogeneity, the samples were sieved through of 0.8mm pore size diameter , and to keep them moisture-free they were put in an oven, in order to reach a constant weight.

These samples were packed in a 1 L polyethylene plastic Marinelli beakers of constant volume, so that there is geometric homogeneity around the Detector , then the respective net weights were measured and recorded with a high sensitive digital weighing balance with a percent of ±0.01% . After that , the plastic Marinelli beakers were sealed with a PVC tape , and stored for about one month before counting , to allow secular equilibrium to be attained between ^{222}Rn and its parent ^{226}Ra in uranium chain [6] .

3.2 Instrument and Calibration

Radioactivity measurements were performed by gamma ray spectrometry (ORTEC Part Number 931000) which consists of detector NaI(Tl) the volume of crystal is (“3 x 3”) ,supplied by (Alpha Spectra,Inc.-12I12/3), coupled with a multi-channel analyzer (MCA) (ORTEC –Digi Base) with range of 4096 channel joined with ADC (Analog to Digital Convertor) unit as shown in Fig.(2), through interface and desperation energy (FWHM) in the peak 1.33KeV for ^{60}Co is 7% . The radioactive background decrease for different radiations by using shield which consist of two layers , first one of stainless steel with width (10 mm) and the second layer lead (30 mm).



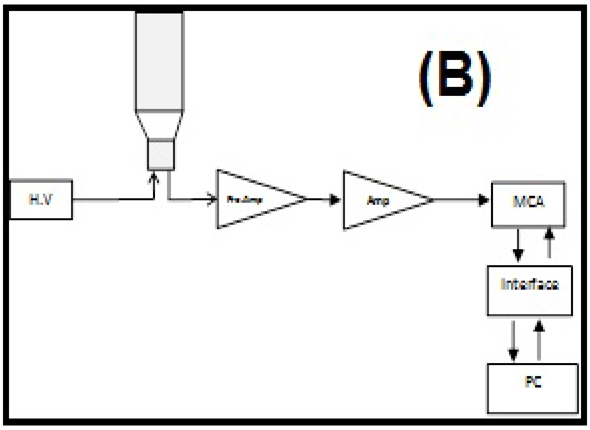


Fig.3: (A) Experimental set-up, (B) set-up block diagram

Energy calibration and efficiency calibration of gamma spectrometer were carried out using (Co-60 ,Cs-137, Na-22) calibration sources in one liter marinelli beaker covering the energy from 25 Kev to 2500 Kev. The standard source put over the detector with a geometric match exactly to the geometrical sample form and with same distance between the sample and the detector. The counting time for each sample, as well as for background was 1000 sec. The absolute efficiency was calculated the equation[7]

$$\boldsymbol{Eff = \frac{N_P}{I_\gamma \times T_{oc} \times A}} \text{ ....(1)}$$

Where: N_p: net peak area (count/ sec) at E_γ, I_γ: intensity of emitted gamma ray (%), T_{oc}: time of counting (sec.) and A: activity of standard source in (Bq). Fig.(3) shows the absolute efficiency curve.

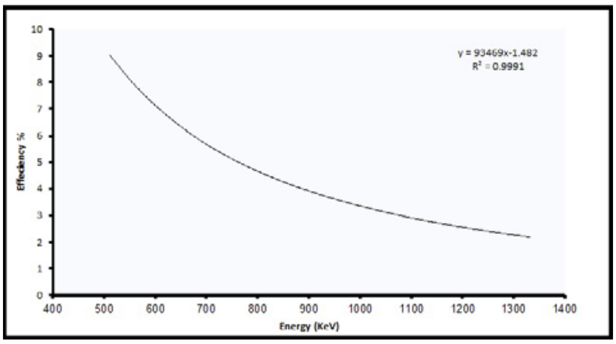


Fig.3 : The Efficiency Calibration Curve of NaI(Tl) (3" × 3")

3.3 Sample Measurements

The gamma spectrum from each samples was recorded using a PC-based multichannel analyzer and processed using the MAESTRO-32 software, as shown in above figure (2). The samples were placed on the detector and measured for a period of 18000 s . To calculate the specific activity for each samples, the net area under the corresponding peaks in the energy spectrum was computed by subtracting count due to background sources from the net area of a certain peak using MAESTRO-32 data analysis package. The background spectrum measured by using Empty 1 L polyethylene plastic Marinelli beakers on the detector and counting under the same time for the sample measurements. Because of the poor resolution of NaI(Tl) detector, at low gamma energies which haven't well-separated photo-peaks, thus the measuring of the activity concentrations is possible at a good separated photo-peaks at high energies as that obtained in our results from the gamma rays emitted by the progenies of ^{238}U and ^{232}Th which are in secular equilibrium with them while, ^{40}K was estimated directly by its gamma-line of 1460 keV. Hence the specific activity of ^{238}U were determined using the gamma-lines 1765 keV (^{214}Bi). The corresponding results of ^{232}Th were determined using the gamma-ray lines 2614 keV(^{208}Tl).

4 Calculation

4.1 Calculation of Activity

The specific activity of each radionuclide can be calculated using the following equation [8].

$$A(Bq \backslash kg) = \frac{C}{\varepsilon \cdot I_\gamma \cdot m \cdot t} \text{ ....(2)}$$

where **A** the specific activity of the radionuclide in Bq/kg, **C** is net peak count (background subtracted), **ε** the relative efficiency, $\mathbf{I_\gamma}$ the percentage of gamma emission probability of the radionuclide under study, **t** the counting time in second and **m** the mass of the sample in kg .

4.2 Calculation of radiation hazard indices

Based on the measured values of ^{238}U, ^{232}Th and ^{40}K, the radiation hazard for all dust storms samples can be calculated such as the radium equivalent activity(Ra_{eq}) , the external hazard index (H_{ex}), internal hazard index (H_{in}), and the total air absorbed dose rate (D) as following:

The radium equivalent activity was calculated using the relation [9-11]:

$Ra_{eq.}$ (Bq/ Kg) = A_{Ra}+1.43A_{Th}+0.77A_k .....(3)

The external hazard index (H_{ex}) and internal hazard index (H_{in}) were calculated by the following equation [12-14]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots\ldots\ldots(4)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots\ldots\ldots\ldots(5)$$

Representative level index (I_γ) are used to estimate the dangerous due to gamma radiation associated with the natural radionuclides (^{238}U, ^{232}Th and ^{40}K), in the study matter, another radiation hazard index ,the activity concentration index (Iγ), is used and is defined as [15].

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_k}{3000} \quad \ldots\ldots\ldots\mathbf{(6)}$$

where A_U, A_{Th}, A_K are the activity concentrations (Bq/kg) of radium, thorium and potassium in the soil samples, respectively.

The representative level index (Iγ) must be lower than unity in order to keep the radiation hazard insignificant [16].

The absorbed dose rates were calculated by the conversion factor[17]:

$$D\left(\frac{nGy}{h}\right) = 0.462A_{Ra} + 0.621A_{Th} + 0.0427A_K \quad \ldots\ldots\ldots(7)$$

Where A_{Ra}: Specific activity of ^{238}U(Secular equilibrium usually occurs when the parent radionuclide must have much longer half-life than that of any other radionuclide in the chain, therefor the specific activity for ^{226}Ra and ^{238}U are equal), A_{Th}: Specific activity of ^{232}Th and A_K: Specific activity of ^{40}K.

Annual Effective Dose Equivalent (AEDE) received outdoor by a member is calculated from the absorbed dose rate by applying dose conversion factor of 0.7 (Sv/Gy) and the occupancy factor for outdoor was 0.2(5/24). AEDE is determined using the following [18]:

$$AEDE_{Outdoor}\left(\frac{\mu Sv}{y}\right) = Absorbed\ dose\left(\frac{nGy}{h}\right)$$

$$\times 8760\,h \times 0.7\,(Sv/Gy) \times 0.2 \times 10^{-3} \quad \ldots\ldots\mathbf{(8)}$$

4.3 Calculation of Excess Lifetime Cancer Risk

This gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being. It is given as [19]:

ELCR = AEDE x DL x RF

Where AEDE is the Annual Effective Dose Equivalent, DL is the average Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

5 Result and Discussion

Table (2) show the values of specific activity in dust storms in this study while Figures (4), (5) and (6) show the relation between specific activity of ^{40}K, ^{238}U and ^{232}Th radionuclides with samples code respectively. Table (3) show the values of Radiation Hazard Indices while Figures (7) and (8) show radium equivalent, the absorbed dose rate and External, internal and Representative level hazed indices in dust storms samples respectively. Table (4) and Figure (9) show the relation between Excess Lifetime Cancer Risk with sample code in this study.

From the result in Table(2) and Fig.(4), the specific activity values have been found to range from (334.939±8.281) to (368.689±17.697) Bq/kg with an average value (308.168±46.124) Bq/kg for ^{40}K, also from Table (2) and Fig.(5), the specific activity values have been found to range from (11.531±2.080) to (34.997±2.683) Bq/kg with an average value (21.4775±8.406) Bq/kg for ^{238}U, while in Table (2) and Fig.(6), it is found that the range of specific activity of ^{232}Th varied from (2.805±0.370) to (11.162±1.638) Bq/kg with an average value of (5.446±2.738) Bq/kg . From Table (3) and Fig. (7) the values of Radiation Hazard Indices of Ra_{eq}, and absorbed dose rate have been found to range of (35.224932) to

(67.968386) Bq/kg with an average of (52.994±13.041) Bq/kg and (17.756826) to (33.556434) nGy/h with an average value of (26.384±6.263) nGy/h respectively. Also from Table (3) and Fig. (8) the values of radiation hazard indices of H_{ex}, H_{in}, I_{γ} and AEDE have been found to range from (0.146277) to (0.295247) with an average value of (0.220.224±0.0569), from (0.130148) to (0.271788) with an average value of (0.201±0.057) , from (0.1362537) to (0.255583) with an average value of (0.202±0.048) and from (0.021776971) to (0.041153611) with an average value of (0.0324±0.007185) respectively. And from Table (4) and Fig. (9) the values of Excess Lifetime Cancer Risk have been found to range of (0.0762194) to (0.144037637) with an average of (0.1132494±0.025147)**.**

The results are comparable to the world average activity concentration which are 412, 32, and 45 Bq/kg For ^{40}K,^{238}U and ^{232}Th respectively as reported by UNSCEAR 2008 [4]. The reasons found radioactivity in all samples in this study may depend on meteorological parameters (such as wind direction) which it is arrived from radioactivity in soil of Neighboring countries (such as Saudi Arabia, Jordan and Iran).

The results obtained for the radium equivalent activity and adsorbed dose rate in air is below the permissible values of 370 Bq/kg and 58 nGy/h respectively [20]. Also, external hazard index, internal hazard index and representative gamma index are less than the world permissible value of unity [21] . The present values of outdoor annual effective dose equivalent is lower than the world average values (70μSv/y) [21]. Average excess lifetime cancer risk (ELCR) for all samples is less than the world average of (0.29× 10^{-3}) [19]. This means that the chances of having cancer in dust storms samples are insignificant. Therefore, the dust storms in studied area no health hazard effect according to natural radioactivity.

Table(2) : Specific activity of ^{238}U , ^{232}Th and ^{40}K in dust storms samples in this study.

Sample Code	Specific activity in (Bq/Kg)		
	^{40}K	^{238}U	^{232}Th
D1	296.975± 5.373	23.089±2.514	4.333±0.450
D2	332.349±5.788	13.687± 2.095	5.482±0.454
D3	265.057±4.679	11.531±2.080	3.775±0.390
D4	237.166±5.834	12.952 ±1.615	2.805±0.370
D5	277.622±6.455	22.451±2.297	5.115±0.479
D6	334.939±8.281	34.997±2.683	3.362±0.604
D7	368.689±17.697	23.063±4.612	11.162±1.638
D8	352.548±7.881	30.05±2.26	7.533±0.538
Range	234 – 370	11 - 35	2 - 12
Mean ±S.D	308.168±46.124	21.4775±8.406	5.446±2.738

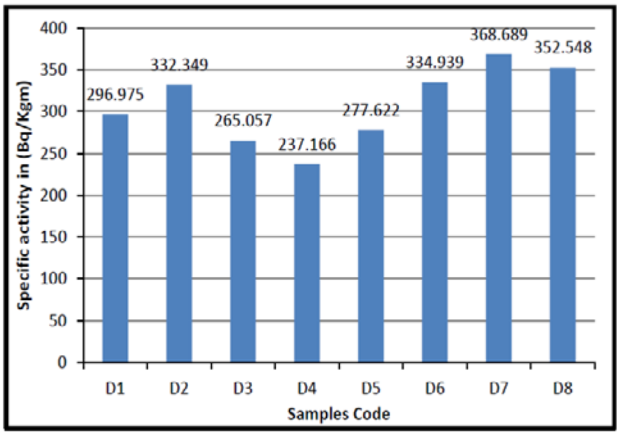


Fig. 4: Specific Activity of ^{40}K in (Bq/Kg)

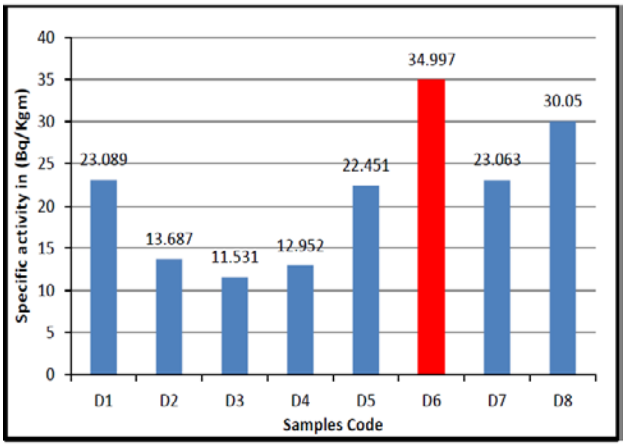


Fig. 5: Specific Activity of ^{238}U in (Bq/Kg)

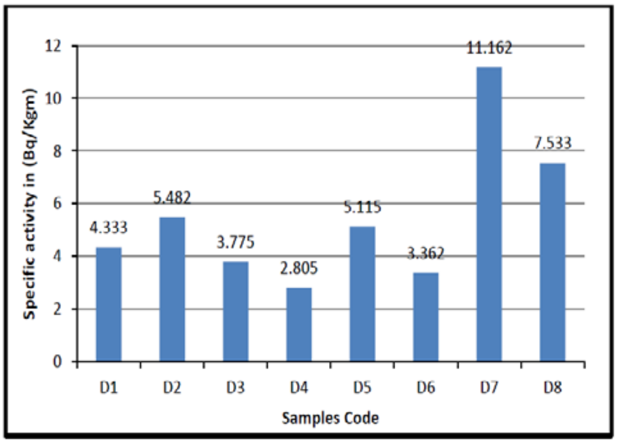


Fig. 6: Specific Activity of ^{232}Th in (Bq/Kg)

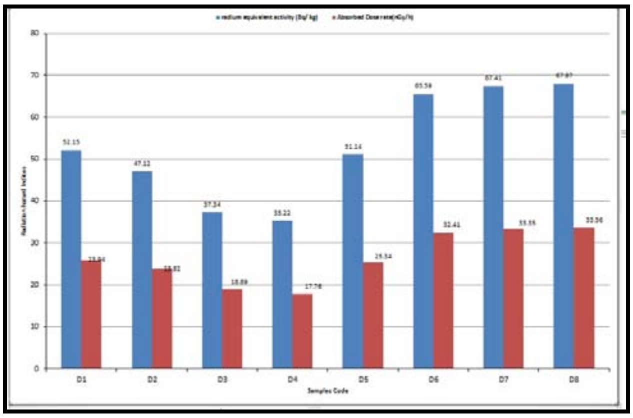


Fig. 7: Radium equivalent and the absorbed dose rate in dust storms samples .

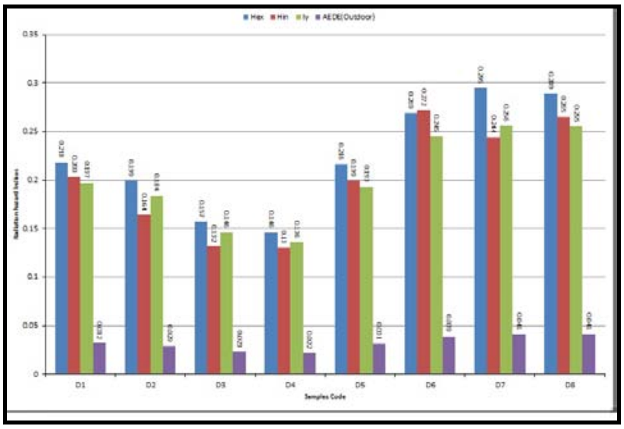


Fig. 8: External, internal, Representative level and annual effective dose equivalent in dust storms samples

Table(3):Radium equivalent and the absorbed dose rate in dust storms samples in this study.

Sample Code	radium equivalent activity (Bq/kg)	External hazard index	Internal hazard index	Representative level index	Absorbed Dose rate(nGy/h)	Annual Effective Dose Equivalent (Outdoor)(mSv/y)
D1	52.152265	0.217871	0.203276	0.19762	25.939186	0.031811818
D2	47.117133	0.199581	0.164245	0.1838163	23.823424	0.029217047
D3	37.338639	0.156765	0.13201	0.145664	18.898366	0.023176956
D4	35.224932	0.146277	0.130148	0.1362537	17.756826	0.021776971
D5	51.142344	0.215953	0.198823	0.1929523	25.336776	0.031073022
D6	65.594963	0.269625	0.271788	0.245113	32.407904	0.039745053
D7	67.413713	0.295247	0.244412	0.255583	33.350696	0.040901294
D8	67.968386	0.289033	0.264812	0.2553477	33.556434	0.041153611
Range	35 - 70	0.1 - 0.3	0.1 -.0.3	0.13-0.26	17 - 34	0.02-0.045
Mean ±S.D	52.994±13.041	0.224±0.0569	0.201±0.057	0.202±0.048	26.3.84±6.263	0.0324±0.007185

Table(4): Excess Lifetime Cancer Risk in dust storms samples

Sample Code	Excess Lifetime Cancer Risk (X10-3)
D1	0.111341362
D2	0.102259665
D3	0.081119346
D4	0.0762194
D5	0.108755577
D6	0.139107687
D7	0.143154528
D8	0.144037637
Range	0.07-0.15
Mean ±S.D	0.1132494±0.025147

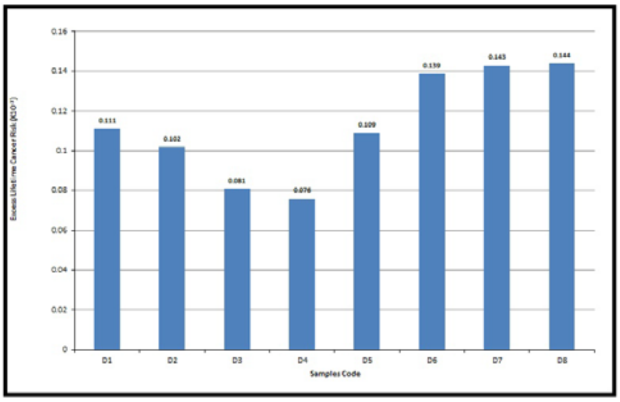


Fig. 9: Excess Lifetime Cancer Risk in dust storms samples

6 Conclusion

In the light of the study, we conclude that, the dust storms samples in this study have radioactivity and significant variation in various time. The uranium activities were within normal level in the studied area in all samples exception of one samples higher than the range of worldwide average, while the thorium and the potassium radionuclide in all samples lower than the range of worldwide average. The radium equivalent activity, external hazard index , internal hazard index, the absorbed dose rates and Representative level index of all dust storm samples are lower than the permissible limit.

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