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Natural Occurring Radionuclide Materials

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1. Introduction

The stellar material, from which the earth was formed, about 4.5 billion years ago, contained many unstable nuclides (Scholten and Timmermans, 1996). Some of the original primordial nuclides, whose half-lives are about as long as the earth's age, are still present. Radiation comes from outer space (cosmic), the ground terrestrial, and even from within over bodies. It present in the air we breathe, the food we eat, the water we drink and in the construction materials used to build our houses. So, radiation is all around us, it is naturally in our environment and it has been since the birth of our planet (Maher and Raed, 2007). Radioactivity of soil environment is one of the major sources of exposure to human (Abusini, 2007).

The ^{235}U, ^{232}Th series and natural ^{40}K are the main source of natural radioactivity in soil (Yasir et al., 2007; Vosniakos et al., 2002). Since these natural occurring radio nuclides materials, (NORMs) such as ^{238}U, ^{232}Th, ^{235}U, and ^{40}K have very long half- lives (up to 10^{10} years), their presence of soils and rocks can simply be considered as permanent. The geological and geographical conditions are the major factors effects, the natural environmental radioactivity and the associated external exposure due to gamma radiation. Thus these radiation levels appear at different levels in the soil of each region in the world (UNSCEAR, 2000).

Issue in terms of radiological protection exposure to natural source of radiation becomes an important. In 1992 the national radiological protection Board (NRPB), estimated that radon accounts for approximately 50% of annual dose of radiation from all sources in the most of the world (Ibrahim, 1999).

An average person receives a radiation dose of about 300 millirem per year from natural sources compared to a dose of about 50 millirem from produced material source of radioactive materials such as medical x-ray (UNSCEAR, 1988). Exposure of public to radiation from any sources is unlikely. The European committee has issued a draft proposal for revision of the basic safety standards for the protection of workers and the general against the dangers of ionizing radiation (Marcelo and Pedro, 2007).

The United Nations Scientific Committee on the Effects of Atomic Radiation established that the world mean dose from natural radiation sources of normal area is estimated to be 2.4 $mSv.y^{-1}$ while for all man- made sources including exposure, is about 0.8 $mSv.y^{-1}$ (UNSCEAR, 1993; Valter at el., 2008). Thus 75% of the radiation dose received by humanity is come from natural radiation source. It is clear that the assessment of gamma radiation dose from natural source is of particular importance as natural radiation is the largest contributor to the external dose of the world population (UNSCEAR, 1988).

Since predominate part of the environmental radiation is found in the upper soil layer, this knowledge ensures radiological control. The ^{238}U, ^{232}Th and ^{40}K have a non-negligible radioactivity (WHO, 1993; José at el., 2005). The high radioactivity of ^{226}Ra and ^{228}Ra and their pressure in soil require particular attention. It is known that even a small amount of a radiation substance may produce a damaging biological effects and that ingested and inhaled radiation can be a serious health risk (Rowland, 1993).

The radiological impact of natural radio nuclides is due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. In general exposure to ionizing radiation often comes from medical diagnosis and therapy application in just food and air and environmental sources. The radiation from the last one cannot be switched of thus the environmental radioactivity surveillance becomes, therefore a necessity. Generally, in Iraq and especially in the middle region area, there is a lack of the scientific information on radioactivity contents of naturally occurring radioactive materials in soil especially in terms of environmental radiological studies.

Based on these facts, one can certify that the knowledge of natural occurring radionuclide materials (MORMs), such as ^{238}U, ^{232}Th and ^{40}K, is an important pre-requisite for evaluation of the rate of exposure absorbed dose by the population in order to estimate their radiological impacts and to establish a data base which will be used as reference to radiation observer in the studied area (NCRP, 1987).

2. Background

According to the source of radiation, radioactivity in the environment may be classified into two general categories; artificial and natural. Natural radioactivity comes from naturally-occurring, Uranium, Thorium and Actinium radioactive series as well as from radioisotopes like Rubidium-87, Indium-115, Lanthanum-138, Neobynium-144, Samarian-147, Luteium-176, Hafinium-174, Vanadium-150, Gadolinium-152, Platinum-190 and 192, Rhenium-187 and Potassium-40. Except for K-40 these non-series radioisotopes occur scarcely. In contrast, K-40 is ubiquitous (Vosnikos et al., 2003). In the other hand artificial activity arises mainly from discarded sources, radioactive wastes, and radioactive fallout in the nature.

There are four distinct natural series: Uranium, Actinium, thorium, and Neptunium as listed in (Table 1). Only uranium, actinium, and thorium series are found in natural. Since the isotope ^{237}Np has a half-life much shorter than the age of the earth (about 5 billion of years), virtually all neptunium decayed within the first 50 millions of years after the earth formed.

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Series	First Isotope	Half-life(years)	Last Isotope
Uranium	^{238}U	4.5×10^{9}	^{206}Pb
Actinium	^{235}U	7.10×10^{8}	^{207}Pb
Thorium	^{232}Th	1.39×10^{10}	^{208}Pb
Neptunium	^{237}Np	2.14×10^{6}	^{209}Bi

Table 1. Natural series of uranium, actinium, thorium and neptunium

2.1 The NORM decay series

Uranium and thorium are not stable; they decay mainly by alpha-particle emission to nuclides that themselves are radioactive. Natural uranium is composed of three long lived isotopes, ^{238}U, a smaller proportion of ^{235}U and an even smaller proportion of ^{234}U, the decay-series daughter of ^{238}U. Natural thorium has one single isotope, ^{232}Th. Each of these nuclides decays to an unstable daughter leading, in turn, to a whole series of nuclides that terminate in one or other of the stable isotopes of lead. Under normal circumstances, in a natural material, the $^{235}U/^{238}U$ ratio will be fixed and all nuclides in each of the series will be in equilibrium.
Gamma spectrometry of materials containing these nuclides can only be effectively done with a detailed understanding of the decay chains of the nuclides involved.

2.1.1 Uranium series

The products of the decay are called radioactivity series. This series starts with the Uranium-238 isotope, which has a half-life 4.5×10^{10} year as shown in Figure 1 (Henery and John, 1972; Littlefield and Thorley, 1974). Since nuclides have very long half-life, this chain is still present today. The radionuclide ^{238}U decays into ^{234}Th emitting an alpha-particle, the newly formed nuclide is also unstable and decay further (Figure 1). Finally, after total of 14 such steps, emitting 8 alpha particles and 6 Beta particles, accompanied by gamma radiation, stable lead is formed. This series is said to be in secular equilibrium because all their daughters following ^{238}U have shorter half-life than the parent nuclide ^{238}U (Benenson, 2002).
This decay series includes the ^{226}Ra which has half-lives of 1600 year and chemical properties clearly different from those of uranium. ^{226}Ra decay into ^{222}Rn which is an inert noble gas that not form any chemical bonds and can escape into the atmosphere and attacks rapidly to aerosols and dust particles in the air deposited. The radiation emitted at the decay of these products, can cause damage to the deep lungs.

2.1.2 Actinium series

It is also known as Uranium-235 series and starts with ^{235}U and by successive transformations and up in a stable lead ^{207}Pb. It comprises 0.72% of natural uranium. Although only a small proportion of the element, its shorter half-life means that, in terms of radiations emitted, its spectrometric significance is comparable to ^{238}U. The decay series, shown in (Figure 2), involves 12 nuclides in 11 decay stages and the emission of 7 alpha particles (ignoring a number of minor decay branches). Since its abundance is very small, it dose not taken into account in the measurements (Harb, 2004).
Within this series, only ^{235}U itself can readily be measured, although ^{227}Th, ^{223}Ra and ^{219}Rn can be measured with more difficulty. Even though the uncertainties may be high, measurement of the daughter nuclides can provide useful support information confirming the direct ^{235}U measurement or giving insight into the disruption of the decay series.

2.1.3 Thorium series

Natural thorium is 100% ^{232}Th. The decay series is shown in (Figure 3). Six alpha particles are emitted during ten decay stages. Four nuclides can be measured easily by gamma spectrometry: ^{228}Ac, ^{212}Pb, ^{212}Bi and ^{208}Tl. The decay of ^{212}Bi is branched – only 35.94% of decays produce ^{208}Tl by alpha decay. The beta decay branch produces ^{212}Po that cannot be measured by gamma spectrometry. If a ^{208}Tl measurement is to be used to estimate the thorium activity, it must be divided by 0.3594 to correct for the branching (Harb, 2004).

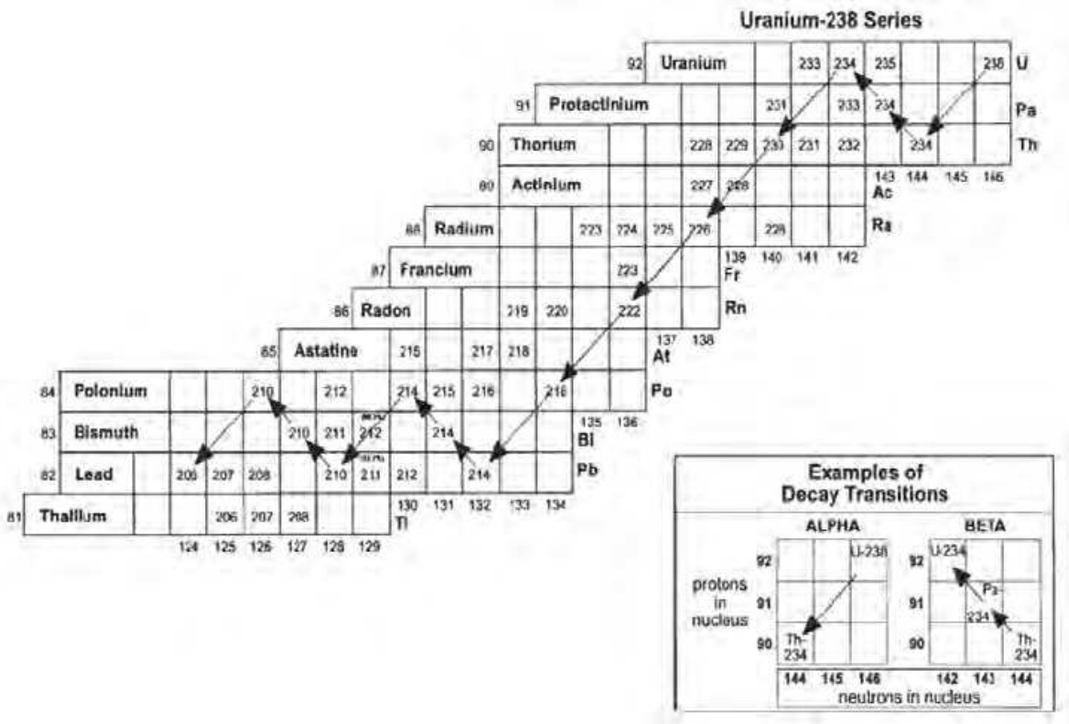

Fig. 1. Schematic diagram of the Uranium-238 series.

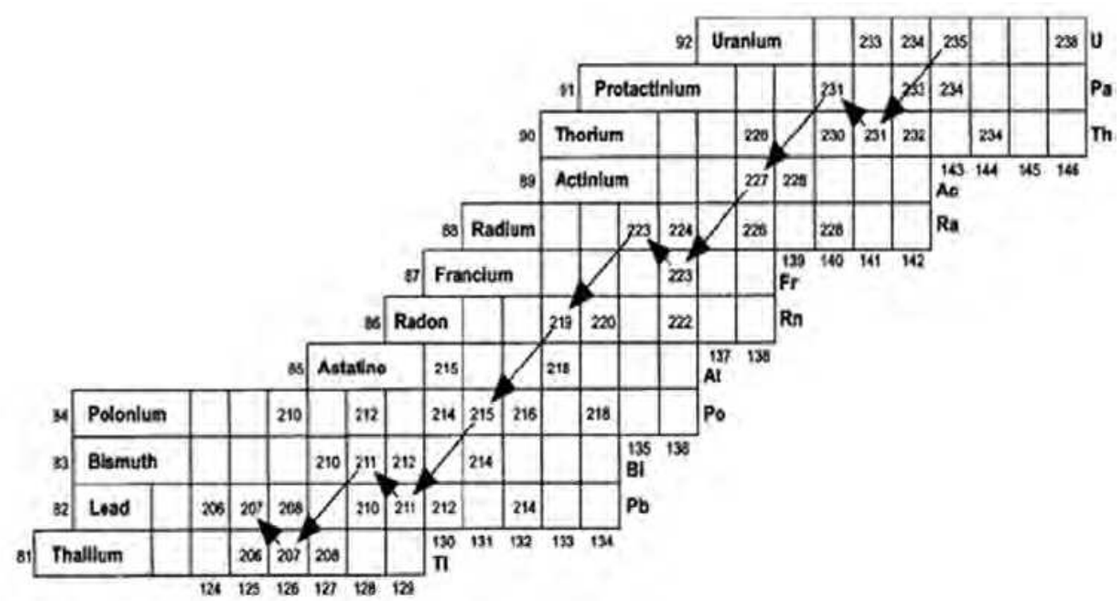

Fig. 2. A schematic diagram of Uranium-235 series (actinium).

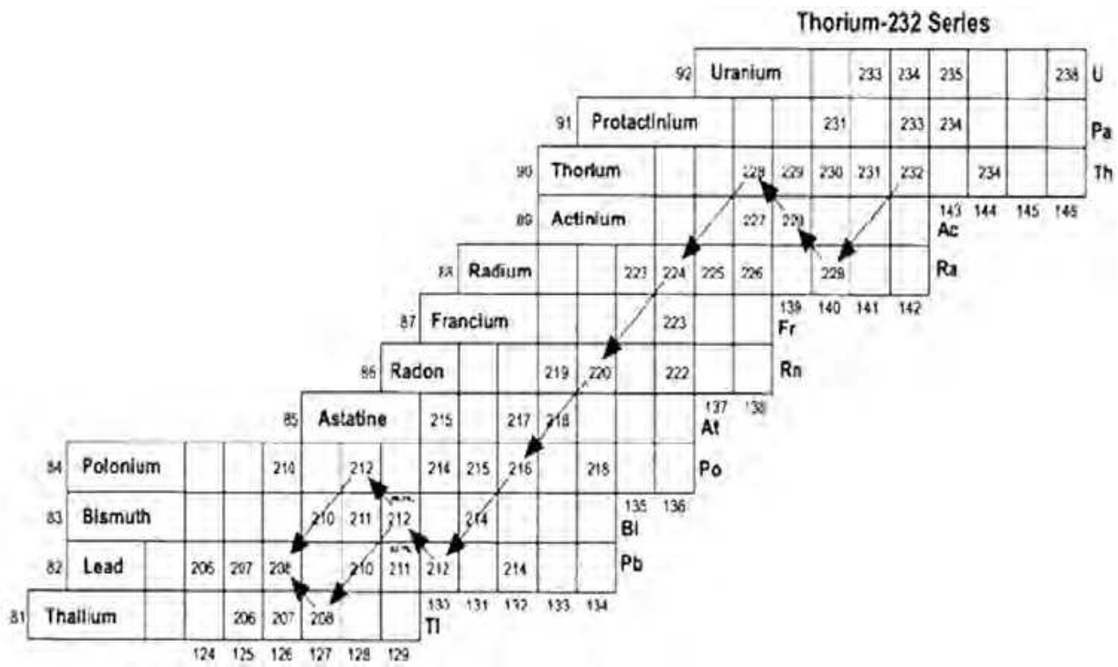

Fig. 3. A schematic diagram of the Thorium-232 series.

2.1.4 Potassium radionuclide

In 1905, J.J. Thompson discovered the radioactivity in ^{40}K is what makes everybody radioactive, it is present in body tissue. This radionuclide can be decayed by three general modes:

a. Positron emission.
b. K- electron capture.
c. Beta emission.

In first mode, ^{40}K radionuclide disintegrates directly into the ground state of ^{40}Ca by the emission of Beta- particle of energy 1321 keV in probability of 88.8% of the decays and no gamma emission is associated with this type of formation (Podgorsak, 2005).

Through the second mode, ^{40}K nuclide can be transformed into stable state (ground state) of ^{40}Ar by two ways, in the first one, ^{40}K disintegrates directly with one jump into ground state of ^{40}Ar with sixteen hundredths of the decays go by electron capture. In the second way, ^{40}K nuclide can be decayed indirectly into the ground state of ^{40}Ar by two stages. firstly, ^{40}K decay into the first excited state of ^{40}Ar. Secondly, the excited nuclide ^{40}Ar, decayed into ground state, accompanied by gamma radiation of 1460 keV energy in probability of 11% of the ^{40}K atoms undergo this change. In the last one (beta emission), a proton will be decayed into positron and ^{40}K changed into ^{40}Ar by probability of 0.0011%.

2.2 Biological effects of radiation

The study of the biological effects of radiation is a very complex and difficult task for two main reasons.

1. The human body is a very complicated entity with many organs of different sizes, functions, and sensitivities.
2. Pertinent experiments are practically impossible with humans.

The existing human data on the biological effects of radiation come from accidents, through extrapolation from animal studies, and from experiments in vitro. How and why does radiation produce damage to biological material? To answer the question, one should consider the constituents and the metabolism of the human body. In terms of compounds, about 61 percent of the human body is water. Other compounds are proteins, nucleic acids, fats, and enzymes. In terms of chemical elemental composition, the human body is, by weight, about 10 percent H, 18 percent C, 3 percent N, 65 percent 0, 1.5 percent Ca, 1 percent P, and other elements that contribute less than 1 percent each. To understand the basics of the metabolism, one needs to consider how the basic unit of every organism, which is the cell, functions.

The understandings of natural radiation concepts are essential for radiation protection purpose. The presences of radionuclides in soil affect the common people immensely. Since, the natural radionuclides form 10% of the average annual dose to the human body from all other types of radiation (UNSCEAR, 1993) and exposure to ionizing radiation, in generally considered undesirable at all levels.

Researchers drew attention to the low level exposure; there are three ways, through which the radio nuclides enter the human body: (1) direct inhalation of air born particulates, (2) ingestion through the mouth and (3) entry through the skin (Dipak et al., 2008). Direct exposure to skin is also responsible for radioactive contamination. Some of radionuclide which inters the lung by inhalation affects the blood. Their effectiveness, depend primarily upon two factors:

1. Kind of the radionuclide.
2. Physiological of the exposed person

The effects of radioactive in take depend upon the physical and chemical form and the root through which the radionuclide inter the body. These effects may cause damage to genetic organs, and eye defects and skin smear and destroy the circulatory system and lung cancer.

Exposure to low radiation ray lead to somatic infirmities like cancer and genetic defects such as mutation and chromosome aberrations. Gene modifications may result such conditions and diseases as asthma, diabetes, anemia. Genetic changes are passed on from one generation to another (Gerrado, 1974).

When people are exposed to certain levels of ^{238}U, ^{232}Th and ^{40}K for a long period of time cancer of the bone and hazard cavity may result (Nour, 2004). When radium inters the body by ingestions and inhalation, its metabolic behavior in similar to that of calcium faction of it will be deposited in bone where the remaining fraction being distributed uniformly in the soft tissues, thus the most radiotoxic and most important, among the several radionuclide in the radioactive decay chain the two natural series of uranium and thorium are ^{226}Ra and ^{228}Ra. The biological radiation effectiveness can be dividing into two types:

2.2.1 Body effectiveness

Cell is the basic unit of living tissue. Cells are complex structures enclosed by a surface membrane. DNA (deoxyribonucleic acid) is existed in the central of nucleus and considered as code of the structure, function, and replication of the cell. The famous "double helix" of the DNA molecule has a diameter of about (2nm). The induction of cancer or of hereditary disease by low levels of ionizing radiation is believed to be related to damage of the DNA molecules. This can be happen direct by ionization of the molecule, or indirectly through ionization of the water molecules in the cell (Cottingh and Greenwood, 2001). A single broken start and of DNA is rapidly repaired by cellular enzyme system, the unbroken strand of the DNA acting as template.

The water represents nearly 80% of the human body. When a body exposed to an ionized radiation, the large effect will be happened on the water molecules. The break up of water molecule may Produce ($.OH^{-}.$) on that is highly reactive chemically and may attack the DNA molecule.

If, at the same time, there is adjacent damage to the other cell that may be errors in the repair process. The cell may die or damage to cell which cause later uncontrolled cell division. The incident radiation on the body, the water molecule will be ionized the water molecule and free electron will be liberated. The mechanism of this process can be summarized in the following equations.

$$H_2O \longrightarrow H_2O^{+} + {}^{-}e$$

(^{-}e) is called dried electron, its energy proportional with the incident radiation energy. This dried electron will be losses its energy through its path in the body and caused some ionizing and excitation of other atoms and nuclides.

At low energy some water molecules shall be capture these dried electrons produced water electron which denoted by e- symbol. The velocity of water electron e- in the human cells is less than of dried electrons by factor of 105 times (Podgorsak, 2005).

The water positive ion (H_2O^{+}) will be interacts with the free Hydrogen according to the following equation:

$$H_2O^{+} + H_2O \longrightarrow {}^{\bullet}OH + H_3O^{+}$$

The water electron e- will be interacting with H_3O^{+} reduced water and free hydrogen root ($H^{\bullet}$):

$$^{-}e + H_3O^{+} \longrightarrow H_2O + H^{\bullet}$$

It is found that the effectiveness of free hydroxyl root five times of that of free hydrogen root. This free root will be interacting with the organic molecules and other constituent of the cell causing change in their chemical properties which leads to distortion in their functions which may be lead to death. The effect degree of ionizing radiation depends on the type, energy and intensity of radiation and exposure time. The body effective classified into two types:

2.2.2 The early effectiveness

The germ cells in human are the most sensitive in the body if they exposed to radiation, in a dolts these cells presents in double number as compared with children in infancy this increase related to cell division and generation of completely similar new cells.

During division there are spindle-like particulars cells as chromosomes that reveal a hung number of granulated particles with a special arrangement called as genes the later are the responsible for the individually inherited character. the destruction or change of the geneses or chromosomes many reveal a character that not previously present in parents this change called as genetic mutation .

Radiation will increase the probability of occurring of genetic mutation and childhood abnormalities or infection with certain genetic discuses. If the divided cell exposed to radiation, these cells may undergo abnormal cell division, in the same time these cells may have the capacity proof reading of genetic mistakes that faced with hence may repair any

Biological disturbance. The radiation in this harm, but in accordance, they have new characters that may transform to embryos ending with exposed obvious genetic mutations. These genetic mutations not always harmful, in contrast, may result in favorable characters like the gain a good quality fruits in shape or size in the same time, animal's cell if exposed to genetic mutation may result in improved characters.

This type take place when the whole body expressed to radiation for high dose through short time some results can be appear in a few days or weeks, likes, reducing in weigh change in the blood cells hair loss and redness of the skin, and sometime the death is probable.

3. Experimental study

3.1 Gamma spectrometer

In this study we used gamma spectroscopy to determine the ^{238}U, ^{232}Th and ^{40}K in surface soil layer around the uranium mine at Najaf city.

Gamma spectroscopy is one of many famous techniques are used to measure the NORMs contents in the different environmental elements. It has many advantages such as high accuracy, measure wide energy range and different type samples and not need a chemical method in sample preparation. Beside these advantages gamma spectrometry of NORM is still difficult for a number of reasons. First, the activity levels are low and, if statistically significant results are to be obtained, need long count periods, ideally on a gamma spectrometer whose construction and location are optimized for low activity measurements. The second difficulty is the matter of spectrometer background (i.e. a large number of peaks that one might see in background spectra). Many of these are due to the NORM nuclides in the surroundings of the detector. Any activity in the sample itself must be detected on top of all that background activity. In many cases, it will be necessary to make a peaked-background correction in addition to the normal peak background continuum subtraction. All of those difficulties are then compounded by the fact that there are a large number of mutual spectral interferences between the many nuclides in the decay series of uranium and thorium.

The gamma rays levels were measured by integral counting using a spectrometer consist of a scintillation detector NaI(Tl) of $(2'' \times 2'')$ crystal dimension with resolution value of 6.48% for line energy of 662 keV, scalar, shielding and specially designed sample container that allowed the sample to surround the scintillation detector at the top and on the sides. This system was computer controlled. The detector was connected to the amplifier through preamplifier unit; an analog to digital converter (ADC) of 4096 channels was assembled to the system. The spectroscopic measurements and analysis were performed via the CASSAY software into the PC of the laboratory.

In order to reduce the background radiation due to different radiation hazard, the detector was maintained in vertical position and shield by a cubic chamber of two layers starting with copper of 2mm thick followed by lead of 10 cm thick. The cosmic rays, photons and electrons, are reduced to a very low level by the 10 cm of lead shielding. This interaction will produced x-ray with low energy which can be suppressed by the copper layer (Aziz, 1981). The x-rays can be also come from radioactive impurities like antimony in the lead.

The spectrometer was calibrated for energy by acquiring a spectrum from radioactive standard sources of known energies like ^{60}Co (1332 keV, 1773 keV) and ^{137}Cs (662 keV). To measure the counting efficiency of the system, ^{22}Na, ^{57}Co, ^{60}Co, ^{109}Cd, ^{133}Ba and ^{137}Cs

standard sources of gamma rays were used (Table 2). The relative intensities of the photo-peaks corresponding to their gamma rays lines have been measured.

Isotope	E (keV)	I %	Isotope	E (keV)	I %
^{22}Na	1274.5	99.95	^{133}B	80.99	34
^{57}Co	122.1	85.6		276.39	7.16
	136.4	10.88		302.85	18.3
^{60}Co	1173.2	99.97		356	62
	1332.5	99.98		383.85	8.9
^{109}Cd	88.03	3.6	^{137}Cs	661.6	85.1

Table 2. Energies and transition probabilities of standard sources (Heath, 1997)

3.2 Study area and sampling

Twenty five soil samples were collected in area of approximately 40000 m^2, located around the uranium mine at Najaf governorate. The latitude and longitude of this area are 31^o 52′ 254″ N and 22^o 26′ 221″ E. We used systematic grid sampling system involves subdividing the area of concern by using a square and collecting samples from the nodes (intersections of the grid lines). The origin and direction for placement of the grid is done, where the mine was centred in grid. From that point, a coordinate axis and grid is constructed over the whole site. The distance between sampling locations was 50 m (Figure 4). Systematic grid sampling is often used to delineate the extent of contamination and to define contaminant concentration gradients (IAEA, 2004).

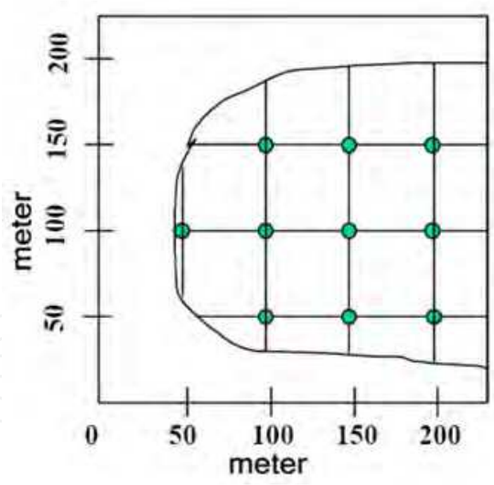

Fig. 4. Systematic grid sampling method

In order to measure the NORMs in soil surface, 25 soils samples were collected, one sample average from each point, was taken by digging a hole at a depth of 35 cm before the ground surface. The soil texture for all samples was very similar. The collected samples were transferred to labeled closed polyethylene bags and taken to the laboratory of radiation detection and measurement in the physics department, collage of science, university of Kufa. In this work a 1.4 litter polyethylene marinelli beaker was used as a sampling and measuring container. Before use, the containers were washed with dilute hydrochloric acid

and rinsed with distilled water. The soil samples were prepared for analysis by drying, sieving and kept moisture free by keeping 24 hours in the oven at 100C°. They were mechanically crushed and sieved through of 0.8 mm pore size diameter sieved to get homogeneity (R2).
To remove completely the air from sample, the later was pressed on by light cap of the marinelli beaker. The respective net weights were measured and record with a high sensitive digital weighting balance with a percent of ±0.01%. After that about 1 kg of each sample was then packed in a standard marinelli beaker that was hermetically sealed and dry weighted. The sample was placed in face to face geometry over the detector for along time measurement.

3.3 Specific activity

The definition of activity refers to the number of transformations per unite time. Since the fundamental unite time is the second the quantity activity is measured in disintegrations per second or (dps). In 1950, the international joint commission on standards Unit and constants of radioactivity define the curie by accepting 37 billion dps as curie of radioactivity regardless of its source or characteristics. The SI derived unit of activity is the Becquerel (Bq) and is that quantity of radioactive material in which one atom is formed per second or under goes one disintegration per second (1 dps).
The activity of ^{238}U was estimated from the 1765 keV gamma transition energy of ^{214}Bi (17% possibility). Also the activity of ^{232}Th was measured from the 2614 keV gamma transition energy of ^{208}Tl (100% possibility) whereas ^{40}K activity was determined using the 1460 keV gamma ray line (10.7% possibility) (Vosniakos, 2003).
The specific activity is defined as activity per unite mass of radioactive substance and the reported in units such as Curie per gram or Becquerel per kilogram (Bq/kg). The specific activity of each radionuclide was calculated using the following equation (UNSCEAR, 2000).

$$A = \frac{A'}{\varepsilon \cdot I_{\gamma} \cdot m \cdot t}$$

Where A the specific activity of the radionuclide in Bq/kg, A' the liquid count, ε the counting efficiency, I_{γ} 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.

3.4 Radium equivalent activity

To represent the activity levels of ^{238}U, ^{232}Th and ^{40}K which take into account the radiological hazards associated with them, a common radiological index has been introduced. This index is called radium equivalent activity (Ra_{eq}) and is mathematically defined by (UNSCEAR, 2000).

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

Where A_U, A_{Th} and A_K are the specific activities of Uranium, Thorium, and potassium respectively. This equation is based on the estimation that 10 Bq/kg of ^{238}U equal 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produced equal gamma dose. The maximum value of Ra_{eq} must be less than 370 Bq/kg. Also the Ra_{eq} value of 370 Bq/kg is equivalent to the annual dose

equivalent of 1.5 mSv/y, which we assumed to be the maximum permissible dose to human from their exposure to natural radiation from soil in one year.

3.5 Absorbed does rate in air

Absorbed dose rate defined as the ratio of an incremental dose (dD) in a time interval (dt).

$$AD = \frac{dD}{dt}$$

Gamma dose rate in air, one meter above the ground, is used for the description of terrestrial radiation, and is usually expressed in nGy/h or pGy/h. the absorbed dose rate due to gamma radiation of naturally occurring radionuclide (^{238}U, ^{232}Th, and ^{40}K), were calculated on guidelines provided by (UNSCEAR, 2000).

$$AD(nG/h) = 0.462A_U + 0.621A_{Th} + 0.0417A_K$$

Where 0.462, 0.621 and 0.0417 are the conversion factors for ^{238}U, ^{232}Th and ^{40}K assuming that the contribution natural occurring radionuclide can be neglected as they contribute very little to total dose from environmental background.

3.6 Annual effective doses

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. In the UNSCEAR 1993 Report, the Committee used 0.7 Sv.Gy/y 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. These values are retained in the present analysis. From the data summarized in this Chapter, the components of the annual effective dose are determined as follows: (UNSCEAR, 1993).

Indoor (nSv) = absorbed dose nGy/h × 8760 h × 0.8 × 0.7 SvG/y

Outdoor (nSv) = absorbed dose nGy/h × 8760 h × 0.2 × 0.7 SvG/y

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.

3.7 Hazard index

To reflect the external exposure, a widely used hazard index, called the external hazard index (H_{ex}), which is defined as following:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

There is another hazard index called internal hazard index (H_{in}), which is given by equation.

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

The values of the index must be less than the unity in order to keep the radiation hazard to be insignificant unity corresponds to the upper limit of radiation equivalent activity (370 Bq/kg).

4. Results and discussion

The spectra of twenty five surface soil samples surrounded the abandoned Uranium mine hole have been analyzed. The specific activity of ^{238}U, ^{232}Th, ^{40}K and Radium equivalent activity (Ra_{eq}) are given in Table 3. The specific activity (Bq/kg) varied from 37.31 to 1112.47 (mean = 268.16), 0.28 to 18.57 (mean = 6.68) and 132.25 to 678.33 (mean = 277.49) for ^{238}U, ^{232}Th and ^{40}K respectively.

The obtained results are comparable to the worldwide average recommended by UNSCEAR which are 30, 35 and 400 Bq/kg for ^{238}U, ^{232}Th and ^{40}K respectively (UNSCEAR, 2000). It was found that all values of ^{238}U specific activities are higher than the worldwide average whereas those of ^{232}Th are less than it. For ^{40}K, it is clear that the specific activities, with the exception of five samples, are found to be less than worldwide average.

Obviously demonstrate that the minimum and maximum specific activity values of ^{238}U are least by factor of 4 and 37 higher than the corresponding values obtained worldwide average. The large variation between the specific activities obtained for ^{238}U and other two radionuclides can be easily ascribed to the high content of uranium in the neglected waste of drilling and exploration operations on the surface soil surrounding the mine. The contour maps (radiological maps) of the activity distribution of ^{238} U, ^{232}Th and ^{40}K in the study area are shown in Figures 5, 6 and 7. From Figure 5, we can observe three regions with a highest specific activity values of ^{238}U situated at northeast, east and south-west portions of the hole mine. In contrast, Figure 7 indicates that high concentrations of ^{40}K occupies the same positions of ^{238}U while for ^{232}Th there are no placements have activities require attention as shown in Figure 6.

The calculated Ra_{eq} values for all samples were also presented in Table 3. It may be seen that Ra_{eq} oscillates between 52.727 and 1189.845 with an average of 299.09 Bq/kg. It is observed that the values of Raeq in twenty one samples were less than the acceptable safe limit of 370 Bq/kg (OECD, 1979; UNSCEAR, 1982; UNSCEAR, 1988). As shown in Table 3 there are four values greater than worldwide average. As a rule, the matter whose Ra_{eq} exceeds 370 Bq/kg is discouraged (Beretka and Mathew, 1985). Figure 8 demonstrates the distribution of Ra_{eq} and it appears three positions have highest values.

The calculated absorbed dose rate of samples was listed in Table 3. As shown in Table 3, the values ranged from 25.02 to 553.01 with an average value of 139.61 nG/h which is nine fold higher than the world average of 15 nG/h recommended by UNSCEAR (UNSCEAR, 2000). It can be seen that all values were much higher than the world average.

Sample code	specific activity (Bq/kg)			Ra_{eq} (Bq/kg)	AD nG/h
	^{238}U	^{232}Th	^{40}K		
S11	72.17±4.43	3.38±0.69	253.19±8.79	96.49	46.00
S12	59.37±4.02	0.28±0.20	184.47±7.51	73.97	35.29
S13	213.24±7.62	5.63±0.89	238.84±8.54	239.68	111.97
S14	39.76±3.29	0.28±0.20	174.70±7.30	53.61	25.82
S15	480.12±11.43	8.02±1.06	415.06±11.26	523.54	244.10
S21	138.07±6.13	2.81±0.63	176.23±7.34	155.65	72.88
S22	645.42±13.26	10.13±1.19	521.04±12.61	700.02	326.20
S23	312.64±9.23	6.47±0.95	409.87±11.19	353.45	165.54
S24	249.18±8.24	4.08±0.76	283.43±9.30	276.83	129.47
S25	37.31±3.19	3.66±0.72	132.25±6.36	52.72	25.02
S31	122.82±5.78	2.39±0.58	153.63±6.85	138.06	64.63
S32	285.95±8.82	12.94±1.35	219.60±8.19	321.36	149.30
S33	122.82±5.78	5.35±0.87	153.52±6.85	142.29	66.46
S34	273.97±8.64	6.47±0.95	211.96±8.05	299.54	139.43
S35	78.43±4.62	4.08±0.76	232.12±8.42	102.13	48.44
S41	142.43±6.23	4.92±0.83	205.85±7.93	165.31	77.44
S42	324.07±9.39	7.03±0.99	264.49±8.99	354.48	165.11
S43	860.29±15.31	13.65±1.39	678.33±14.39	932.04	434.21
S44	175.38±6.91	3.80±0.73	229.67±8.38	198.49	92.96
S45	1112.47±17.41	18.57±1.62	459.96±11.85	1189.84	553.01
S51	167.48±6.75	7.32±1.01	302.06±9.60	201.20	94.51
S52	276.69±8.68	10.41±1.21	156.98±6.92	303.66	140.84
S53	139.16±6.16	7.32±1.01	158.21±6.95	161.81	75.43
S54	85.78±4.83	7.88±1.05	201.27±7.84	112.54	52.91
S55	288.94±8.87	10.27±1.20	320.38±9.89	328.29	153.22
Min.	37.31	0.28	132.25	52.72	25.26
Max.	1112.47	18.57	678.33	1189.84	553.01
mean	268.16	6.68	277.49	299.09	139.61

Table 3. Specific activity, Radium equivalent activity and absorbed dose rate of soil samples.

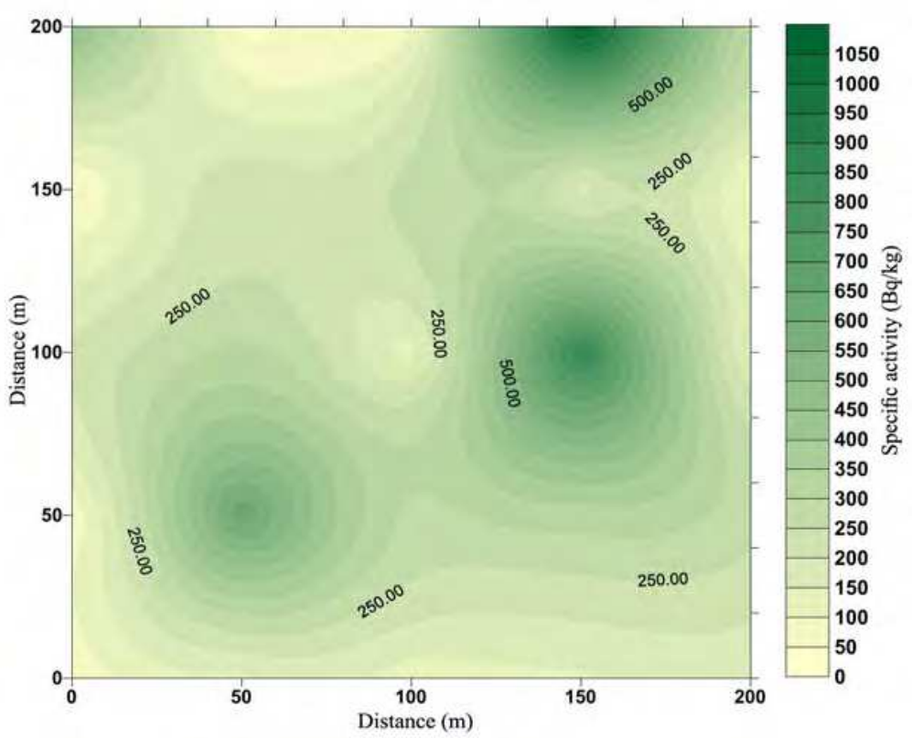

Fig. 5. Specific activity distribution of ^{238} U.

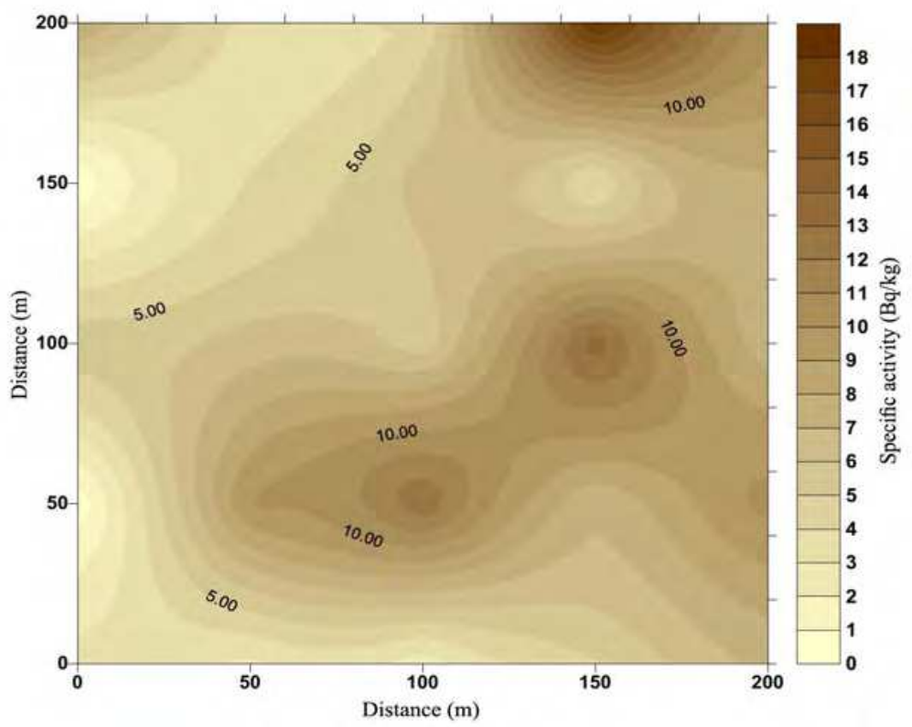

Fig. 6. Specific activity distribution of ^{232}Th.

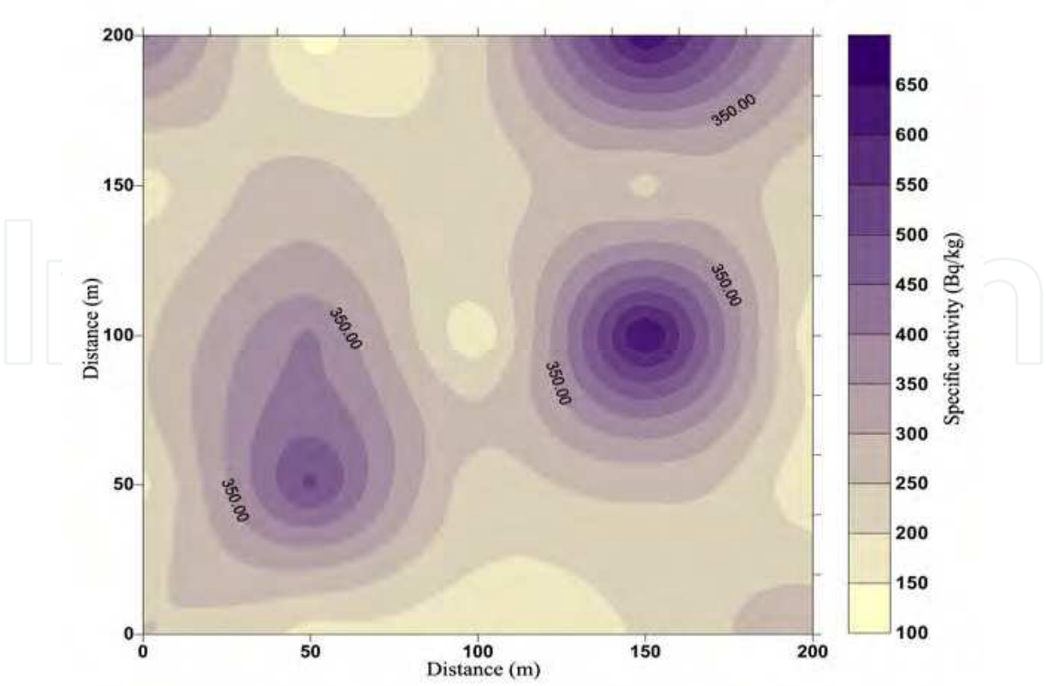

Fig. 7. Specific activity distribution of ^{40}K.

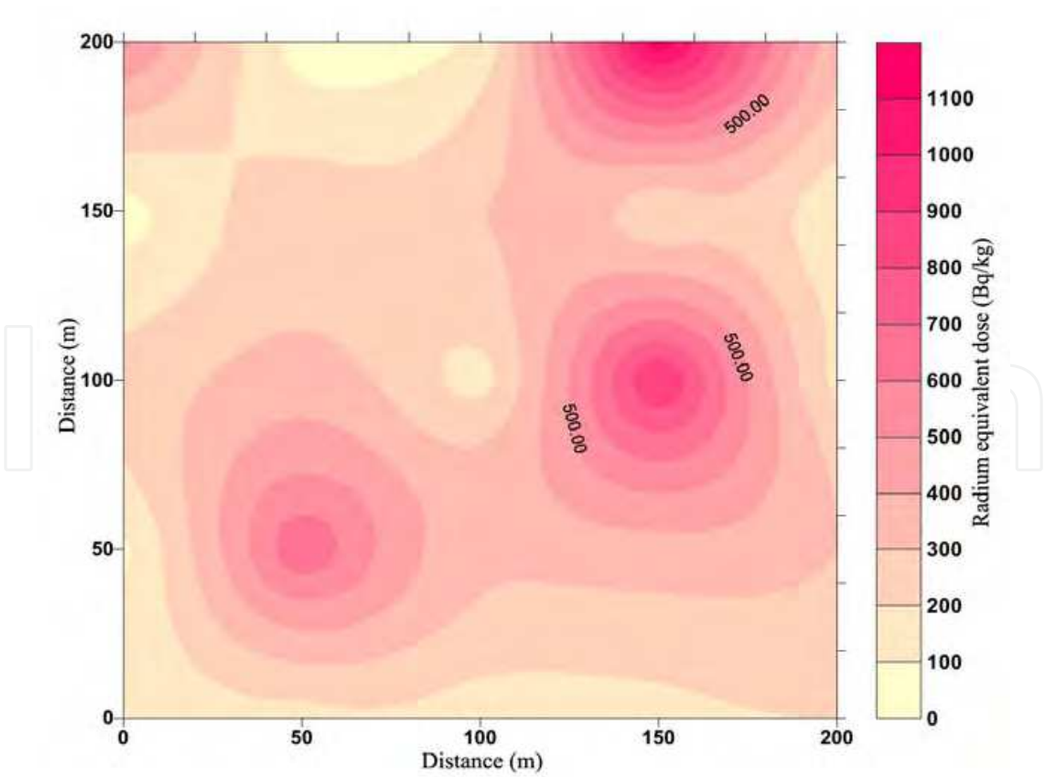

Fig. 8. Distribution of Radium equivalent in surface soil around mine.

The annual effective dose values were calculated and listed in Table 4. They were found to be in the range 0.123 to 2.713 mSv/y with an average value 0.68 mSv/y and from 0.031 to 0.6780 with an average value of 0.17 mSv/y for indoor and outdoor annual effective dose respectively. In general and as shown in Table 4, for indoor annual effective dose, It is important here to notice that there are fourteen sample have values higher than the word average whereas, the values of the rest samples are close or slightly above of the world average value of soil. In other words, all values of outdoor annual effective dose were below the worldwide average.

Sample code	Annual dose (mSv)		Hazard index	
	indoor	outdoor	H_{ex}	H_{in}
S11	0.22	0.05	0.26	0.45
S12	0.17	0.04	0.20	0.36
S13	0.54	0.13	0.64	1.22
S14	0.12	0.03	0.14	0.25
S15	1.19	0.29	1.41	2.71
S21	0.35	0.08	0.42	0.79
S22	1.60	0.40	1.89	3.63
S23	0.81	0.20	0.95	1.80
S24	0.63	0.15	0.74	1.42
S25	0.12	0.03	0.14	0.24
S31	0.31	0.07	0.37	0.70
S32	0.73	0.18	0.86	1.64
S33	0.32	0.08	0.38	0.71
S34	0.68	0.17	0.81	1.55
S35	0.23	0.05	0.27	0.48
S41	0.38	0.09	0.44	0.83
S42	0.81	0.20	0.95	1.83
S43	2.13	0.53	2.51	4.84
S44	0.45	0.11	0.53	1.01
S45	2.71	0.67	3.21	6.22
S51	0.46	0.11	0.54	0.99
S52	0.69	0.17	0.82	1.56
S53	0.37	0.09	0.43	0.81
S54	0.26	0.06	0.30	0.53
S55	0.75	0.18	0.88	1.66
Min.	0.12	0.03	0.14	0.24
Max.	2.71	0.67	3.21	6.22
Mean	0.68	0.17	0.80	1.53

Table 4. Annual effective dose and hazard indexes of soil samples.

The international commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1 mSv/y for the individual members of the public and 20 mSv/y for the radiation workers (ICRP, 1993). The worldwide average annual effective dose is approximately 0.5 mSv and the results for individual countries being generally within the 0.3 to 0.6 mSv range (UNSCEAR, 2000).

In addition, the calculated values of hazard index for the soil samples were ranged from 0.142 to 3.216 with an average value of 0.808 and from 0.243 to 6.222 with an average value of 1.533 for external (H_{ex}) and internal (H_{in}) respectively as mentioned in Table 2.
Out of 25 positions, 4 for H_{ex} and 13 for H_{in}, have values very higher than unity. Since these values are dispersed randomly within a limited area around the min hole, therefore, according to the report of European Commission in Radiation Protection, the area study is not safe and posing significant radiological threat to the population (European Commission, 1999).

5. Conclusion

The surface soil layer around the uranium mine hole has uranium activities greater than worldwide average; this can mainly due to the waste of drilling and exploration left on the surface layer of soil surrounding the mine.
The thorium activities were within normal level in the studied area. Generally, potassium radionuclide in soil samples was in the range of worldwide average.
The absorbed dose rates of studied area are higher than the criterion limit of gamma radiation dose rate with an average of nine times.
Finally, from the radiation protection point of view the studied area is considered to be not safe inhabitants because the values of both internal and external hazard indexes associated with the samples are higher than unity. Thus, the human inside the area are supposed to acquire radiological complication.

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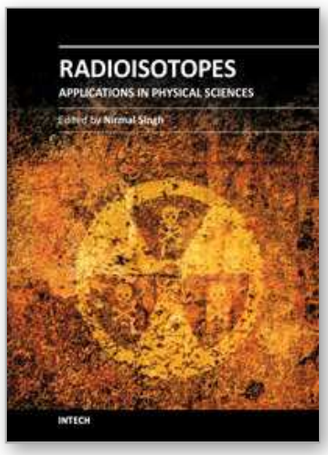

Radioisotopes - Applications in Physical Sciences

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The book Radioisotopes - Applications in Physical Sciences is divided into three sections namely: Radioisotopes and Some Physical Aspects, Radioisotopes in Environment and Radioisotopes in Power System Space Applications. Section I contains nine chapters on radioisotopes and production and their various applications in some physical and chemical processes. In Section II, ten chapters on the applications of radioisotopes in environment have been added. The interesting articles related to soil, water, environmental dosimetry/tracer and composition analyzer etc. are worth reading. Section III has three chapters on the use of radioisotopes in power systems which generate electrical power by converting heat released from the nuclear decay of radioactive isotopes. The system has to be flown in space for space exploration and radioisotopes can be a good alternative for heat-to-electrical energy conversion. The reader will very much benefit from the chapters presented in this section.

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