Natural Radioactivity and Radiological Implications of Stream Sediments at Wadi Aidib Area, South Eastern Desert, Egypt

Moustafa B. Bayoumi1,*, Osama A. Ebyan1, Abdelhay M. El Shafey1 and Mohamed Hassan1

1 Nuclear Materials Authority, P.O. Box 530, El Maadi, Cairo, Egypt
* Correspondence: moustafanma@yahoo.com

Abstract

Wadi Aidib lies at the extreme southern part of the Eastern Desert, Egypt, between 22°15'-22°21' N and Longitudes 36°20'-36°30' E. Landsat ETM+ false color composite image (bands 3, 2, 1) was used for regional discrimination for different rock types and provide an excellent base map for the study area, morphological features of the stream deposits of the study area were known from Landsat ETM images, in addition to several field observations. The studied stream sediments accumulate in the form of alluvial fans. They are mainly composed of sands, gravels, boulders and contain some heavy valuable minerals which are derived from metavolcanics, metasediments, quartz diorite, biotite and alkali feldspar granites. Heavy liquid separation and magnetic separation techniques in addition to microscopic examination for the studied stream sediment samples were applied to identify the heavy minerals in these sediments. These minerals are represented by magnetite, ilmenite, rutile, garnet, zircon, monazite and Green silicates. The distribution of some elements in the study area is clear that they are concentrated near the outcrops of granites. The radionuclide concentrations were measured in different stations using a calibrated gamma-ray portable detector (RS 230) and the heavy minerals causing radioactivity were separated by heavy liquids and determined by binuclear and environmental scanning electron microscopes. Uranium ranges between 5.25 and 32.05 ppm with an average of 16.63 ppm, Th between 4.4 and 17 ppm with an average and potassium fall between 1.8 and 5.15% with an average of 3.4 %. Correlation between soil radioactivity and its mineralogical content indicate that the high radionuclides contents are mainly attributed to the presence monazite which is the principal source of both uranium and thorium. Uranium high concentrations could be related to the metamict zircon. Absorbed Dose Rate (D), annual effective dose equivalent radium equivalent activity, external and internal hazard index, in addition to activity gamma index caused by gamma emitting natural radionuclide are determined from the obtained values of 238U, 232Th and 40K. Fairly, some of the studied stations do not satisfy the universal standards. 40K plays the main and most important role in dose rate contribution.

Keywords: Wadi Aidib; Heavy minerals; Gamma-ray; Uraniferous rocks and dose rate

1. Introduction

The Precambrian basement of the Arabian Nubian Shield, is exposed in Egypt in the Eastern Desert, southern part of Sinai Peninsula and the south western corner of the Western Desert. The study area is

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situated in the Halaib district, South Eastern Desert, along the Red Sea coast. This area is located at Abu Ramad City on the coastal highway. The source of investigated stream sediments is generally from the moderate to high relief, where its highest peaks are Gabal Elba (557m.a.s.l). Main Wadis dissecting the area are Wadi Aidib and Wadi Yoider. They all drain eastwards towards the Red Sea. On the other hand, few mineralogical studies were conducted on the Egyptian Red Sea coastal plain sediments. (Dabbour, 1999) threw the light on the presence of heavy minerals concentration on the Red Sea beach in the area between Halaieb and Shalateen. The present study will discuss the sediments composing the one of the important wadis at Gabal Elba area on the southern part of the Egyptian Red Sea with special emphasis on the heavy minerals content. The radioactive mineralizations of the Egyptian Eastern Desert have been studied by many authors (El Ghawaby, 1973; El Shazly and El Ghawaby, 1974; El Kassas, 1974; Ammar et al., 1991; Ammar, 1997; Ramadan et al., 2004; Bayoumi., 2011; Abu Halawa et al., 2010; El Afandy et al., 2011 and El Afandy et al., 2012. The rocks and sediments in the Earth's crust have variable contents from radionuclides with long half-lives, such as $^{40}$K, $^{238}$U, and $^{232}$Th. The activity of these radionuclides is the main reason of natural radiation. Determination of the activity levels of the radionuclides in the soils, waters, local vegetation, and air of a region may help in determination of the natural radioactivity in the study area. Soil is considered one of the principal sources of radiation exposure to human and non-human populations by the transfer of radionuclides into the environment (Ahmad et al., 2015; Durusoy and Yildirim, 2017). The highest levels of activity concentrations in soils were firstly recorded in Brazil, India and China (UNSCEAR, 1993a and 1993b). It is attributed to high concentrations of radioactive minerals in the soil of high radiation levels. Monazite is one of these minerals, a non-high-soluble rare earth mineral that is found in the sands of the beach with ilmenite. Radionuclides in monazite are mainly of 232Th series, but there are also some lower contents of uranium and radium (Moustafa, M. I.; Abdelfattah, N. A., 2010 and Moustafa, M.I., 2010. On the other hand, the soil works as a medium for migration for transfer radionuclides to the biological system, and therefore, it is the primary indicator of radioactive contamination in the environment. Natural radionuclides in river sediments generate important elements of background radiation exposure of the population. The studied area lies at the extreme southern part of the Eastern Desert, Egypt, between 22° 15' - 22° 21' N and Longitudes 36° 20' - 36° 30' E, (Fig.1). The studied stream sediments accumulate in the form of alluvial fans. They are mainly composed of sands, gravels, boulders and contain some heavy valuable minerals which are derived from metavolcanics, metasediments, quartz diorite, biotite and alkali feldspar granites. This work aims to determine the natural radioactivity in different stations from Wadi Aidib area and their environmental impacts. The morphological features of the stream deposits of the study area were known from Landsat ETM image, in addition to several field observations. Landsat ETM+ false color composite images (bands 3, 2, 1), was used for regional discrimination for different rock types and provide an excellent base map for the study area. Because of deformation, these rocks exhibit shearing, dissolution and grain reduction features. The emplacement of the studied granitic rocks occurs at the intersection of major reactivated Precambrian NE-SW and NW-SE deep - seated tectonic zones. Moreover, the deformed fragments were transported with the drainage of wadis towards the sea and recognized from the Landsat ETM+ images and field verification, as pal green to yellowish colors in RGB more ever the granitic rock shows redish colors. Fig. 2 proved to be also useful in the discrimination between different rock unites. The basic rocks are displayed as reddish color graded according to the types and the mineral composition of rocks. The metavolcanic rocks are displayed by blue color, while granitic rocks indicated by violet colors. The wadi sediments and alluvial deposits appear as pale blue colors in RGB.
Fig. 1. Location map of the study area

Fig. 2. False color composite image FCC, (band 3, 2, 1) in RGB of study area
2. Sampling and Analytical Procedure

The study area is 10 Km long and 3 Km width. Nine samples were collected from Wadi Aidib at a depth of one meter and with a distance between samples about 1000 m (Fig. 3 A and B). The concentration and separation of economic heavy minerals using ore dressing techniques are the closest to reality, cheapest, fastest, and least dangerous to human health compared with the laboratory (heavy liquid) techniques. The nine representative samples were weighted and poured inside a calibrated cylinder and compacted well by shaking to be analogous to the field deposit. The weight of the sand was divided by its volume to obtain the apparent specific gravity (Reedman, 1979). Each field sample was split into two halves using John's Splitter. One of them was kept as a reference sample and the second was subjected to splitting again to obtain a representative sample weighing about 50 grams for the different analyses while the rest was used as composite sample. Each composite sample was quartered by rotary splitter to a proper weight (about 50 gm). The quartered samples were weighed, and then washed with water, followed by decantation to get rid of slimes and salts. About 5ml of ammonium hydroxide was added for the disaggregation of the clay particles. Samples with organic matter were treated with few drops of hydrogen peroxide 30%. The treated samples were sieved and washed several times using 50μ screen to determine the amount of slime. Both the oversize and the undersize fractions were dried and weighted. The slime free fraction was separated using bromoform (Sp. gr. 2.89) into heavy and light fractions. Methylene Iodide (specific gravity of 3.3 gm/cm3) was used to reduce the size of the obtained heavy fraction by the separation of the light-colored silicates in the float sub-fraction while the dark colored silicates as well as the heavy economic minerals were sunk. A hand magnet was used to separate magnetite from the heavy Methylene Iodide fraction. The individual magnetite free samples were treated by laboratory Frantz Isodynamic Magnetic Separator Model (L-1) with longitudinal slope of 20°, side slope 5° and at ampere values of 0.2, 0.5, 1.0 and 1.5. Then, five fractions were obtained. Each fraction was weighted and about 1000 grains were counted under the binocular microscope. Binocular and optical microscope, Environmental Scanning Electron Microscope (ESEM) performed detailed mineralogical investigation and identification. A Philips (XL30) ESEM, equipped with an energy dispersive X-ray spectrometer (EDX), was used for scanning electron micrographs of the surface features of economic minerals. In addition, semi-quantitative (EDX) were performed for determination of the chemical composition of the economic minerals. All analyses were carried out in the laboratories of the Nuclear Materials Authority, Egypt.

Fig. 3. A and B, photographs shows manuals procedures for sampling at the study area
3. Drainage Patterns

Geomorphologically, the area is characterized by four main categories namely Red Sea mountains, moderate isolated hills, conical low hills, wadi deposits, sand dunes, coastal plain (fans) and beach sand. The most important mountains within the area are Gabals: El Sela, Qash Amer, Elba and Shendib. The area is traversed by many wades, the most important of them are, wadi Eishimhai, wadi EiKwan and wadi Yoider, Diit, Sarmati and Wadi Aidib. Drainage systems follow patterns of water flow and network connection that is influenced mainly by geologic structures, surficial processes, terrain properties and rainfall behavior. These patterns often reflect a normal stable condition of the terrain surface on which they developed. However, in many instances, drainage patterns exhibit anomalies in their orientation as a result of subsequent events and processes, (Fig. 4).

4. Geologic Setting

Precambrian basement rocks, developed during the Pan African tectono-thermal event of 950-550 Ma. (Kroner et al., 1984). Geological studies using Landsat ETM+ images and field investigation revealed that the study area is mainly covered by Sol Hamid ophiolitic ultramafic rocks, intermediate metavolcanics, intrusive gabbros, granodiorites, biotite granites, monzogranites and garnetiferous muscovite granites. These rocks are injected by pegmatitic and quartz veins and cut by acidic and basic dykes. The granodiorites are less abundant and occur in the south eastern part of the study area forming highly weathered isolated hills. They are intruded in the metavolcanic rocks and are in their turn, intruded by biotite granites. They are characterized by exfoliation texture and contain xenoliths of various sizes and compositions.

![Fig. 4. Drainage patterns image for wadies at study area](attachment:image.png)
to coarse-grain crystals, red color, highly weathered surfaces and presence of numerous joints and fractures. These granites are mainly composed of potash feldspars, quartz, and biotite. The accessory minerals are zircon, rutile and opaques. Chlorite, sericite and epidote represent the secondary minerals. The garnetifrous muscovite granites are less abundant and occur only in the south western part of the study area. These granites occur in a series hills, constituting Gabal Elba (1437 m.a.s.l.), according to geological map, (Fig.5) (modified after Nasr et.al. 1994). They are characterized by being medium to coarse grained, pale pink in color, slightly weathered and affected by joints and fractures. The area is cut by many wadis, the most important of them are: wadi Serimtai, wadi Baashoia, wadi Eib, wadi Hibro, wadi Oqhoq, wadi Aideib and wadi Ei Kwan. These wadis represent the receivers of the rain water and the most favorable places to seek the fresh water along (Fig.4). Fig. 6 shows Gabal Elba where consider as Mather source of derived sediments with its mineralogical contents and b, show the volume of alluvial but c and d illustrated the extinctions along the study wadi.

![Fig. 5. Geologic map of Gabal Elba area (modified after Nasr et al., 1994)](image)

5. Mineralogical Investigations

Correlation between soil radioactivity and its mineralogical content was investigated. The high radionuclides contents are mainly attributed to the presence of radio- and rare earth bearing monazite which is the main source of thorium, and rare earth elements. In the studied stream, monazite is the principal source of both uranium and thorium (El shafey, 2016). Uranium high concentrations in the stream sediments samples are mainly related to the metamict zircon and this indicated from the fact that most zircon grains vacant from any radioelements. The essential minerals in the studied sediments include opaque minerals (ilmenite, magnetite, and leucoxene), in addition to rutile, zircon, garnet, monazite, titanite and colored silicate minerals (amphibole, pyroxene, apatite, epidote, sturolite, kyanite)

5.1. Opaque Heavy Minerals

Mineralogical analysis has shown that, almost the same minerals occur in all samples with varying percentages. The mineral components include opaque minerals (ilmenite, magnetite, and leucoxene), rutile, zircon, garnet, monazite, titanite, colored silicate minerals (amphibole, pyroxene, apatite, epidote, sturolite, kyanite).
Fig. 6. Field Photographs shows, A and B Gabal Elba and C, D extinctions for streem sedemints at Wadi Adieb, South Eastern Desert, Egypt

5.1.1. Magnetite
Magnetite reaching up to 29.25 % of the total heavy minerals of study area (Table 2) occurs as octahedral angular to sub-rounded, sub-metallic grains. Magnetite is usually deep reddish brown to black color, with metallic to dull luster. Partial weathering of the studied detrital magnetite to oxides (hematite) and oxyhydroxides (hydrate iron oxide limonite) is frequently observed on the surface grains and along the fractures. Chemical analysis using Energy dispersive X-ray spectrometer (EDX) is applied to throw some light on the chemical composition of the separated detrital magnetite. The EDX/BSE images of magnetite of study area ESEM were shown in Fig.7A (El Kammar et al., 2007) suggested granitic source for magnetite based on its euhedral form.

5.1.2. Hematite
Is one of the most abundant minerals on Earth’s surface and in the shallow crust. It is Iron oxide, may contain slight amounts of titanium. Hematite is the world’s most important ore of iron. Pure hematite has a composition of about 70% iron and 30% oxygen by weight. Like most natural materials, it is rarely found with that pure composition. Its colour, ranges between black, gray to silver gray, brown to reddish brown and red. Because of its red colour when powdered, hematite lends itself well to use as a pigment, and it was used by ancient cultures as a colouring for red and brown paint. The red colouring of soils all over the planet is due to hematite. A few hematite euhedral grains were picked using binocular stereomicroscope from the weakly magnetic ilmenite concentrate. These grains were subjected to elemental analyses using Environmental Scanning Electron Microscope. The Energy Dispersive X-ray and the back scattered electron image were graphically represented in Fig.7b and the elemental chemical composition of the analyzed grains.
5.1.3. Ilmenite

Ilmenite reaching up to 55% of the total heavy minerals of study area contains 40 - 65% TiO$_2$ depending on its geological history. It is the most abundant Fe-Ti oxide mineral that occur in a wide variety of igneous rocks, some metamorphic rocks and as a detrital mineral. Ilmenite is economically important and considered as a major source of titanium and a minor source of iron (Zhang et al., 2011). Under the binocular microscope, ilmenite occurs as deep blue to black, ilmenite and leucoxene are subangular to rounded and some grains are well preserved the crystallographic faces and their surfaces are strongly pitted due to dissolution during transportation. The EDX/BSE images of Ilmenite of study area ESEM were shown in Fig. 8.

5.2. Non-Opaque Heavy Minerals

5.2.1. Zircon

Zircon is found in most igneous rocks and some metamorphic rocks as accessory mineral (<1 wt. % of the total rock). It is also found as alluvial grains in some sedimentary rocks and naturally occurring beach sand due to its high hardness (Pettijohn, 1975). Zircon reaching up to 8.25% of the total heavy minerals of study area Zircon grain habits show euhedral crystals (bipyramidal, octahedral, rhombic dodecahedron crystals) or irregular, spherical, ovoid and elongated grains. It is usually colorless, red, brown, yellow, gray, pink and green in color. Theoretically stoichiometric zircon (ZrSiO$_4$) contains 67.2% ZrO$_2$ and 32.8% SiO$_2$. Hafnium substitutes for zirconium, EDX and BSE images show variation in chemical composition and morphology of prismatic bipyramidal zircon and rhombic dodecahedron zircon shown in (Figs. 9 and 10) respectively. Zircon being a nonmagnetic, nonconductor, can easily be separated from other heavy minerals by utilizing specific gravity differences, differences in magnetic properties or differences in conductive properties. Zircon grains may contain inclusions that are magnetic and/or conductive, thus altering the separation properties.
Fig. 8. EDX semi-quantitative analyses and BSE images of ilmenite Euhedral grains
Fig. 9. EDX semi-quantitative analyses and BSE images of prismatic bipyramidal zircon grains subjected to elemental chemical analysis.
5.2.2. Rutile

The recorded rutile grains are prismatic, elongated, tabular and of irregular shape. Reaching up to 3.5% of the total heavy minerals of study area. Rutile grains of different colors generally reflect the variation in chemical composition. The recorded varieties are translucent foxy red prismatic, the color of rutile is yellow, brown, red, black, straw yellow and green. This variation in color is due to the impurity ions in the crystal structure, especially the ferric iron, niobium and tantalum. The major element compositions of selected rutile grains show that the grains are highly enriched in TiO2 (95.62 wt. %) which is indicated by EDX and the corresponding back scattered electron images of prismatic and spherical rutile grains (Fig. 11). Rutile concentrates with about 94 wt. % TiO2 can be used in pigment industry, welding rods coating and metallurgical uses.

Fig. 10. EDX semi-quantitative analyses and BSE images of prismatic and rhombic dodecahedron zircon grains subjected to elemental chemical analysis

Fig. 11. EDX semi-quantitative analyses and BSE images of prismatic and spherical rutile grains subjected to elemental chemical analysis
5.2.3. Garnet minerals

Garnet has a general formula $A_3B_2(\text{SiO}_4)_3$, where $A$, may be calcium, magnesium, iron or manganese, and $B$ may be aluminum, iron, or less commonly, chromium and vanadium. Because of increase of iron, manganese, calcium and magnesium content. Garnet is reaching up to 3.25 % of the total heavy minerals of study area. Garnet is a common mineral of metamorphic rocks; garnet follows the order of abundance; almandine $>$ spessartine $>$ pyrope $>$ grossularite but solid solution phases are occasionally encountered. Garnet grains are angular to subangular, irregular to rounded, and rhombic-dodecahedron to octahedron. The encountered garnets are commonly reddish-brown to almost black in color. The EDX data, although of low precision, suggest that the studied garnet is occasionally radioactive due to Th (Fig. 12), which may reach about 1%. (El-Kammar, et al., 1992), (Garzanti, et al., 2006) and others agree that garnet is mostly derived from metamorphic basement passing through the White Nile.

![Fig. 12. EDX semi-quantitative analyses and BSE images of Euheiral garnet crystal subjected to elemental chemical analysis](image)

5.2.4. Monazite

Monazite is phosphates of the light lanthanides respectively. Thorium and too much less extent uranium are generally associated with the lanthanides where their assays attain 5 - 6% and <1 respectively. In other words, the mineral monazite is composed of rare earth phosphates (Ce, La, Nd) $\text{PO}_4$ in addition to thorium and uranium to a much less extent. Monazite grains display different levels of roundness but occasionally preserve the prismatic and bipyramidal habit. Some grains are broken into irregular shaped fragments, monazite is reaching up to 3.25 % of the total heavy minerals of study area.
According to (El-Shafey, 2016). Concluded that the monazite contains 61.5% $\sum$REEs, 5.75% ThO$_2$, 0.65% U$_3$O$_8$, 28.0% P$_2$O$_5$.

Fig. 13. EDX semi-quantitative analyses and BSE images of subrounded monazite grains with contaminated surfaces picked (A); Rare earth elements bearing monazite (B)

The EDX/BSE images of Monazite of study area ESEM were shown in Fig. 13. Samples of monazite concentrate under the binocular microscope reveals that the majority of monazite grains have light to deep canary and lemon-yellow colors and traces have colorless. Most of grains are rounded to subrounded fine grained but some have relatively coarser sizes.

6. Field Radiometric Investigation

Regional field radiometric measurements using a portable four channel, gamma-ray spectrometer Model RS-230 (Fig.14), was carried out along the Wadi Aidib. Regional field radiometric measurements delineated the localization of low and high radiometric measurements associated with mineralogy in streams along the studied wadi, (Table 1).

Fig. 14. Photograph image shows the RS 230 instrument
6.1. Assessment of Dose

6.1.1. Absorbed dose rate in air (D)

The D at 1m above the ground surface for the uniform distribution of radionuclides (\(^{226}\text{Ra}, \ 232\text{Th}\) and \(^{40}\text{K}\)) were calculated by using Eq.1 on the basis of guide lines provided by UNSCEAR, (2000) and Örgün et al. (2007).

\[
D \text{ (nGy h}^{-1} \text{)} = 0.462A_{\text{Ra}} + 0.604A_{\text{Th}} + 0.0417A_{\text{K}}
\]  

(1)

where \(A_{\text{Ra}}\), \(A_{\text{Th}}\) and \(A_{\text{K}}\) are the average specific activities of \(^{226}\text{Ra}, \ 232\text{Th}\) and \(^{40}\text{K}\) in Bq/kg, respectively.

6.1.2. Annual effective dose equivalent (AEDE)

The annual effective dose equivalent (AEDE) was calculated from the absorbed dose by applying the dose conversion factor of 0.7 Sv/Gy and the outdoor occupancy factor of 0.2 (UNSCEAR, 2000 and Örgün et al., 2007).

6.1.3. Radium equivalent activity (\(R_{\text{aq}}\))

The radium equivalent activity for the samples was calculated. The exposure to radiation (Tufail et al., 1992) can be defined in terms of the radium equivalent activity (\(R_{\text{aq}}\)), which can be expressed by the following equation:

\[
R_{\text{aq}} = \frac{AR_{\text{Ra}}}{10} + \frac{AT_{\text{Th}}}{7} + \frac{AK}{130}
\]

(2)

where \(AR_{\text{Ra}}, AT_{\text{Th}}\) and \(AK\) are the specific activities of Ra, Th and K, respectively, in Bq/kg.

6.1.4. External and internal hazard index (\(H_{\text{ex}}\) and \(H_{\text{in}}\))

To limit the annual external gamma-ray dose (Saito and Jacob, 1995; and UNSCEAR, 2000) to 1.5 Gy for the samples under investigation, the external hazard index (\(H_{\text{ex}}\)) is given by the following equation:

\[
H_{\text{ex}} = \frac{AR_{\text{Ra}}}{370} + \frac{AT_{\text{Th}}}{259} + AK/4810
\]

(3)

The internal exposure to \(^{222}\text{Rn}\) and its radioactive progeny is controlled by the internal hazard index (\(H_{\text{in}}\)), which is given by Nada (2003):

\[
H_{\text{in}} = \frac{AR_{\text{Ra}}}{185} + AT_{\text{Th}}/259 + AK/4810
\]

(4)

These indices must be less than unity in order to keep the radiation hazard insignificant (Lakehal et al., 2010 and Baykara et al., 2010).

6.1.5. Activity concentration index (\(I_{\gamma}\))

Another radiation hazard index called the representative level index, \(I_{\gamma}\), is defined as follows (NEA-OECD, 1979):

\[
I_{\gamma} = \frac{AR_{\text{Ra}}}{150} + AT_{\text{Th}}/100 + AK/1500
\]

(5)

where \(AR_{\text{Ra}}, AT_{\text{Th}}\) and \(AK\) are the activity concentrations of 226Ra, 232Th and 40K, respectively in Bq/kg (Abbady et al., 2005). The safety value for this index is \(\leq 1\) (El Galy et al., 2008 and El Aassy et al., 2012).
7. Results and Discussion

About 135 readings were recorded and measured radiometrically for stream sediment samples from nine stations in Wadi Aidib area. U, Th and K% contents are wildly varied, U ranges from 5.25 to 32.05 ppm, with an average of 16.63 ppm, Th ranges from 4.4 to 17 ppm, with 11.34 ppm as an average and potassium fall between 1.8 and 5.15% with an average of 3.4 % (Table. 1). Comparing the studied sediments with the averages of arenaceous and argillaceous sediments reported by IAEA (1979) and Boyle (1982) (Table. 1), indicate that these sediments have higher contents of uranium and thorium relative to the arenaceous sediments. Average of uranium contents in the studied Wadi deposits are higher than the average of argillaceous sediments but thorium values lie within the range of argillaceous sediments. Th/U ratio average (0.68) of Wadi Aidib area is lowers than the average of arenaceous and argillaceous sediments, respectively.

The average Th/U ratio for all the studied sediments is lower than those quoted for the Upper Continental Crust by (McLennan and Taylor 1980, 1991), (Rudnick and Gao, 2004) and (Tawfic et al., 2019). eU-eTh variation diagram indicates that there is no any correlation between these elements (R=0.06), suggesting their incorporation in discrete minerals, eTh/eU with eU and eTh confirms this conclusion. eTh-K relation illustrates thorium increasing with alteration by adsorption on clay minerals while eU-K diagram shows uranium mobilization with alteration. Low eTh/K ratios are considered an indication of potassium alterations (Shives et al., 1995).

When this ratio is lesser than unity (eTh/eU<2), could illustrate uranium enrichment and suggesting reducing conditions, in contract, when this ratio >7 may indicate uranium removal by leaching (Adams and Weaver, 1958, El Nahas et al., 2011). Average of eTh/eU ratio of the studied sediments (0.68) is lesser than 2 which may indicate the prevailing reducing conditions in these sediments. The eU/eTh ratio is an important radiometric parameter to identify the sites of U-mineralization. It is used also to detect the oxidation state in which U transported (Naumov, 1959). The productive uraniferous rocks have U/Th ratio > 1 (Darnely and Ford, 1989, El Feky et al., 2011., El Mezayen et al., 2020). The studied sediments have eU/eTh ratio varied between 1.19 and 1.89 with an average of 1.47, suggesting that these sediments are considered productive uraniferous rocks. The studied sediments could be a favorable environment for uranium deposits where they show eU/eTh average ratios greater than 0.4 (Cambon, 1994; El Nahas et al., 2011).

7.1. Evaluation of Radiological Hazard Effects

Values of eU and eTh in ppm, as well as K, in %, were converted to activity concentration, Bq/kg, using the conversion factors given by International Atomic Energy Agency, (IAEA, 1989) and by Polish Central Laboratory for Radiological Protection (Malczewski et al., 2004 and Harpy et al., 2019b). The specific parent activity of a sample containing 1 ppm, by weight, of U is 12.35 Bq/kg, 1 ppm of Ra is 11.1 Bq/kg, and 1 ppm of Th is 4.06 Bq/kg, and 1% of ^40K is 313 Bq/ kg. Therefore, it can be easy to estimate the effects of this radiation through the calculation of the following parameters. The average absorbed γ- dose rate (D) values for Wadi Aidib area are registered in Table. 2. The values obtained in all the studied stations ranged between 86.97 and 264.79 nGyh-1 with an average166.95 nGyh-1. These estimated values of absorbed γ- dose rate in the studied stations is comparably higher than the world average value 57 nGyh-1 (Tzortzis et al., 2003 and Abbady et al., 2005). Furthermore, the average values of annual effective dose for all stations were also shown. The values obtained varied between 0.11 and 0.32 with 0.20 mSvyr-1 as an average. The mean value (0.20) is lesser than 0.48 mSvyr-1 [recommended by UNSCEAR (2000), as the worldwide average of the annual effective dose.
Table 1. Average of radionuclides contents in various stations with some calculated ratios

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Number of readings</th>
<th>eU ppm</th>
<th>eTh ppm</th>
<th>K%</th>
<th>eTh/eU</th>
<th>eU/eTh</th>
<th>eTh/K</th>
<th>eU-eTh/3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>St.1</td>
<td>15</td>
<td>5.25</td>
<td>7</td>
<td>3.05</td>
<td>1.33</td>
<td>0.75</td>
<td>2.30</td>
<td>3.25</td>
</tr>
<tr>
<td>St.2</td>
<td>15</td>
<td>16</td>
<td>9</td>
<td>4.25</td>
<td>0.56</td>
<td>1.78</td>
<td>2.12</td>
<td>13.43</td>
</tr>
<tr>
<td>St.3</td>
<td>15</td>
<td>18</td>
<td>12.5</td>
<td>3.15</td>
<td>0.69</td>
<td>1.44</td>
<td>3.97</td>
<td>14.43</td>
</tr>
<tr>
<td>St.4</td>
<td>15</td>
<td>12.5</td>
<td>14.25</td>
<td>4.3</td>
<td>1.14</td>
<td>0.88</td>
<td>3.31</td>
<td>8.43</td>
</tr>
<tr>
<td>St.5</td>
<td>15</td>
<td>5.9</td>
<td>13.65</td>
<td>5.15</td>
<td>2.31</td>
<td>0.43</td>
<td>2.65</td>
<td>2.00</td>
</tr>
<tr>
<td>St.6</td>
<td>15</td>
<td>10</td>
<td>11</td>
<td>1.8</td>
<td>1.10</td>
<td>0.91</td>
<td>6.11</td>
<td>6.86</td>
</tr>
<tr>
<td>St.7</td>
<td>15</td>
<td>15</td>
<td>17</td>
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<td>27.19</td>
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<td>1.47</td>
<td>3.34</td>
<td>13.39</td>
</tr>
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<td>3</td>
<td>1.4</td>
<td>3</td>
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</tr>
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<td></td>
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<td>0.33</td>
<td></td>
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</table>

* Arenaceous sediments (IAEA, 1979 and Boyl, 1982)
** Argillaceous sediments (IAEA, 1979 and Boyl, 1982)
*** International average

Table 2. Average of activity concentrations of U, Th and K with the calculated environmental parameters

<table>
<thead>
<tr>
<th>eU</th>
<th>eTh</th>
<th>K</th>
<th>Abs. Dose</th>
<th>Eff. Dose</th>
<th>Ra&lt;sub&gt;eq&lt;/sub&gt;</th>
<th>Hin</th>
<th>Hex</th>
<th>Iγ</th>
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<tbody>
<tr>
<td>Bq/kg</td>
<td>Bq/kg</td>
<td>Bq/kg</td>
<td>(nGy/h)</td>
<td>(mSv)</td>
<td>(Bq/kg)</td>
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<td>0.66</td>
<td>0.48</td>
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<td>169.09</td>
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<td>0.95</td>
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*** International average

The radium equivalent activity Ra<sub>eq</sub> for all the studied stations in the area ranges between 178.94 and 555.66 BqKg<sup>-1</sup> with 352.86 BqKg<sup>-1</sup> as a mean value. Many of the studied stations are higher than the maximum permitted world values of 370 Bq kg<sup>-1</sup>. The values of external and internal hazard indices (H<sub>ex</sub> and H<sub>in</sub>) for the studied stations in the area range between (0.66, 2.60) and (0.48, 1.53), respectively. External and internal hazard indices are higher than unity for certain stations indicating that these stations cannot be used as building and interior decorative material of dwelling. The gamma activity index (I<sub>γ</sub>) used to assess safety requirement for building materials were evaluated and presented in table 1. The obtained values for both of them ranged between 1.35 and 3.97 with 2.54 as an average. The
obtained values of gamma activity indices in all commercial granite samples were higher dose criterion (0.3mSv/y) and corresponds to an activity concentration index of $2 \leq I_{\gamma} \leq 6$ proposed by EC (1999) for materials used in bulk construction.

8. Conclusions
Wadi Aidib lie at the extreme southern part of the Eastern Desert, Egypt, between 22° 15’ - 22° 21’ N and Longitudes 36° 20’ - 36° 30’ E. The studied stream sediments accumulate in the form of alluvial fans and are mainly composed of sands, gravels, boulders and contain some heavy valuable minerals which are derived from metavolcanics, metasediments, quartz diorite, biotite and alkali feldspar granites. Heavy liquid separation and magnetic separation techniques in addition to microscopic examination for the studied stream sediment samples were applied to identify the heavy minerals in these sediments. These minerals are represented by magnetite, hematite, ilmenite, rutile, garnet, zircon, monazite and Green silicates. In the studied stream, monazite is the principal source of both uranium and thorium, uranium high concentrations in the stream sediments samples are mainly related to the metamict zircon and this indicated from the fact that most zircon grains vacant from any radioelements. The distribution of some elements in the study area it is clear that they are concentrated near the outcrops of granites. The average concentrations of K, U and Th in the stream sediments of Wadi Aidib are 2.6-5.8%, 4-43.8 ppm and 5-19.5 ppm, which are higher than the Clarke values for earth crust. On the other hand, eTh/eU ratios are low, indicating uranium enrichment which could be attributed to the presence of monazite and zircon mineralization, D AEDE Raeq Hex and Hin $I_{\gamma}$ caused by gamma emitting natural radionuclide clarify that the studied stations do not satisfy the universal standards. $^{40}$K plays the main and most important role in dose rate contribution.

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