

Natural Radioactivity Hazard Assessment on Soil in Kassala Town-Sudan

Suleiman Awad Hamouda Belal

University of Kassala, Faculty of Education, Department of Physics

Abstract

Human beings have always been exposed to natural radiation, which is mainly due to the activity concentration of primordial radio nuclides. In this study, measure the concentration of natural activity radiation, absorbed dose rate, annual effective dose (indoor/outdoor) and assessment of radiation hazard index are measured for some soil sample from various geographical locations in Kassala Town-Kassala State – Sudan , for the elements ^{226}Ra , ^{232}Th and ^{40}K , using gamma-ray spectrometry. The study conduct to the average concentration for ^{226}Ra , ^{232}Th and ^{40}K were found to be 18.19 Bq/Kg, 19.56 Bq/Kg and 732.37 Bq/Kg respectively. The calculated average absorbed dose rate was 50.75nGy/h, annual effective dose were 0.25mSv/y(indoor), 0.06mSv/y(outdoor) and the radiation hazard index was 0.29. The study conclude that the average concentration of all elements in the study is less than the average worldwide ($^{226}\text{Ra} = 35 \text{ Bq/Kg}$), ($^{232}\text{Th} = 30 \text{ Bq/Kg}$) except ^{40}K ($^{40}\text{K} = 400 \text{ Bq/Kg}$) and also the absorbed dose rate and annual effective dose (indoor/outdoor) are less than the average worldwide (60 nGy/h), (0.41mSv/y(indoor), (0.07mSv/y(outdoor)). The assessment of radiation hazard index to the soil of Kassala Town is more less than the standard (≤ 1).

Keywords: Natural Radioactivity Hazard, Soil sample, Gamma Spectrometry, Kassala.

المستخلص

لقد ظلت البشرية تتعرض إلى تأثير الإشعاع الطبيعي الناتج بصورة رئيسة من تركيز النشاط للنويدات المشعة، في هذه الدراسة تم قياس تركيز النشاط الإشعاعي وحساب معدل متوسط الجرعة الممتصة، والجرعة الفعالة السنوية بالداخل والخارج وتقييم الخطر الإشعاعي لعينات من تربة مدينة كسلا- ولاية كسلا- السودان، لمواقع جغرافية مختلفة للعناصر ^{226}Ra ، ^{232}Th و ^{40}K ، باستخدام مطيافية أشعة غاما، توصلت الدراسة إلى أنّ تراكيز متوسط النشاط الإشعاعي لكل من ^{226}Ra ، ^{232}Th و ^{40}K كانت Bq/Kg 18.19، 19.56 Bq/Kg و 732.37 Bq/Kg، ومعدل متوسط الجرعة الممتصة يساوي 50.75nGy/h والجرعة الفعالة السنوية تساوي 0.25mSv/y (بالداخل) و 0.06 msv/y (بالخارج). كما أنّ قيمة مؤشر الخطر الإشعاعي تساوي 0.29. خلصت الدراسة على أن متوسط تراكيز كل العناصر المدروسة بالنسبة لتربة مدينة كسلا ولكل المواقع الجغرافية أقل من المتوسط العالمي (($^{226}\text{Ra} = 35 \text{ Bq/Kg}$ ، $^{232}\text{Th} = 30 \text{ Bq/Kg}$) و ^{40}K عدا ($^{40}\text{K} = 400 \text{ Bq/Kg}$)، وكذلك معدل متوسط الجرعة الممتصة ومتوسط الجرعة الفعالة السنوية بالداخل والخارج أقل من المتوسط العالمي ((60 nGy/h، 0.41 mSv/y (بالداخل)) (0.07 mSv/y (بالخارج))

أما بالنسبة لتقييم الخطر الإشعاعي على تربة مدينة كسلا نلاحظ أنه أقل بكثير جداً من قيمة الخطر القياسي (≤ 1)).

Introduction

Radiation is energy in the form of waves or streams of particles, there are many kinds of radiation all around us, when people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms, Sound and visible light are familiar forms of radiation; other types include ultraviolet radiate (that produces a suntan), infrared radiation (a form of heat energy), and radio and television signal. Some atoms are naturally stable while others are unstable. Atoms with unstable nuclei which spontaneously transform, releasing energy in the form of radiation are known as radio nuclides. This energy can interact with other atoms and ionize them. Ionization is the process by which atoms become positively or negatively charged by gaining or losing electrons. There are two forms of radiation non-ionizing and ionizing. Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight. Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials. Alpha radiation ,Beta radiation and gamma radiation (Canadian Nuclear Safety Commission, Catalogue ,2012).

Sources of Radiation:

The sources of radiation are broadly divided into two main types, namely the natural sources and artificial sources.

Natural Sources of radiation:

The assessment of the radiation doses in human beings from natural sources is special importance because natural radiation is by far the largest contributor to the collective dose received by the world population.

The natural radiation sources are classified into: (a) external sources of extraterrestrial origin (that is, cosmic radiation) and radiation of terrestrial origin (that is, the radioactive nuclides present in the crust of the earth, in building materials and in air). (b) internal sources, comprising the naturally occurring radio nuclides that are taken into the human body (UNSCEAR , 1988).

Artificial Sources:

The uses of radiation have increased significantly over the past decades as scientists learned to use the energy of the atom for a wide variety of purposes, from military to medical applications (e.g. cancer treatment), and from electricity production to domestic applications (e.g. smoke detectors). These and other artificial sources add to the radiation dose from natural sources for both individuals and the global population.

Individual doses from artificial sources of radiation vary greatly. Most people receive a relatively small dose from such sources but a few receive many times the average. Artificial sources of radiation are generally well controlled by radiation protection measures (UNSCEAR ,1988).

Effects of Radiation:

Radiation can effect health through biological mechanism, It can produce effects at the level of cells, causing their death or modification usually because of direct damage to DNA.

Radio nuclides can be transferred to plants and then to animals from rocks and mineral present in the soil and water.(UNSCEAR,2008).

Human beings have always been exposed to natural radiation, which is mainly due to the activity concentration of primordial radio nuclides ^{238}U (^{226}Ra) series, ^{232}Th series and ^{40}K that present in the earth's crust, in building materials, in air, water, foods and in the human body itself.

Radiation Doses:

When ionizing radiation penetrates the human body or an object, it deposits energy. The energy absorbed from exposure to radiation is called an absorbed dose. The absorbed dose is measured in a unit called the Gray (Gy). A dose of one gray is equivalent to a unit of energy (Joule) deposited in a Kilogram of a substance. However, the biological effects per unit of absorbed dose varies with the type of radiation and the part of the body exposed. To take account of those variations, a weighted quantity called the effective dose is used and its unit is the Sievert (Sv).

In addition a radioactive source is described by its activity ,which is the number of nuclear disintegrations per unit of time. The unit of activity is the Becquerel (Bq). One Becquerel is one disintegration per second. Types of ionizing radiation differ in the way in which they interact with biological materials, so that equal absorbed doses (meaning equal amounts of energy deposited) do not necessarily have equal biological effects. For instance, 1Gy to tissue from alpha radiation is more harmful than 1 Gy from beta radiation because an alpha particle, being slower and more heavily charged, loses its energy much more densely along its path. So in order to put all the different types of ionizing radiation on an equal basis with respect to their potential for causing harm, we need another quantity, which is called the equivalent dose. It is expressed in a unit called the sievert, symbol Sv. Submultiples of the Sievert are commonly used, such as the milli sievert, mSv, which is one-thousandth of a Sievert.

Absorbed Dose Rate

The measured activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K are converted into doses (nGy h^{-1} per Bq kg^{-1}) by applying the factors 0.462, 0.604 and 0.042 for Radium , thorium and potassium, respectively. These factors are used to calculate the total absorbed gamma dose rate in air at one meter above the ground level using the following equation:

$$D_R = 0.462 A_{\text{Ra}} + 0.604 A_{\text{Th}} + 0.0417 A_{\text{K}} \quad (1)$$

Where the numerical values 0.462, 0.621 and 0.417 are the dose conversion factors for converting activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K into doses.

The Annual Effective Dose Equivalent (H_E)

The annual effective dose equivalent rate H_E was calculated from the absorbed dose by applying the dose conversion factor of $0.7 \text{ Sv}\cdot\text{Gy}^{-1}$ with an outdoor occupancy factor of 0.2 and 0.8 for indoor, The effective dose rate in units of $\text{mSv}\cdot\text{y}^{-1}$ was calculated by following equation:

$$H_E = D_R \times T \times F \quad (2)$$

Where D_R is the calculated dose rate (in $\text{nGy}\cdot\text{h}^{-1}$), T is the outdoor occupancy time ($24 \text{ h} \times 365.25 \text{ days} \times 0.2 = 1,753 \text{ h}\cdot\text{y}^{-1}$), and F is the conversion factor ($0.7 \text{ Sv}\cdot\text{Gy}^{-1}$).

$$H_{E, \text{Outdoor}} = D_R (\text{nG}\cdot\text{h}^{-1}) \times 8760 (\text{h}\cdot\text{y}^{-1}) \times 0.7 \times (10^3 \text{ mSv/nGy } 10^9) \times 0.2 \quad (3)$$

$$H_{E, \text{Outdoor}} = D_R \times 1.226 \times 10^{-3} \text{ (mSv}\cdot\text{y}^{-1}\text{)} \quad (4)$$

$$H_{E, \text{Indoor}} = D_R \text{ (nG}\cdot\text{h}^{-1}\text{)} \times 8760 \text{ (h}\cdot\text{y}^{-1}\text{)} \times 0.7 \times (10^3 \text{ mSv/nGy } 10^9) \times 0.8 \quad (5)$$

$$H_{E, \text{Indoor}} = D_R \times 4.905 \times 10^{-3} \text{ (mSv}\cdot\text{y}^{-1}\text{)} \quad (6)$$

To estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. The average numerical values of those parameters vary with the age of the population and the climate at the location considered. A report by the UNSCEAR Committee, used $0.7 \text{ Sv}\cdot\text{Gy}^{-1}$ for the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.8 for the indoor occupancy factor, *i.e.* the fraction of time spent indoors and outdoors is 0.8 and 0.2, respectively. The resulting worldwide average of the annual effective dose is 0.48 mSv, with the results for individual countries being generally within the 0.3 - 0.6 mSv range. For children and infants, the values are about 10% and 30% higher, in direct proportion to an increase in the value of the conversion coefficient from absorbed dose in air to effective dose.

Radiation Hazards Indexes:

Soils and aggregate materials can be used in industries and building constructions, the γ -ray radiation hazards due to the specified radio nuclides were assessed by three different indices.

In comparing the specific activity of samples containing different amounts of ^{226}Ra , ^{232}Th and ^{40}K , it is necessary to introduce the term radium equivalent activity (Ra_{eq}). It was defined as a single quantity that represents the combined specific activities of ^{226}Ra , ^{232}Th and ^{40}K , and develops a numerical indicator of an external dose to public and internal dose due to radon and its daughters Equation (7) is used to calculate radium equivalent activity and stated the value of 370 $\text{Bq}\cdot\text{kg}^{-1}$ as the maximum allowed value for public dose considerations according to:

$$A_{Ra} + 1.43A_{Th} + 0.077A_K, \quad (7)$$

Where A_{Ra} , A_{Th} and A_K are the specific activities of ^{226}Ra , ^{232}Th and ^{40}K in $\text{Bq}\cdot\text{kg}^{-1}$, respectively.

The external hazard index (H_{ex}) is a radiation hazard index defined to evaluate the indoor radiation dose rate due to the external exposure to γ -radiation from the natural radio nuclides in the construction building materials of dwellings. This index value must be less than unity to keep the radiation hazard insignificant, *i.e.* the radiation exposure due to the radioactivity from construction materials to be limited to $1.5 \text{ mSv}\cdot\text{y}^{-1}$ or $1.0 \text{ mSv}\cdot\text{y}^{-1}$, based on the formula:

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810) \leq 1 \quad (8)$$

Where A_{Ra} , A_{Th} and A_K are the specific activities of ^{226}Ra , ^{232}Th and ^{40}K in $\text{Bq}\cdot\text{kg}^{-1}$ respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} ($370 \text{ Bq}\cdot\text{kg}^{-1}$).

Materials and Methods

The Study Area

Kassala Town is located to the eastern part of the Sudan, in Kassala State. The state lies between latitudes $14^\circ 45'$ and $17^\circ 15'$ N, and longitudes of $34^\circ 40'$ and 37° E, in an area of 42330

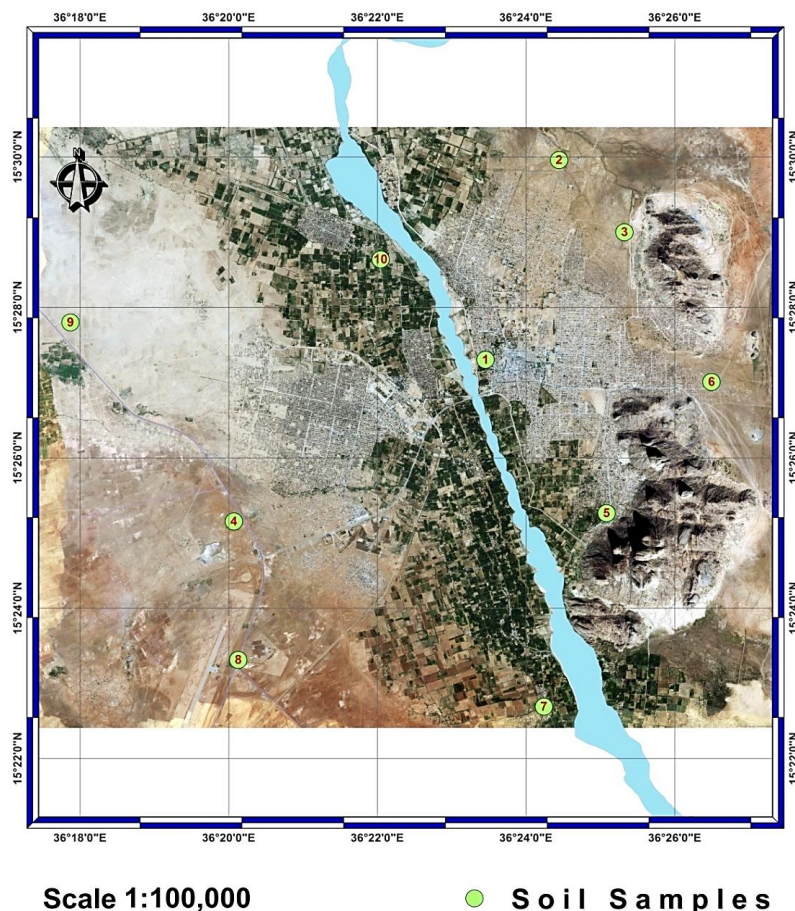
km². Kassala Town is the capital of the state. The town is located at latitude at a 15° 27' N and longitude 36° 24' E and at a distance of 625 km from Khartoum.

Sample Collection and preparation:

To measure radioactivity in soil, thirty samples of soil were collected from ten locations. Each soil sample was collected from a large area covering the town geographically. The ten locations were chosen in away to cover the town as follows: North , South , West , East , North east, North west, South east , South west, Centre and the extreme far North west. From each location three samples were taken. One sample is from residential area , another sample is from open area and the third sample is from an area of natural plants. The GPS device was used to determine the geographical position of each point of the samples. The samples were collected soil surface (about 0–10 cm).

Sample Preparation has been done at Sudan atomic energy commission in the lab of food and environment monitoring. The samples were dried and crushed in careful way such that no contamination could happen, after that a weight 500g taken from each sample using highly sensitive balance. This packaged in a plastic bottle In order to have reasonable result the sample kept packaged for a period of four weeks, this can insure that the samples reach the equilibrium between uranium and his daughters. After that Gamma-ray spectrometry detector was used to measure the activity concentration for each sample.

figure : Sample locations in Kassala Town



In the measurement of these samples, we used High Purity Germanium (HpGe) detector with sensitive material type P. This has relative efficiency 37% compare to NaI standard detectors and

resolution for Gamma lines 1.33 Mev were 1850. Moreover, system attached to multichannel analyzer that can represents the values of energy between 3 to 10000 Kev, it also attached to software on computer disk from Russian company BSI for radiation detection instrument .A typical analog HPGe detector-based gamma spectroscopy system consists of a HPGe detector, high voltage power supply, preamplifier (which is usually solid as part of the detector), amplifier, Analogue to Digital Converter (ADC), and Multi- Channel Analyzer (MCA).

Calculations:

The activity concentrations of the natural radio nuclides in the measured samples (AS) should be computed using the following relation

$$AS (\text{Bq}\cdot\text{kg}^{-1}) = Ca/\varepsilon Pr Ms \quad (9)$$

Where Ca is the net gamma counting rate (counts per second), ε the detector efficiency of the specific γ -ray, Pr the absolute transition probability of Gamma-decay and Ms is the mass of the sample (Kg).

Absorbed Dose Rate

From the equation (1) the absorbed dose is given by:

$$D_R = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K (\text{nGy/h}) \quad (10)$$

Where the numerical values 0.462, 0.621 and 0.417 are the dose conversion factors for converting activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K into doses.

The Annual Effective Dose Equivalent (H_E)

From the equation(2) the annual effective doe are given by:

$$H_{E, \text{Outdoor}} = D_R \times 1.226 \times 10^{-3} (\text{mSv/y}) \quad (11)$$

$$H_{E, \text{Indoor}} = D_R \times 4.905 \times 10^{-3} (\text{mSv/y}) \quad (12)$$

Radiation Hazards indexes

From the equation (8) the radiation hazard index is given by:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K, (\text{Bq/Kg}) \quad (13)$$

Where, Ra_{eq} is the radium equivalent activity , A_{Ra} , A_{Th} and A_K are the specific activities of ^{226}Ra , ^{232}Th and ^{40}K in $\text{Bq}\cdot\text{kg}^{-1}$ respectively.

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810) \leq 1 \quad (14)$$

Where A_{Ra} , A_{Th} and A_K are the specific activities of ^{226}Ra , ^{232}Th and ^{40}K in $\text{Bq}\cdot\text{kg}^{-1}$ respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} ($370 \text{ Bq}\cdot\text{kg}^{-1}$).

Results And Discussion

The activity concentration for all samples from the different town locations were obtained directly from the detector as shown. The following tables the average activity concentration for each element in all locations in the overall average for the town were calculated . (table 1 – 21).

From table (1) it can be seen that, there are some differences in the activity concentrations for the studied elements between three results for each element. These results are taken from three types of areas, for example sample S₁, S₄, S₇, S₁₀, S₁₃, S₁₆, S₁₉, S₂₂, S₂₅ and S₂₈ from residential area, S₂, S₅, S₈, S₁₁, S₁₄, S₁₇, S₂₀, S₂₃, and S₂₉ from an area with plants and S₃, S₆, S₉, S₁₂, S₁₅, S₁₈, S₂₁, S₂₄, S₂₆ and S₂₇ are from an open area. From this table it is found that ²²⁶Ra, is highest in plant area (37Bq in residential area(1880Bq/Kg) and lowest in open area(1140Bq/Kg), for ²³²Th, is highest in plant area (17.8Bq/Kg), while it lowest in the open area (14.7Bq/Kg), for ⁴⁰K, highest in the plant area(59Bq/Kg) and lowest in the open area(13Bq/Kg). From table (2) ²²⁶Ra is highest in the plant area (17.8Bq/Kg) and lowest in the open area(6.7Bq/Kg). ⁴⁰K is highest in the plant area(600Bq/Kg) and lowest in the open area(320Bq/Kg). ²³²Th is highest in plant area(5.1Bq/Kg) and lowest in the residential area(2.7Bq/Kg). From table (3) ²²⁶Ra is highest in open area(23.3Bq/Kg) and lowest in plant area(13.7Bq/Kg). ⁴⁰K is highest in plant area(730Bq/Kg) and lowest in residential area. ²³²Th is highest in the open area(4.9Bq/Kg) and lowest in the plant area(2.6Bq/Kg). From table (4) ²²⁶Ra is highest in plant area(27.2Bq/Kg) and lowest in residential area(12.7Bq/Kg). ⁴⁰K is highest in plant area(1320Bq/Kg) and lowest in residential area(442Bq/Kg). ²³²Th is highest in plant area(30Bq/Kg) and lowest in open area(1.9Bq/Kg). From table(5) ²²⁶Ra is highest in plant area(36Bq/Kg) and lowest in residential area(10.9Bq/Kg). ⁴⁰K is highest in residential area(977Bq/Kg) and lowest in open area(452Bq/Kg). ²³²Th is highest in plant area(47.9Bq/Kg) and lowest in residential area(30.3Bq/Kg). From table(6) ²²⁶Ra is highest in open area(31.7Bq/Kg), and lowest in residential area(14.6Bq/Kg). ⁴⁰K is highest in plant area(1550Bq/Kg) and lowest in residential area(633Bq/Kg). ²³²Th is highest in open area(32.9Bq/Kg) and lowest in plant area(25.2Bq/Kg). From table (7) ²²⁶Ra is highest in one open area S₂₁(30.9 Bq/Kg), lowest in residential area (8.8 Bq/Kg). ⁴⁰K, highest in open area S₂₂ (468Bq/Kg), lowest, residential area (380 Bq/Kg). ²³²Th, highest in open area S₂(45.7Bq/Kg), lowest in residential area(18.6 Bq/Kg). From table (8) ²²⁶Ra, highest in residential(17.2Bq/Kg), lowest in open(12.6Bq/Kg). ⁴⁰K, is highest in residential(810Bq/Kg), lowest in open(482Bq/Kg). ²³²Th, highest in plant(28.9Bq/Kg), lowest in open(23.3Bq/Kg). From table (9) the area of the two samples S₂₆ and S₂₇, is an open area with the activity concentration of ²²⁶Ra in S₂₆(14.7Bq/Kg), in S₂₇(6.7Bq/Kg). For ⁴⁰K, the corresponding values are (550Bq/Kg) and (320Bq/Kg) respectively. For ²³²Th the values are (2.7Bq/Kg) and (5.1Bq/Kg). From table (10) ²²⁶Ra is highest in plant(37Bq/Kg), lowest in both open and residential areas (0Bq/Kg). ⁴⁰K, is highest in plant (850Bq/Kg), lowest in residential(214Bq/Kg). ²³²Th, is highest in plant (4.4Bq/Kg), lowest in residential (1.3Bq/Kg). From the above discussion it concluded that the background of the area of the samples, whether being there is no relationship between the activity concentration according to the area in all locations.

From the discussion of the results of all locations showed that the average concentration of ⁴⁰K is higher than the average concentrations ²²⁶Ra and ²³²Th

In general, the average annual effective dose from this study is found to be, 0.06mSv/Y, 0.25mSv/y outdoor and indoor respectively, these values when compared with the corresponding

average values worldwide 0.07mSv/y outdoor and 0.41mSv/y indoor, there are found to be less .From this study it is found that the average external radiation hazard index for Kassala town is 0.29 which is less than "1

Table(1): The Activity concentration(Bq/kg), (Alkara)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₁	30	1880	31
S ₂	37	1430	59
S ₃	14.7	1140	13
Average	27.23	1483.33	34.33

Table(2):The Activity concentration(Bq/kg), (Shamal Alhalanga)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₄	6.7	320	5.1
S ₅	14.7	550	2.7
S ₆	17.8	600	4.7
Average	13.07	490	4.17

Table(3):The Activity concentration(Bq/kg), (Mokram Sharq)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₇	13.7	750	2.6
S ₈	15.2	470	3.3
S ₉	23.3	700	4.9
Average	17.4	640	3.6

Table(4):The Activity concentration(Bq/kg), (Alsomaa)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₁₀	19.5	920	1.9
S ₁₁	12.7	442	14.6
S ₁₂	27.2	1320	30
Average	19.8	894	15.5

Table(5):The Activity concentration(Bq/kg), (Awitala)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₁₃	10.9	977	30.3
S ₁₄	36	465	47.9
S ₁₅	30.5	452	43.5
Average	25.8	631.33	40.57

Table(6):The Activity concentration(Bq/kg), (Alengaz Sharq)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₁₆	31.7	1250	32.9
S ₁₇	25	1550	25.2
S ₁₈	14.6	633	30.6
Average	23.77	1144.33	29.57

Table(7):The Activity concentration(Bq/kg), (Alsabeel)

Sample code	²²⁶ Ra Bq/kg	⁴⁰ K Bq/kg	²³² Th Bq/kg
S ₁₉	8.8	380	18.6
S ₂₀	9.9	416	20.3
S ₂₁	30.9	452	45.7
S ₂₂	11	468	22.8
Average	15.15	429	26.85

Table(8):The Activity concentration(Bq/kg),(Sharq Almatar)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₂₃	15.7	750	28.9
S ₂₄	12.6	482	23.3
S ₂₅	17.2	810	28.8
Average	15.17	680.67	27

Table(9):The Activity concentration(Bq/kg) (Hamasyeb)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₂₆	14.7	550	2.7
S ₂₇	6.7	320	5.1
Average	10.7	435	3.9

Table(10):The Activity concentration(Bq/kg),(Alkurmota)

Sample code	²²⁶ Ra	⁴⁰ K	²³² Th
S ₂₈	N.D	430	1.6
S ₂₉	37	850	4.4
S ₃₀	N.D	214	1.3
Average	12.33	498	2.43

*N.D:Not detected

Table(11):The Activity concentration(Bq/kg),Overall the Town

The element	²²⁶ Ra	⁴⁰ K	²³² Th
Average	18.19	732.37	19.56
Max	37	1880	59
Mini	6.7	320	1.3

Table(12): Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alkara)

Sample code	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	Ra _{eq} Bq/Kg	H _{index}
S1	110.98	0.14	0.54	219.09	0.59
S2	112.36	0.14	0.55	231.48	0.63
S3	62.18	0.076	0.31	121.07	0.33
Average	95.17	0.12	0.47	190.53	0.52

Table(13):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Shamal Alhalanga)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq} Bq/Kg	H_{index}
S ₄	19.51	0.02	0.095	38.63	0.1
S ₅	31.36	0.04	0.15	64.01	0.17
S ₆	36.08	0.04	0.18	11108.71	0.29
Average	28.98	0.03	0.14	70.45	0.19

Table(14):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Mokram Sharq)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq} Bq/Kg	H_{index}
S ₇	39.17	0.05	0.19	75.17	0.20
S ₈	28.61	0.04	0.14	56.11	0.15
S ₉	42.91	0.05	0.21	84.21	0.23
Mean	36.9	0.05	0.18	71.83	0.19

Table(15) absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alsomaa)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq} Bq/Kg	H_{index}
S ₁₀	48.52	0.06	0.24	93.06	0.25
S ₁₁	33.12	0.04	0.16	67.61	0.18
S ₁₂	85.73	0.11	0.42	171.74	0.46
Mean	55.79	0.07	0.27	110.80	0.29

Table(16):Absorbed dose rate, annual effective dose (indoor/outdoor), radiation hazard index and radium equivalent, (Awitala)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq} Bq/Kg	H_{index}
S ₁₃	64.08	0.079	0.31	129.46	0.35
S ₁₄	64.95	0.079	0.32	140.3	0.38
S ₁₅	59.21	0.073	0.29	127.51	0.34
Average	62.75	0.077	0.31	132.42	0.36

Table(17):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (AlengazSharq)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq} Bq/Kg	H_{index}
S ₁₆	86.64	0.11	0.42	174.99	0.47
S ₁₇	91.41	0.11	0.45	180.39	0.49
S ₁₈	51.62	0.06	0.25	107.1	0.29

Mean	76.56	0.09	0.37	154.16	0.42
-------------	-------	------	------	--------	------

Table(18):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alsabeel)

Sample code	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	Ra _{eq} Bq/Kg	H _{index}
S ₁₉	31.15	0.04	0.15	64.66	0.17
S ₂₀	34.18	0.04	0.17	70.96	0.19
S ₂₁	60.73	0.07	0.29	131.06	0.35
S ₂₂	38.37	0.05	0.19	196.65	0.22
Mean	41.11	0.05	0.2	115.83	0.23

Table(19):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (SharqAlmatar)

Sample code	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	H _{index}	Ra _{eq} Bq/Kg
S ₂₃	55.98	0.07	0.27	0.31	114.78
S ₂₄	39.99	0.05	0.19	0.22	83.03
S ₂₅	59.12	0.07	0.29	0.33	120.75
Average	51.69	0.06	0.25	0.29	106.19
Sample code	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	Ra _{eq} Bq/Kg	H _{index}
S ₂₆	31.36	0.04	0.15	60.91	0.47
S ₂₇	19.52	0.02	0.095	38.63	0.10
Average	25.44	0.03	0.12	49.77	0.29

radiation hazard index and radium equivalent, (Hamasyeb)

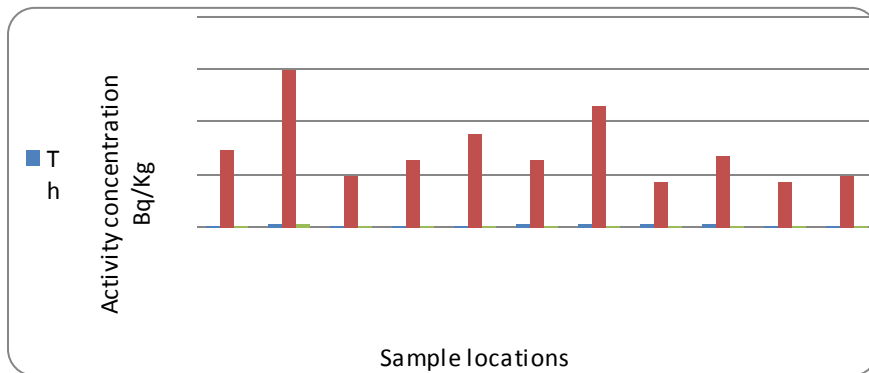
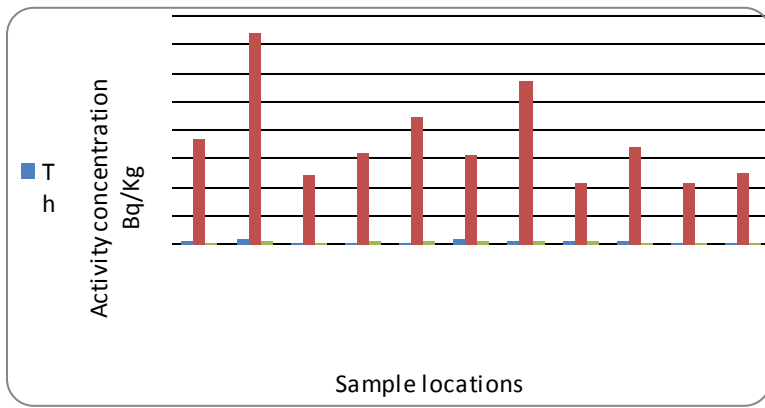
Table(20):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent(Alkurmota)

Sample code	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	Ra _{eq} Bq/Kg	H _{index}
S ₂₈	18.89	0.02	0.09	35.39	0.09
S ₂₉	55.19	0.07	0.27	108.74	0.29
S ₃₀	9.71	0.01	0.05	18.34	0.05
Average	27.93	0.03	0.14	54.16	0.14

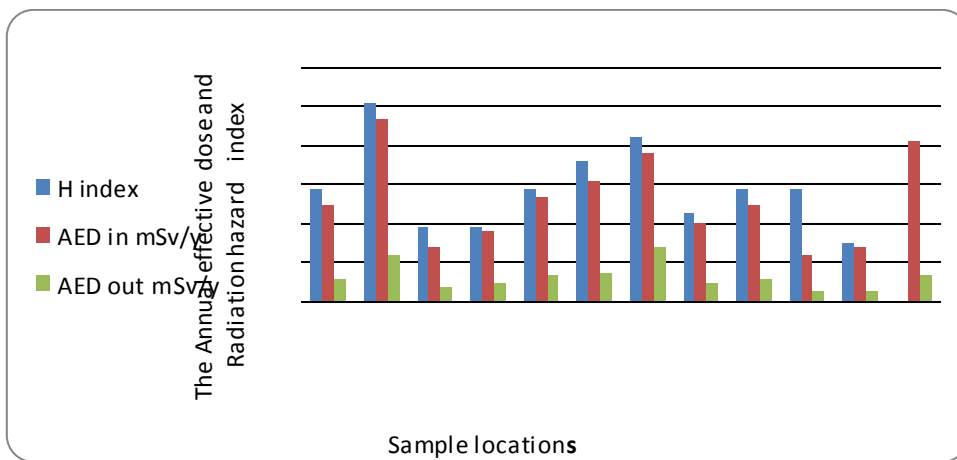
Table(21): Absorbed dose rate, annual effective dose (indoor/ outdoor) , radiation hazard index and radium

equivalent for the Town

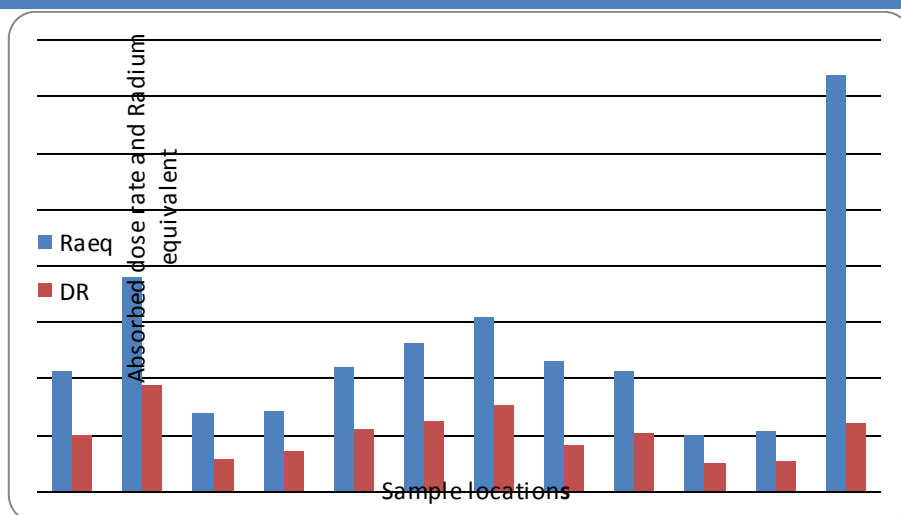
Doses	D _R (nGy/h)	H _E out mSv/y	H _E in mSv/y	Ra _{eq} Bq/Kg	H _{index}
Average	50.75	0.06	0.25	107.82	0.29
Max	112.36	0.14	0.42	231.48	0.59
Mini	9.71	0.01	0.05	18.34	0.05



Figure(1):The Histogram representing the average activity concentration for the locations and the town



Figure(2):The annual effective dose and radiation hazard index for the different locations, the town and worldwide



Figure(3):The absorbed dose rate and radium equivalent for the different locations,the town and worldwide

Discussion

Since the general aim of this study is to measure the concentration of natural radioactivity in soil samples in Kassala town and the special objective is to determine the activity concentration of the elements ^{226}Ra , ^{232}Th and ^{40}K , using gamma-ray spectrometry and calculate the absorbed dose rate, annual effective dose and estimate the radiological hazard from the soil of the town according to the standard. The average concentration of all elements in the study is less than the average worldwide except the element ^{40}K .

The mean absorbed dose rate was calculated and compared with the corresponding worldwide average(which is found to be less than the worldwide average).

The annual effective dose was estimated and found to be(outdoor) and (indoor), while are less than the worldwide and the radiation hazard index was found to less than "1"

References

- Augustine** KolapoAdemola, AdekunleKazeemBello, Adeniyi Caleb Adejumobi (2014), "Determination of natural radioactivity and hazard in soil samples in and around gold mining area in Itagunmodi, south-western, Nigeria", Journal of Radiation Research and Applied Sciences 249-255.
- Abd –Elmoniem** A. Elzain, Adam K.Sam and Othman M. Mukhtar, Mustafa A. Abbasher, (2009), "Measurement of Radon Gas Concentration In Soil at Some Towns in Kassla State", Gezira Journal of Engineering and Applied Sciences, 4(1):15-42.
- Fathi Awad**, Fath Alrahman Alnaem, Khadija Abobakr, Abdelrahman Higazi (2018), "Measurement of Gamma Radiation Levels In Soil Samples From Port Sudan And Estimation of population Exposure", Red Sea University Journal .
- Hashi Gad ELseed**, Mohammed Hashim ALbashir, (2016), "Assessment of Natural Radioactivity Concentration and Dose in Surface Soil Samples from Atbara", European Academic Research, Vol. IV, Issue 7/ October.
- Introduction to Radiation**, (2012), Minister of Public Works and Government Services Canada (PWGSC), Canadian Nuclear Safety Commission, Catalogue number (CNSC) C172-93/2012E-PDF ISBN 978-1-100-21572-3, Published by the Canadian Nuclear Safety Commission.
- Jean-Louis** Basdevant, James Rich, Michel Spiro, (2005), "Fundamentals in Nuclear Physics, From Nuclear Structure to Cosmology, Printed in the United States of America. (EB), 987654321 SPIN10925645 springeronline.com.
- Kaleel Mohammed** Thabayneh, Mohanad Mohammed Jazzar (2012), "Natural Radioactivity Levels and Estimation of Radiation Exposure in Environmental Soil Samples from Tulkarem Province-Palestine", Open Journal of Soil Science, 1616 <http://dx.doi.org/10.4236/ojss2012.21002> Published Online March (<http://www.SciRP.org/journal/ojss>).
- Katse Piet** Maphoto, (2004) "Determination of Natural Radioactivity Concentrations in Soil", University of the Western Cape, August.
- Nooreldin** Fadol, Elfadil Mahmoud, Yousef, (2017), "Assessment of Natural Radioactivity in Soil and Rock Samples Round EL-obeid Refinery-Sudan", Journal of Radiation Researches, vol.4 No1 Baku5-11.
- Nicola Pallavicini**, (2011), "Activity concentration and transfer factors of natural and artificial radio nuclides in the Swedish counties of Uppsala and Jämtland", SLU, Swedish University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences Department of Soil and Environment, Uppsala.
- Radiation Effects and Sources**, (2016), United Nations Environment Programme "UNEP", Cataloguing: Radiation effects and sources, ISBN: 978-92-807-3517-8 Job No.: DEW/1937/NA, Copyright © United Nations Environment Programme, Printed in Austria.
- Nafaa Reguigui** (2006), "Gamma Ray Spectrometry Practical Information", September, University of Texas at Austin, Nuclear Teaching, Sheldon Lands Berger, Practical Gamma-

Ray Spectrometry by Gordon Gilmore and John Hemingway, John Wiley & Sons, NY,. CEA Documents, Canberra web site NY University web site.

Radiation, People and the Environment, Printed by the IAEA in Austria, February 2004 IAEA/PI/A.75 /04-00391.

Saleh Alashrah and A. El-Taher (2016), "Assessment of natural radioactivity level and radiation hazards in soil samples of Wadi Al- Rummah-Qassim province- Saudi Arabia", Journal of Environmental Biology, Vol.37, 985-991, September.

UNSCEAR (1988), United Nations Scientific Committee on the Effects of Atomic Radiation,: Sources, Effects and Risks of Ionizing Radiation, Report to the General Assembly, United Nations, New York.

UNSCEAR (2008), "United Nations Scientific Committee on the Effects of Atomic Radiation Source and Effects of Ionizing Radiation", Report to the General Assembly with Scientific Annexes, New York, 2010.