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Radiological Effectual and Mineral Salts Measurements of Sandstone Used in the Construction from Al Wajh, Al Ula and North Al Ula, Az Zabirah-Saudi Arabia

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Abstract

The activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K, were measured in (16) sandstone samples collected from two regions of Saudi Arabia, Region 1 (Al Wajh on Red Sea coast and Al Ula north-East of Medina), Region 2 (North of Al Ula and Az Zabirah, North-West of Hail) by (HPGe gamma spectrometer). The activity concentration average values of the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in the sandstone samples (Region 1) ranged from 10.97 ± 0.43, 27.68 ± 0.37 and 64.56 ± 0.74 Bq/kg respectively. These values are less than the international values reported by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000), in (Region 2), average values ranged from 2465.49 ± 0.00, 2042.00 ± 0.00 and 2259.65 ± 0.64 Bq/kg respectively. These values are higher than the values reported by (UNSCEAR, 2000). Average values of radium equivalent activity Ra_{eq} (Bq/Kg), absorbed dose rate D (nGy/h), annual effective radiation dose D_{eff} (mSv/y), External index (H_{ex}) and Internal index (H_{in}) were in (region 1) 21.13, 27.22, 11.75, 0.07 and 0.10 respectively, in (region 2) 5775.19, 1787.78, 846.58, 11.57 and 15.64 respectively. These results are lower (except annual effective radiation dose) in (region 1) and higher in (region 2) than the world recommended values by (UNSCEAR, 2000). Also, samples were analyzed by Atomic Absorption spectrometer (AAS) for Al, Ca, Fe, K, Mg and Bi in % elements concentrations. Average value in (region 1) (Al Wajh and Al Ula) are 4.42, 0.41, 1.37, 0.04 and 0.03, (in region 2) (N. Al Ula and Az Zabirah) are 12.50, 10.05, 1.01, 1.19, 0.04 respectively. Classifications of sandstone depend on the content of these elements. These results are important for the safety of dwellers and user of sandstone in constructions.

Keywords

Gamma Spectrometer, AA Spectrometer, Natural Radioactivity, Chemical Elements

1. Introduction

Natural activity arises from radioactive elements in the earth crust and terrestrial radionuclides. Natural radioactive materials can be reach hazardous radiological levels. It is necessary to study the natural radioactivity levels in building matter such as sandstone (Baxter, 1993). Human exposure to ionizing radiation emitted from these natural radioactive sources is an ongoing and unavoidable fact of life on earth (UNSCEAR, 2008). The external exposure (indoor and outdoor) results from gamma-rays of radionuclides ^{226}Ra, ^{232}Th, and their radioactive series and ^{40}K are existing in all environmental media may vary depending on the geological and geochemical structure of the region (UNSCEAR, 2008). The sandstone is an important environmental material which is used for many purposes such as building materials concentrations. Sandstone has a wide variation from region to another on the crust of earth (Roger & Adams, 1969). Hence, the specific level of ambient background radiation in the crust varies from one region to another as the concentrations of these natural radioactive elements vary due to their non-uniform nature in sandstone and the types of rock from which they originate. Therefore, the terrestrial radiation depends on the geological conditions of the area (Roger & Adams, 1969; NCRP, 1975; Florou & Kritidis, 1992; Tzortzis et al., 2003). Sandstone is containing natural radionuclides that contribute to indoor and outdoor exposure. The measurement of natural radioactivity in sandstone concentrations of ^{226}Ra, ^{232}Th, and ^{40}K is very important to determine the amount of change of the natural background activity with time as a result of any radioactive release. The aim of this work is to measure the sandstone samples activities from two regions: (Al Wajh on Red Sea coast, Al Ula north-East of Medina) and (North of Al Ula, Az Zabirah, North-West of Hail) in Saudi Arabia and to estimate the potential health impact to the human in these areas under investigation. In addition, to calculate elements concentrations of Al, Ca, Fe, K, Mg and Bi in % in these areas, classifications of sandstone depend on the content of these elements. These results are important for the safety of dwellers and user of sandstone in constructions.

2. Geological Setting

2.1. Study Area

Sixteen sandstone samples were collected from two regions of Saudi Arabia (Al Wajh on Red Sea coast and Al Ula north-East of Medina) (SS: 1 to 7), (North of Al Ula and Az Zabirah, North-West of Hail) (SS: 8 to 16) **Table 1**, **Figure 1**.

Table 1. Name and location of sandstone samples.

Sample No.	Sample Names	Location	Lat. and Long.
SS1	Sand Stone	Al Wajh	N: 27˚19'04" E: 37˚34'00"
SS2	Sand Stone	Al Ula-Madina	N: 19˚59'01" E: 38˚53'02"
SS3	Sand Stone	Al Ula-Madina	N: 21˚58'05" E: 39˚10'00"
SS4	Sand Stone	Al Ula-Madina	N: 22˚48'06" E: 38˚22'01"
SS5	Sand Stone	Al Ula-Madina	N: 23˚59'00" E: 39˚11'00"
SS6	Sand Stone	Al Ula-Madina	N: 24˚58'41" E: 37˚49'03"
SS7	Sand Stone	Al Ula-Madina	N: 17˚29'36" E: 43˚37'46"
SS8	Sand Stone	North-Al Ula	N: 26˚29'05" E: 37˚55'01"
SS9	Sand Stone	North-Al Ula	N: 26˚38'00" E: 37˚55'00"
SS10	Sand Stone	North-Al Ula	N: 26˚49'09" E: 37˚21'01"
SS11	Sand Stone	North-Al Ula	N: 25˚49'00" E: 37˚55'00"
SS12	Sand stone	Az Zabirah-Hail	N: 28˚3'9" E: 3˚41'9"
SS13	Sand Stone	Az Zabirah-Hail	N: 28˚4'7" E: 3˚41'9"
SS14	Sand Stone	Az Zabirah-Hail	N: 28°4'10" E: 3˚41'9"
SS15	Sand Stone	Az Zabirah-Hail	N: 28˚8'13" E: 3˚41'9"
SS16	Sand Stone	Az Zabirah-Hail	N: 28˚16'17" E: 3˚41'9"

Figure 1. Al Wajh, a city on Red Sea coast, Al Ula and North Al Ula, north-East of Medina Az Zabirah, North-West of Hail.

2.2. Samples Preparation

The samples were dried in oven of one hundred ˚C to remove the moisture completely, crushed in an agate mortar, sieved in 2 mm to be homogenized in size. Each weighted sample (550 gm) was transferred to cylindrical plastic-container (Marinelli Beaker) then labelled and taped up tightly. The samples were stored for two months before counting to reach secular equilibrium between ^{238}U and

^{232}Th with their daughter nuclides.

3. Experimental Measurements

3.1. Gamma Spectroscopic and the Activity Concentration Calculations

The samples were analysed non-destructively, using gamma-ray spectrometry with Canberra (Model number GC2520) high purity coaxial germanium (HPGe) detector with efficiency of 25% and energy resolution of 2 keV FWHM for the 1332 keV line of ^{60}Co, and (16 k) MCA card with software Gamma (Gennie 2000) was used for Gamma acquisition and data analysis in our nuclear lab Jeddah university. The detector is boarded inside a thick lead shield (100 mm) with a fixed bottom and movable cover to reduce gamma ray background. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick) to absorb X-ray generated in the lead. In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples. Each sample was counted for 28,800 s. The background was measured many times at the same conditions of the measurement. The system was calibrated for energy and efficiency (IAEA, 2018). The lowest detection limits (DL) of HPGe detector system were 0.33, 0.27, and 2.31 for ^{226}Ra, ^{232}Th, and ^{40}K respectively for a counting time of 82,800 seconds. ^{226}Ra activity concentrations were evaluated using gamma-ray lines of its related isotopes, ^{214}Pb (352 keV) and ^{214}Bi (609.31, 1120.27, 1764.49 keV). For ^{232}Th, gamma ray lines of ^{212}Pb (238.6), Tl (583) KeV and ^{228}Ac (338.42, 911.16, 964.6, 968.97 KeV) were used to measure the activity concentrations. The activity concentrations of ^{40}K were determined by using 1460.8 keV gamma ray line.

3.2. Atomic Absorption Spectroscopy (AAS)

(AAS) is a method often used in environmental studies (Haswell, 1991). The application of (AAS) to soil analysis has been discussed by (Ure, 1991). For this study, the samples were analysed by Atomic Absorption spectrometer model OPTIMA 4000 DV Series Perkin Elmer for Al, Ca, Fe, K, Mg and Bi % for the concentrations.

4. Calculations

4.1. Activity Concentrations

Determination of activity concentrations in Bq/kg dry weight was calculated from the following equation (Amrani & Tahtat, 2001).

$$A = \frac{C}{m\beta\varepsilon} \quad (1)$$

where: C is the net peak area of specific gamma ray energy (count per second), m is the ass of the samples in (kg), β is the transition probability of gamma-decay, ε is the detector absolute efficiency at the specific gamma-ray energy. The measured dry weight activity concentrations of the gamma emitting radionuclides of the ^{226}Ra series, ^{232}Th series and ^{40}K in 16 sandstone samples are reported in Table 2 and Figure 2.

In region 1 (SS: 1 - 7), the measured activity concentration averages of ^{226}Ra, ^{232}Th and ^{40}K Bq/kg were 10.97 ± 0.43, 27.68 ± 0.37 and 64.56 ± 0.74 Bq/kg respectively. These values are less than the recommended reference Levels (50, 50 and 500) (UNSCEAR, 2000). In region 2 (SS 8 - 16), the average of measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K Bq/kg were 2465.49 ± 0.01, 2042.02 ± 0.10 and 2259.65 ± 0.64 Bq/kg respectively. These values are higher than the recommended reference Levels (50, 50 and 500) (UNSCEAR, 2000), the variations in the concentrations of the radioactivity in region 1 and region 2 depend upon the geological and geochemical conditions of the areas. These results are given in Table 2 and shown in Figure 2.

Table 2. The specific activity concentrations in Bq/kg in sand stone samples measured by Gamma spectroscopy.

Sa. No.	Region	District	Specific activities (Bq/ kg)		
			^{226}Ra	^{232}Th	^{40}K
SS1		Al Wajh	58.10 ± 0.53	33.00 ± 0.64	95.00 ± 0.22
SS2	Region 1	AL ULA	1.50 ± 0.20	3.40 ± 0.40	18.20 ± 0.40
SS3	Region 1	AL ULA	42.50 ± 0.23	126.00 ± 0.21	129.00 ± 0.30
SS4	Region 1	AL ULA	2.10 ± 0.70	4.60 ± 0.75	18.20 ± 2.00
SS5	Region 1	AL ULA	18.20 ± 0.50	6.56 ± 2.40	7.70 ± 0.02
SS6	Region 1	AL ULA	47.20 ± 1.10	18.31 ± 0.31	182.00 ± 2.00
SS7	Region 1	AL ULA	0.63 ± 0.14	1.88 ± 0.23	1.82 ± 0.24
	Range		**0.63 - 58.10**	**1.88 - 126.00**	**1.82 - 182.00**
	Average		**10.97 ± 0.43**	**27.68 ± 0.37**	**64.56 ± 0.74**
SS8	Region 2	North of Al Ula-Al Zzabira Wasia	4200.00 ± 39.7	1762.00 ± 3.03	2380.00 ± 2.00
SS9	Region 2	North of Al Ula-Al Zzabira Wasia	1230.00 ± 6.20	1690.00 ± 2.05	2380.10 ± 0.28
SS10	Region 2	North of Al Ula-Al Zzabira Wasia	947.67 ± 0.91	547.80 ± 0.78	2380.00 ± 1.60
SS11	Region 2	North of Al Ula-Al Zzabira Wasia	1231.33 ± 0.50	2010.00 ± 2.20	2380.21 ± 1.13
SS12	Region 2	North of Al Ula-Al Zzabira Wasia	908.00 ± 0.01	216.70 ± 0.01	1090.00 ± 0.32
SS13	Region 2	North of Al Ula-Al Zzabira Wasia	1360.00 ± 0.08	2052.50 ± 0.10	2380.00 ± 0.30
SS14	Region 2	North of Al Ula-Al Zzabira Wasia	1474.30 ± 0.06	1652.20 ± 0.03	2390.00 ± 0.21
SS15	Region 2	North of Al Ula-Al Zzabira Wasia	1751.67 ± 0.13	2060.70 ± 0.31	2376.00 ± 1.10
SS16	Region 2	North of Al Ula-Al Zzabira Wasia	2077.00 ± 0.10	1924.00 ± 0.01	2460.00 ± 0.34
	Range		**908 - 4200**	**216 - 2060**	**2376.00 - 2460.34**
	Average		**2465.49 ± 0.01**	**2042.00 ± 0.10**	**2259.65 ± 0.64**
	UNSCEAR, 2000		**50**	**50**	**500**

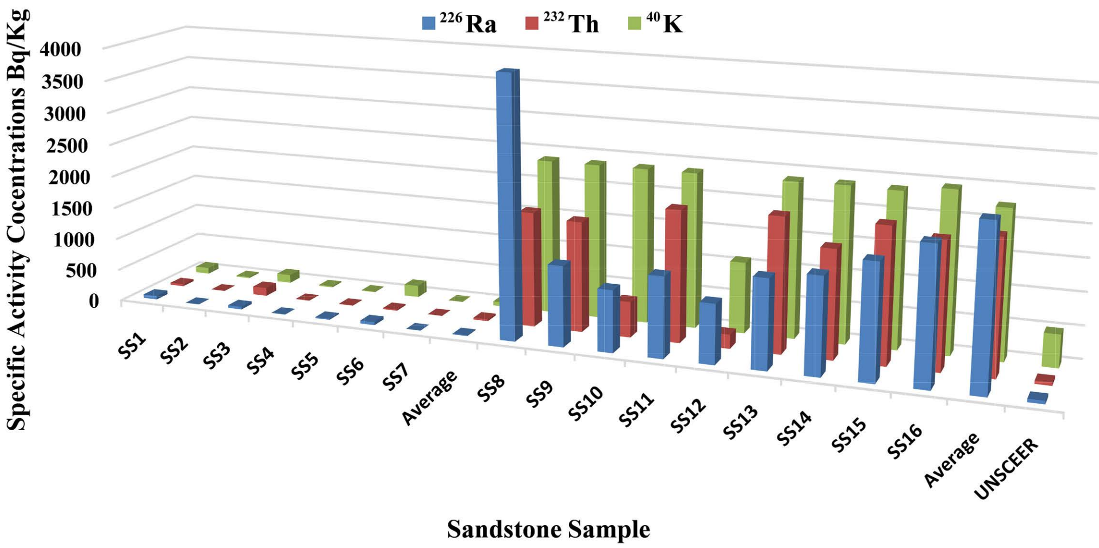

Figure 2. The specific activity concentrations of ^{226}Ra, ^{232}Th, and ^{40} K in Bq/kg for sandstone samples in (Al Wajh, Al Ula) and (N. Al Ula, AzZabira) Sa. Arabia.

The variations in the concentrations of the radioactivity in sandstone samples depend upon the geological and geographical conditions of the area (UNSCEAR, 2000).

4.2. The Radiological Hazard Indices

Exposure to radiation has been defined in terms of the radium equivalent Ra_{eq} Bq/kg which is calculated from equation (Jose, Jorge, Cleomacio, Sueldo, & Romilton, 2005).

$$Ra_{eq} = C_{Ra} + (C_{Th} \times 1.43) + (C_K \times 0.077) \quad (2)$$

where: C_{Ra}, C_{Th} and C_K are the concentrations in Bq/kg dry weight for radium, thorium and potassium respectively. The total air absorbed dose rate (nGy/h) in the outdoor air at 1 m above the ground due to the activity concentrations of ^{226}Ra, ^{232}Th and The concentrations of ^{226}Ra, ^{232}Th and ^{40}K were determined from the average concentrations of gamma ray lines of energies tabulated in **Table 2**.

^{40}K (Bq/kg) dry weight was calculated using the equation (Jose, Jorge, Cleomacio, Sueldo, & Romilton, 2005).

$$D(nGy/h) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_K \quad (3)$$

where: C_{Ra}, C_{Th}, and C_K are the specific activities (concentrations) of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg dry weight respectively. The annual effective dose equivalent D eff (mSv/y) in air was calculated using the values of the absorbed dose rate by applying the dose conversion factor of 0.7 Sv/Gy and the outdoor occupancy factor of 0.2 (people spend about 20% of their life outdoor) the Annual Effective Dose (in mSv/y) received by population can be calculated using equation (Krieger, 1981).

$$D_{eff}(mSv/y) = D(nGy/h) \times 8766h \times 0.7(Sv/Gy) \times 0.2 \times 10^{-6} \quad (4)$$

where: D (nGy/h) is the total air absorbed dose rate in the outdoor. 8766 h is the number of hours in 1 year. 10^{-6} is conversion factor of nano and milli. To limit the annual external gamma-ray dose to 1.5 Gy for the samples under investigation.

The external hazard index (H_{ex}) is given by the equation (Krieger, 1981).

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \tag{5}$$

Internal exposure to radon and its progeny can be quantified using the index H_{in}, which was estimated by the following expression (Krieger, 1981). Results are given in Table 3 and Figure 3.

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \tag{6}$$

4.3. Results and Discussion

In region 1, (Al Wajh, Al Ula). Radium equivalent (Ra_{eq} Bq/Kg) average value in sandstone samples) is 121.13 Bq/Kg. This value of Ra_{eq} is lower than the limit of

Table 3. The radiation hazards, D (nGy/h), D_{eff} (mSv/y), H_{ex} and H_{in} for sandstone samples in sand stone samples.

Sample No.			Radiation hazards				
			Radium equivalent Ra_{eq} (Bq/Kg)	Absorbed dose D (nGy/h)	Annual effective dose D_{eff} (mSv/y)	External index (H_{ex})	Internal index (H_{in})
SS1	Region 1	Al Wajh	167.43	49.45	44.45	0.31	0.46
SS2	Region 1	Al Ula	14.03	3.54	1.32	0.02	0.03
SS3	Region 1	Al Ula	422.73	102.10	41.68	0.63	0.74
SS4	Region 1	Al Ula	18.06	4.55	1.76	0.03	0.03
SS5	Region 1	Al Ula	38.15	12.19	6.56	0.08	0.13
SS6	Region 1	Al Ula	127.60	39.39	18.56	0.24	0.36
SS7	Region 1	Al Ula	6.29	1.52	0.62	0.01	0.01
Average			**121.13**	**27.22**	**11.75**	**0.07**	**0.10**
SS8	Region 2	N. Al Ula	9605.84	2993.47	1596.02	18.65	30.00
SS9	Region 2	N. Al Ula	6429.92	1680.42	747.86	10.34	13.67
SS10	Region 2	N. Al Ula	2880.90	848.27	406.10	5.17	7.73
SS11	Region 2	N. Al Ula	7346.45	1885.34	821.83	11.58	14.91
SS12	Region 2	Az Zabirah-Wasia	2214.70	569.59	310.84	3.52	5.97
SS13	Region 2	Az Zabirah-Wasia	5792.80	1961.90	867.72	12.10	15.77
SS14	Region 2	Az Zabirah-Wasia	5516.20	1761.49	807.54	10.86	14.84
SS15	Region 2	Az Zabirah-Wasia	6188.40	2134.00	979.17	13.19	17.92
SS16	Region 2	Az Zabirah-Wasia	6461.10	2191.35	1039.36	13.56	19.17
Average			**5775.19**	**1787.78**	**846.58**	**11.57**	**15.64**
UNSCEAR, 2000			**370**	**65**	**1**	**≤1**	**≤1**

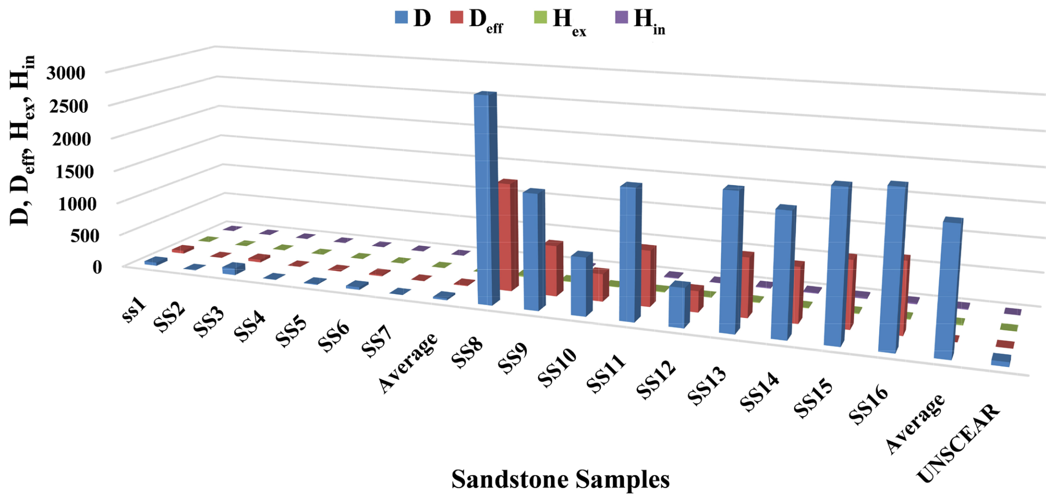

Figure 3. D (nGy/h), D_{eff} (mSv/y), H_{ex} and H_{in} for sandstone samples.

370 Bq/kg recommend by (UNSCEAR, 2000). The Absorbed dose D (nGy/h), External hazard index (H_{ex}) and Internal index (H_{in}) average values are 27.22, 0.07 and 0.10, these values are lower than the limit 65, ≤1, ≤1 recommend by (UNSCEAR, 2000). For the Annual effective dose D_{eff} (mSv/y) average value is 11.75 (mSv/y) this value is higher than the limit 1 (mSv/y) recommend by (UNSCEAR, 2000). As shown in **Table 3**. In region 2, (N. Al Ula, AzZbira-wasia). Radium equivalent (Ra_{eq} Bq/Kg), the absorbed dose D (nGy/h), the Annual effective dose D_{eff} (mSv/y) and External hazard index (H_{ex}) and Internal index (H_{in}) average values are 5775.19 Bq/Kg, 1787.78 D (nGy/h), 846.58 D_{eff} (mSv/y), 11.57 (H_{ex}) and 15.64 (H_{in}), these values for all samples are higher than the limit 370, 65, 1, ≤1 and ≤1 recommend by (UNSCEAR, 2000). As shown in **Table 3**. In region 2, (N. Al Ula, AzZbira-wasia). Radium equivalent (Ra_{eq} Bq/Kg), the absorbed dose D (nGy/h), the Annual effective dose D_{eff} (mSv/y) and External hazard index (H_{ex}) and Internal index (H_{in}) average values are 5775.19 Bq/Kg, 1787.78 D (nGy/h), 846.58 D_{eff} (mSv/y), 11.57(H_{ex}) and 15.64 (H_{in}), these values for all samples are higher than the limit 370, 65, 1, ≤1 and ≤1 recommend by (UNSCEAR, 2000). As shown in **Table 3**. In region 1, the results of the radiological hazard, the values of Radium equivalent (Ra_{eq}), absorbed dose (D), the annual effective dose (D_{eff}), external (H_{ex}) and internal hazard of sandstone samples show that there is no health hazard. It is less threat to the environment and to the human health. In region 2, these values of sandstone samples are higher than the limit 370, 65, 1, ≤1, ≤1 recommend by (UNSCEAR, 2000). These calculated dose rates in sandstone samples put the users, dwellers and people around the area on radiological hazard. This study has refers to background guideline on the natural radioactivity levels in region 2 which will be database to the population.

4.4. Elements Concentrations (%) of Sandstones Measured by AAS

Sandstone is sedimentary rock that is mainly composed of quartz or feldspar (both silicates-SiO_2). Sandstones are resistant to weathering and are very much easy to work. This makes sandstone commonly used as building and tiling material (Mubiayi, 2013). Sex elements (Al, Ca, Fe, K, Mg, Bi) of (16) sandstone samples in two regions were measured by atomic absorption spectroscopy (AAS).

Sandstone may be any colour due to impurities within the minerals. Sandstone that contains more than 90% Silicon (Si) is called Quartz sandstone. When the sandstone contains more than 25% Silicon (Si), it is feldspar sandstone. If sandstone contains 5.0% Iron (Fe), it is Hematite and sandstone with 2.9% Aluminium (Al), it is Kaolinite Clay, when there is a significant with 11% others, it is Impurities (Mundra et al., 2020). Elemental analysis of Al, Ca, Fe, K, Mg %. detection limit lies in %. In region 1, the averages concentrations of Al, Ca, Fe, K, Mg, Bi % are 4.42, 0.41, 1.37, 0.04, 0.03 and ND % respectively. In region 2, the averages concentrations of Al, Ca, Fe, K, Mg % are 12.50%, 10.05%, 1.01%, 1.19% and 0.04% respectively. The colour of sandstone varies, depending on its (elemental composition). The results are listed in **Table 4** and **Table 5**.

Table 4. Elements concentrations of Al, Ca, Fe, K, Mg, Bi (%) for Sandstone samples using AAS.

Element			Al	Ca	Fe	K	Mg	Bi
Units			%	%	%	%	%	%
DL.			0.02	0.02	0.02	0.01	0.01	0.01
SS1	Region 1	Al Wajh	5.63	0.23	0.15	0.010	0.007	ND
SS2		Al Ula	3.04	1.08	5.60	0.011	0.040	ND
SS3			6.78	0.26	0.20	0.062	0.014	ND
SS4			1.83	0.87	3.18	0.058	0.128	ND
SS5			0.91	0.22	0.21	0.017	0.017	ND
SS6			6.81	0.18	0.22	0.062	0.013	ND
SS7			5.92	0.05	0.16	0.022	0.005	ND
Average			4.42	0.41	1.37	0.04	0.03	---
SS8	Region 2	N. Al Ula	7.22	0.05	0.21	0.060	0.009	ND
SS9			6.86	0.10	0.21	0.064	0.010	ND
SS10			6.81	0.06	0.21	0.060	0.011	ND
SS11		Az Zbirah-Wsia	19.08	0.28	4.33	0.022	0.038	ND
SS12			18.11	3.65	0.20	0.021	0.043	ND
SS13			17.16	12.34	1.88	0.030	0.073	ND
SS14			14.51	18.97	0.62	0.048	0.039	ND
SS15			15.18	14.77	0.89	0.030	0.047	ND
SS16			7.58	40.20	0.50	0.030	0.069	ND
Average			12.50	10.05	1.01	1.19	0.04	---

ND: Not Detected.

Table 5. Shows the measured concentrations of Al, Ca, Fe, K, Mg, (%), Elemental Composition and Sandstone and description for the samples.

Sa.	Region1, 2	Element contains %			Elemental Composition	Sandstone description
		Major	Minor	Trace		
SS1	1-Al Wajh	5.63	0.23 - 0.15	0.010 - 0.007	Al (2.9%)	Kaolinite-clay
SS2	1-Al Ula	3.04 - 5.60	1.08	0.040 - 0.011	Al, Fe-5.90, 2.9%	Kaolinite clay-Hematite
SS3	1-Al Ula	6.78	0.26 - 0.20	0.062 - 0.014	Al (2.9%)	Kaolinite-clay
SS4	1-Al Ula	3.18	1.83 - 0.87	0.128 - 0.058	Al (2.9%)	Kaolinite-clay
SS5	1-Al Ula	---	0.91 - 0.22 - 0.21	0.017- 0.017	Others (11%)	Impurities
SS6	1-Al Ula	6.81	0.22 - 0.18	0.062 - 0.013	Al (2.9%)	Kaolinite-clay
SS7	1-Al Ula	5.92	0.16	0.05 - 0.022 - 0.005	Al (2.9%)	Kaolinite-clay
SS8	2-N. Al Ula	7.22	0.21	0.06, 0.05, 009	Al (2.9%)	Kaolinite-clay
SS9	2-N. Al Ula	6.86.	0.21, 0.10	0.065 - 0.001	Al (2.9%)	Kaolinite-clay
SS10	2-N. Al Ula	6.81	0.21	0.06, 0.06, 0.11	Al (2.9%)	Kaolinite-clay
SS11	2-N. Al Ula	19.08	4.33, 0.28	0.038, 0.022	Al (2.9%)	Kaolinite-clay
SS12	2-Az Zabira Wasis	18.11, 3.65	0.20	0.043, 0.021	Al (2.9%)	Kaolinite-clay
SS13	2-Az Zabira Wasis	17.16, 12.34	1.88	0.030, 0.073	Al (2.9%)	Kaolinite-clay
SS14	2-Az Zabira Wasis	14.51, 18.97	0.62	0.048, 0.039	Al (2.9%)	Kaolinite-clay
SS15	2-Az Zabira Wasis	15.18, 14.77	0.89	0.030, 0.047	Al (2.9%)	Kaolinite-clay
SS16	2-Az Zabira Wasis	7.58, 40.20	0.50	0.030, 0.069	Al (2.9%)	Kaolinite-clay

The obtained results show that, in region 1 (Al Wajh and Al Ula), the major element in sandstone samples (except SS2 and SS5) is Aluminium (Al) with content more than 2.9%, the sandstones are Kaolinite-clay. SS2 content is more than (2.9%) and (5.9%) the sandstone is Kaolinite-clay and Hematite. SS5 contents are minor and trace elements. Sandstone description of sample 5 is impurities. In region 2 (North Al Ula and Az Zabira Wasis), the major element in all sandstone samples is Aluminium (Al) with content more than 2.9%, the sandstones are Kaolinite-clay, with elements are dominantly controlled by clay minerals and/or by minerals associated with clays during sedimentation (Boggs, 2006).

5. Conclusion

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K and some chemical elements (Al, Ca, Fe, K, Mg) are measured in 16 sandstone samples used for construction purpose taken from two regions (Al Wajh, Al Ula) and (North Al Ula, Az Zabira Wasis), Saudi Arabia. Region 1, the activity concentrations of the three radionuclides in the samples are less than the worldwide values. The average values of Ra_{eq} Bq/Kg, Absorbed dose, D (nGy/h), External hazard index (H_{ex}) and Internal index (H_{in}) are lower than the worldwide values. The Annual effective dose D_{eff} (mSv/y) average value is higher than the worldwide value. This area is within normal radiation level, which leaves the sandstone radioactivity less of a threat to the environment and the human health. The obtained results for chemical elements show that, the major element content in samples (1, 3, 4, 6, 7) is Aluminium (Al), the sandstones are Kaolinite-clay. Sample 2 content major is (Al) and (Fe), the sandstone is Kaolinite-clay and Hematite. Sample 5 content is minor and trace elements. Sandstone description is impurities. Region 2, for all samples the measured activity concentrations and radiation hazards are higher than the worldwide values. The major element content in all samples is Aluminium (Al), the sandstones descriptions are Kaolinite-clay. The obtained data can provide general background levels of the natural radionuclides and chemical metals exposure to the population in the construction materials to evaluate the risks associated with the use of these materials.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Amrani, D., & Tahtat, M. (2001). Natural Radioactivity in Algerian Building Materials. *Applied Radiation and Isotopes, 54,* 687-689. https://doi.org/10.1016/S0969-8043(00)00304-3

Baxter, M. S. (1993). Environment Radioactivity: A Perspective on Industrial Contributions. *Journal of Environmental Radioactivity, 2,* 33-38.

Boggs, S. (2006). *Principles of Sedimentology and Stratigraphy* (4th ed., pp. 119-135). Pearson Prentice Hall.

Florou, H., & Kritidis, P. (1992). Gamma Radiation Measurements and Dose Rate in the Coastal Areas of a Volcanic Island, Aegean Sea, Greece. *Radiation Report Dosimetry, 45,* 277-279. https://doi.org/10.1093/rpd/45.1-4.277

Haswell, S. J. (1991). *Atomic Absorption Spectrometry, Theory, Design and Applications*. Analytical Spectroscopy Library.

IAEA, International Atomic Energy Agency (2018). *IAEA Safety Glossary, Vienna*.

Jose, A., Jorge, J., Cleomacio, M., Sueldo, V., & Romilton, S. (2005). *Brazilian Archives of Biology and Technology Journal,* 221-228.

Krieger, R. (1981). Radioactivity of Construction Materials. *Betonwerk Fertigteil-Technik, 47,* 468.

Mubiayi, M. P. (2013). Characterisation of Sandstones: Mineralogy and Physical Properties. In *Proceedings of the World Congress on Engineering 2013*. London.

Mundra, S., Agrawal, V., & Nagar, R. (2020). Sandstone Cutting Waste as Partial Replacement of Fine Aggregates in Concrete: A Mechanical Strength Perspective. *Journal of Building Engineering, 32,* 101534.

NCRP (1975). *Background Radiation in the USA Recommendation of the National Council* *of Radiation and Measurements*. Report No. 45.

Roger, J. J. W., & Adams, J. A. S. (1969). Uranium. In K. H. Wedephol (Ed.), *Handbook of Geochemistry* (Vol. 4). Springer.

Tzortzis, M. et al. (2003). Gamma-Ray Measurements of Naturally Occurring Radioactive Samples from Cyprus Characteristic Geological Rocks. *Radiation Means, 37,* 221-229. https://doi.org/10.1016/S1350-4487(03)00028-3

UNSCEAR (2000). *United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly. Annex B: Exposures from Natural Radiation Sources, New York*.

UNSCEAR (2008). *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation Report, New York*.

Ure, A. M. (1991). *Atomic Absorption and Flame Emission Spectrometry Analysis Modern Instrumental Techniques* (2nd ed., pp. 20-21). Marcel Dekker.