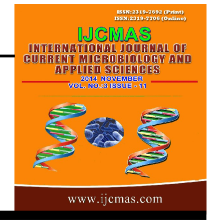
International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 3 Number 11 (2014) pp. 640-648**
http://www.ijcmas.com



Original Research Article

Natural Radioactivity of soil samples from some areas of Aden governorate, south of Yemen Region

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A B S T R A C T

The activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in surface soil samples from Aden governorate south of Yemen region were measured by gamma spectrometry using a NaI(Tl) detector. The activity concentrations for the surface soil from (Beer Ahmed- Beer Fadle) area varies from 19.00±0.48 Bqkg^{-1} to 76.36±1.64 Bqkg^{-1} for ^{226}Ra, from 21.44±0.49 to 74.65±1.53 Bq kg^{-1} for ^{232}Th and from 196.07±6.82 to 555.18±18.41 Bqkg^{-1} for ^{40}K. The activity concentrations for the surface soil from (Daar-saad -Al-Masabian) area varies from 17.6±0.88 Bq kg^{-1} to 66.6±3.33 Bq kg^{-1}, for ^{226}Ra, from 18.3±0.915 to 99.4±4.97 for ^{232}Th and from 110.5±5.525 to 1664±83.2 Bq kg^{-1} for ^{40}K, having an overall mean value of 43.40±0.98 Bqkg^{-1}, 49.12±1.03 Bqkg^{-1} and 361.35±12.36 Bq kg^{-1} and 42.56±2.13 Bqkg^{-1}, 54.14±2.71 and 878.32±43.91 Bqkg^{-1}for ^{226}Ra, ^{232}Th and ^{40}K, respectively. Based on radionuclide's concentration in soil samples the radiological effects were assessed.

Keywords

Activity concentrations, Surface Soil, Aden Governorate, South of Yemen region,

Introduction

The study of the distribution of primordial radionuclides allows the understanding of the radiological implication of these elements due to the γ-ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters (Alam *et al.*, 1999; Singh *et al.*, 2005).

The natural radioactivity in soil mainly comes from the uranium and thorium decay series and potassium (UNSCEAR, 2000). Obviously the actual level of radiation caused by the radionuclide content of rocks and soil varies widely from place to place and the actual background contribution to the external gamma dose rate at a given location can be determined only by measurement. Thus, the dose rate depends on the geological location (Martin and Harbinson). Measurement of natural background radiation and radioactivity in soil has been carried out in many countries to establish the baseline data of natural radiation levels (Ibrahiem *et al.*, 1993).

All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the γ -emitting radionuclides in the U-238 and Th-232 series and K- 40, made approximately equal contributions to the externally incident γ -radiation dose to individuals in typical situations both outdoors and indoors. Since 98.5% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the U-238 and the other Ra-226 precursors are normally ignored (Zastawny *et al.,* 1979).

The paper aimed to measure natural radioactivity (Ra-226, Th-232 and K-40) of surface soil from Beer Ahmed- Beer Fadle and Daar-saad -Al-Masabian areas and estimated of the radiation hazard.

Materials and Methods

Sampling and samples preparation

For the measurement of the natural radioactivity in soil, surface-soil samples were collected randomly from different locations in the Aden governorate south of Yemen region. The soil was collected from an auger hole at a depth of about 0-25 cm so as to sample the natural soil. After collection, samples were crushed into fine powder by using mortar and pestle. The final grain-sizes of the samples were obtained by straining through a 100 micron-mesh size. An average 400g of soil is used per sample.

Before measurement samples were dried in an oven at a temperature of 100°C for 24 hours. Each sample was packed and sealed in an airtight PVC container and kept for about a four-week period to allow radioactive equilibrium among the daughter products of radon (^{222}Ra), thoron (^{220}Ra) and their short lived decay products.

Detection Technique

Each sample was measured with a gamma-ray spectrometer consisting of a NaI(Tl) setup and multichannel analyzer 8192 channel, with the following specifications: resolution (FWHM) at 1.33 MeV ^{60}Co is 60 keV – relative efficiency at 1.33 MeV ^{60}Co is 7.5%. The detector is shielded in a chamber of two layers starting with stainless steel (10 mm thick) and led (30 mm thick). This shield serves to reduce different background radioactivity. To minimize the effect of the scattered radiation from the shield, the detector is located in the center of the chamber. Then the sample was placed over the detector for at least 10h.

The spectra were either evaluated with the computer software program Maestro (EG&G ORTEC), or manually with the use of a spread sheet (Microsoft Excel) to calculate the natural radioactivity. ^{226}Ra activity of the samples was determined via its daughters (^{214}Pb and ^{214}Bi) through the intensity of the 295.22, 351.93 keV, for ^{214}Pb Gamma-lines and 609.31, 1120, 1764.49 keV, for ^{214}Bi Gamma-lines. ^{232}Th activity of the sample was determined from the daughters (^{228}Ac), (^{212}Pb) and (^{208}Ti) through the intensity of 209.25, 338.32, 911.2 keV Gamma-lines for (^{228}Ac), (^{212}Pb) emissions at 238.63 keV and (^{208}Ti) emissions at 583.19, 2614 keV Gamma-lines. ^{40}K activity determined from the 1460.7 keV emissions Gamma-lines.

The detector was calibrated using standard source QCYB41 from Physikalisch Technische Bundesanstalt PTB, Germany; which has ten radionuclides with twelve γ-ray emitters ranged from 230 to 1836 keV, the efficiency calibration has been calculated (Fig. 1 and 2).

Measurement of natural radioactivity

Through calculating the area under the peak (net area) and by means of the detector efficiency curve, the specific activity (activity concentration) A_{Ei} was determined using the formula.

$$A_{Ei} = \frac{NP}{t_c . I_\gamma (E_\gamma) . \varepsilon (E_\gamma) . M} \quad (1)$$

Where NP is the number of count in a given peak area corrected for background peaks of a peak at energy E,ε (E_γ) the detection efficiency at energy E, t_c is the counting lifetime, I_γ (E_γ) the number of gammas per disintegration of this nuclide for a transition at energy E, and M the mass in kg of the measured sample (Harb, 2004).

Calculation of air-absorbed dose rate

The external, terrestrial γ-radiation, absorbed dose rate in air at a height of about 1 m above the ground is calculated by using the conversion factor of 0.042 nGy h^{-1}/ Bq kg^{-1} for ^{40}K, 0.455 nGy h^{-1}/Bq kg^{-1} for ^{226}Ra, and 0.583 nGy h^{-1}/Bq kg^{-1} for ^{232}Th (UNSCEAR, 1993) assuming that ^{137}Cs, ^{90}Sr and the ^{235}U decay series can be neglected. They contribute very little to the total dose from the environmental background (Kocher and Sjoreen, 1985; Jacob *et al.*, 1986; Leung *et al.*, 1990).

$$D\ (nGy.h^{-1}) = (0.4551)\ A_U + (0.583)\ A_{Th} + (0.042)\ A_K \quad (2)$$

Where: A_{Ra}, A_{Th} and A_K are the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in (Bq kg^{-1}).

Calculation of annual effective dose

To estimate annual effective doses, the following must be considered: (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. The annual, estimated, average, effective- dose equivalent received by a member is calculated using a conversion factor of 0.7 Sv Gy^{-1}, which is used to convert the absorbed rate to human effective-dose equivalent with an outdoor occupancy of 20% and 80% for indoors (UNSCEAR, 1993).

The annual effective doses are determined as follows:

Effective dose rate (mSv.yr^{-1})
$$= Absorbed\ dose\ (nGy\ h^{-1}) \times 8760\ h.yr^{-1} \times 0.7 \times (10^3\ mSv / 10^9) \times 0.2\ (nGy^{-1}) \quad (3)$$

External hazard index

External hazard index due to the emitted gamma-rays of the samples are calculated and examined according to the following criterion:

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad (4)$$

Where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

Internal hazard index

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index (Hin), which is given by the equation. (Beretka and Mathew, 1985).

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad (5)$$

The values of the indeces (Hex, Hin) must be less than unity for the radiation hazard to be negligible.

Results and Discussion

The results for the activity concentrations of U-238 series (Ra-226), Th-232 series (Th-232), as well as K-40, expressed in Bq/kg for samples obtained from Beer Ahmed-Beer Fadle and Daar-saad-Al-Masabian area present in Table 1 and Table 2. From obtained results the range of Ra-226 values was 19.00±0.48 to 76.36±1.64 and 17.6±0.88 to 66.6±3.33. The values for Th-232 were 21.44±0.49 to 74.65±1.53 and 18.3±0.915 to 99.4±4.97. While the values for K-40 were 196.07±6.82 to 555.18±18.41 and 110.5±5.525 to1664±83.2, for Beer Ahmed- Beer Fadle and Daar-saad -Al-Masabian area respectively. From table 1 it can be noticed.

- The average value of Ra-226 and Th-232 at Beer Ahmed- Beer Fadle and Daar-saad -Al-Masabian are closed. This narrow range of the activity concentrations is probably due to the fact that the sites studied cover an area with similar aquifer lithology's and consequent not large differences in radionuclide solubilities and mobilities. While the average values of K-40 at Daar-saad -Al-Masabian higher than that in Beer Ahmed- Beer Fadle this is may be due to the wide using of different quantities or species of fertilizers.
- The activity concentrations of Ra-226, Th-232 and K-40 in all area under study are higher than the Worldwide mean values that recorded by UNSCEAR, 2000 (35, 30)
- Except the value of K-40 in Beer Ahmed- Beer Fadle lower than worldwide mean values that recorded by UNSCEAR (2000), (412 Bq kg^{-1}).
- The average values of Ra-226, Th-232 and K-40 are close to Sana'a, Yemen and Juban, Yemen value and lower than Assalamya-Alhomira, Yemen, (Emran, 2012).

Table 2 shows the average values of absorbed dose rate, annual effective dose, external hazard index and internal hazard index of the studied soil samples. The gamma dose rates due to naturally occurring terrestrial radionuclides Ra-226, Th-232 and K-40 were calculated based on their activities in soil samples, determined by gamma-ray spectrometry.

The absorbed gamma dose rate due to these radionuclides were 63.59, 88.39 $nGyh^{-1}$ for Beer Ahmed-Beer Fadle and Daar-saad -Al-Masabian area, respectively. The estimated mean annual effective dose was 0.078 and 0.108 mSv. The external hazard index (H_{ex}) was calculated the mean value was 0.38 and 0.51 for Beer Ahmed-Beer Fadle and Daar-saad -Al-Masabian area respectively.

The internal hazard index (H_{in}) was also calculated, the value was 0.49 and 0.62 for Beer Ahmed-Beer Fadle and Daar-saad -Al-Masabian.

From table 2 it can be observed that:

- The values of absorbed dose rate in Beer Ahmed-Beer Fadle were lower than its values in Daar-saad -Al-Masabian area.
- The values of absorbed dose rate in Beer Ahmed-Beer Fadle area were lower than its values in Yemen soil which recorded 86.89 $nGyh^{-1}$ and close to its values in Daar-saad -Al-Masabian area. (Shaban *et al.,* 2012)
- The values of absorbed dose rate in Beer Ahmed-Beer Fadle and Daar-saad -Al-Masabian were higher than the world values (57 $nGyh^{-1}$) (UNSCEAR 2000).
- Values of annual effective dose in Beer Ahmed-Beer Fadle were lower than the values in Daar-saad -Al-Masabian.

- The values of annual effective dose in Beer Ahmed-Beer Fadle were close to worldwide values, 0.07 mSv, respectively which reported in (UNSCEAR, 2000)
- The values of annual effective dose in Daar-saad -Al-Masabian area were higher than worldwide values, 0.07 mSv, respectively which reported in (UNSCEAR, 2000).
- Values of Hex and H_{in} in present work are lower than unity.

Finally , from the obtained results, we can concluded that the area under investigation have a normal background radiation and may be not pose radiological risks to the population owing to harmful effects of ionizing radiation from the naturally occurring radionuclides in soil.

Figures 3 and 4 show the average values for absorbed dose rate, annual effective dose and external and internal hazard index in all samples under investigation, respectively.

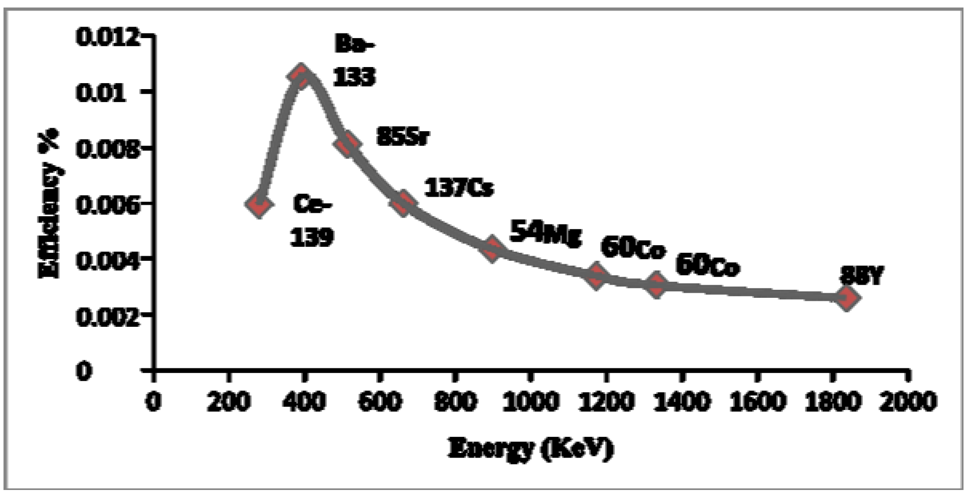

Figure.1 Full energy peak efficiency as a function of gamma ray energy for a typical NaI (Tl) detector

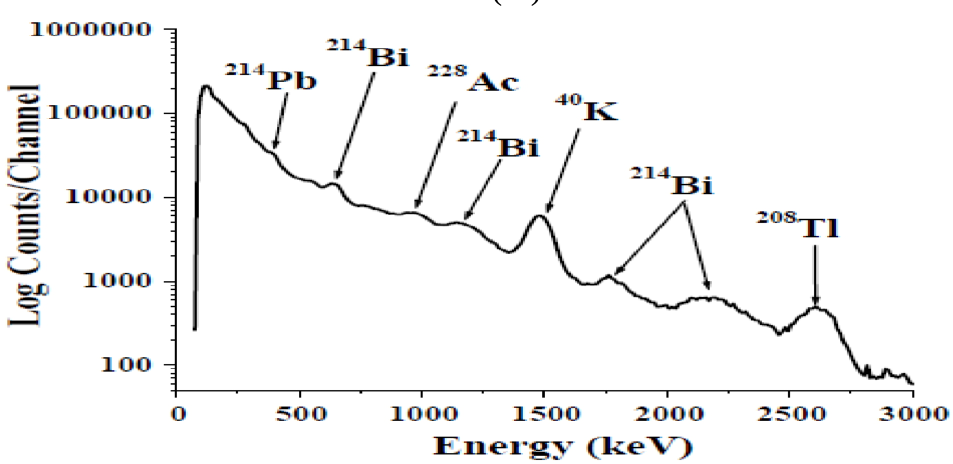

Figure.2 The energy spectrum recorded for soil sample by scintillation detector NaI(Tl)

Table.1 Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from (Beer Ahmed-Beer Fadle and Daar-saad -Al-Masabian)

Sample No	Activity concentration Bq kg^{-1}			Sample No	Activity concentration Bq kg^{-1}		
	^{226}Ra	^{232}Th	^{40}K		^{226}Ra	^{232}Th	^{40}K
	Beer Ahmed-Beer Fadle				Daar-saad -Al-Masabian		
Soil-1	33.44±0.81	35.60±0.79	423.60±14.66	Soil-1	21.5±1.075	18.3±0.915	110.5±5.525
Soil-2	25.76±0.61	26.20±0.58	211.33±7.77	Soil-2	49.8±2.49	61.3±3.065	1180±59.4
Soil-3	25.95±0.63	26.85±0.60	232.05±7.98	Soil-3	33.8±1.69	25.6±1.28	443.1±22.155
Soil-4	34.86±0.84	40.80±0.88	401.90±14.05	Soil-4	66.6±3.33	99.4±4.97	446.1±22.305
Soil-5	31.46±0.75	35.07±0.75	262.95±9.03	Soil-5	40.9±2.045	50.8±2.54	956±47.8
Soil-6	27.96±0.66	31.74±0.69	242.88±8.73	Soil-6	56.6±2.83	37.2±1.86	396.1±19.805
Soil-7	20.02±0.49	22.58±0.50	203.95±7.45	Soil-7	17.6±0.88	30.3±1.515	699±34.95
Soil-8	20.44±0.51	23.38±0.52	224.56±8.05	Soil-8	43.1±2.15	69.4±3.47	1436±71.8
Soil-9	31.49±0.74	34.93±0.75	266.75±9.55	Soil-9	50.5±2.52	112.4±5.62	1613±80.65
Soil-10	29.92±0.71	35.55±0.76	336.34±11.33	Soil-10	40.9±2.525	50.8±2.54	956±47.8
Soil-11	33.22±0.78	47.72±0.99	448.15±14.97	Soil-11	52.1±2.605	80.1±4.005	1664±83.2
Soil-12	51.74±1.15	71.58±1.45	455.11±15.39	Soil-12	32.6±1.63	49.6±2.48	1133±56.65
Soil-13	62.76±1.37	71.03±1.45	431.52±14.54	Soil-13	38.8±1.94	40.9±2.045	678±33.9
Soil-14	58.70±1.29	62.55±1.30	445.74±14.80	Soil-14	52.6±2.55	54.5±2.725	799.1±40.15
Soil-15	62.15±1.36	64.14±1.32	401.04±13.51	Soil-15	36.7±1.8	28.5±1.425	289.3±14.46
Soil-16	62.43±1.36	63.13±1.30	417.41±14.06	Soil-16	49.3±2.46	57.1±2.855	1249±62.5
Soil-17	65.34±1.42	67.27±1.38	358.58±12.30	**Mean**	**42.56±2.13**	**54.14±2.71**	**878.32±43.91**
Soil-18	76.36±1.64	74.65±1.53	420.96±14.47	Soil-24	22.64±0.56	61.16±1.27	419.46±14.01
Soil-19	56.14±1.24	62.73±1.30	397.53±13.39	Soil-25	26.12±0.64	29.49±0.65	555.18±18.41
Soil-20	62.03±1.35	61.80±1.28	394.32±13.29	Soil-26	50.94±1.12	57.65±1.19	461.98±15.43
Soil-21	63.68±1.39	62.23±1.29	397.56±13.39	Soil-27	19.00±0.48	21.44±0.49	196.07±6.82
Soil-22	56.43±1.25	67.21±1.35	351.20±12.05	**Mean**	**43.40±0.98**	**49.12±1.03**	**361.35±12.36**
Soil-23	61.00±1.35	67.85±1.39	398.51±12.93				

Table.2 The average value of absorbed dose rate, annual effective dose rate, external and internal hazard index

Location	Absorbed dose rate (nGy/h)		Annual effective dose (mSv)		External hazard index		Internal hazard index	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Beer Ahmed-Beer Fadle	29.39-95.99	63.59	0.036-0.12	0.078	0.17-0.58	0.38	0.23-0.78	0.49
Daar-saad -Al-Masabian	25.10-156.31	88.39	0.030-0.15	0.108	0.15-0.91	0.51	0.21-1.04	0.62

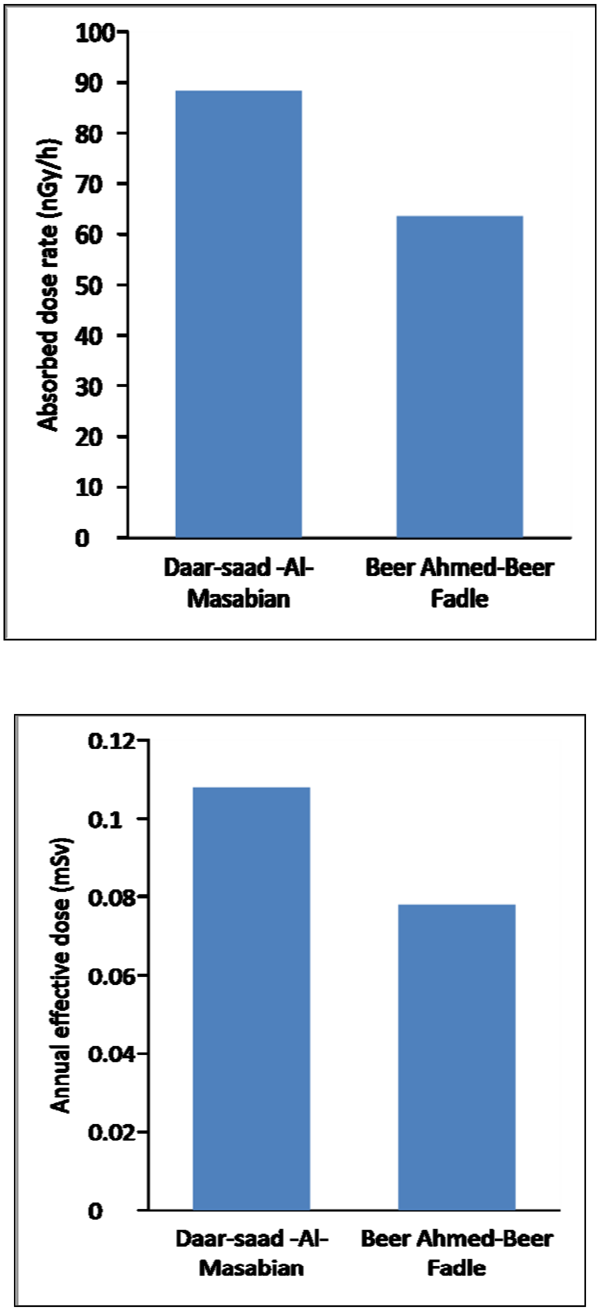

Figure.3 The average value of absorbed dose rate and annual effective dose, in all area under investigation

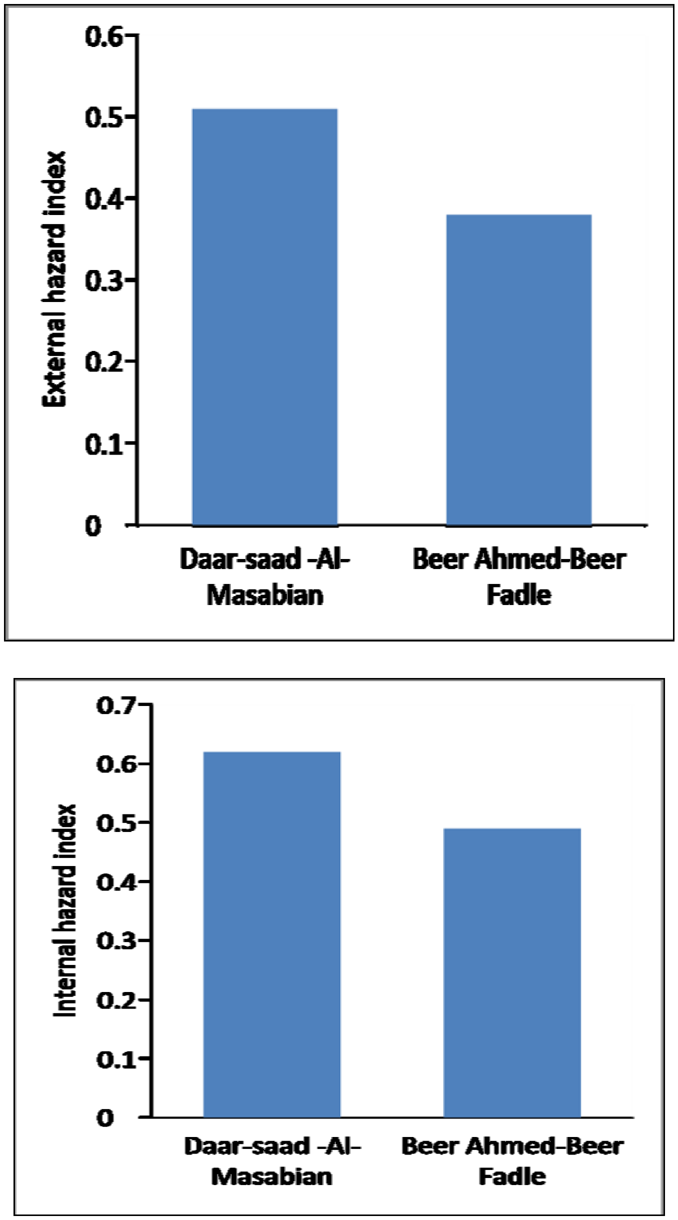

Figure.4 The average value of external hazard index and internal hazard index in all area under investigation

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