

Measurements of the Natural Radioactivity along Red Sea Coast (South Beach of Jeddah Saudi Arabia)

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Abstract: Twenty marine sediment samples were collected (from the ground surface down to depth of 0.50 m) from the south beach located on the western part of Jeddah. The samples were analyzed by XRD spectroscopy for the chemical and mineral compositions, results show that the major concentrations for the samples are ALBITE, ARAGONITE, MICROLINE, AUGITE, and QUARTZ, with minor and trace concentrations. The samples were also analyzed for concentrations of ^{238}U , ^{232}Th series, ^{235}U , and ^{40}K by HPGe gamma spectrometer. The activity concentrations in Bq/kg dry weight of ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U , and ^{40}K for ten samples from the ground surface are found in the range of 09.43 ± 0.76 to 18.32 ± 0.75 , 20.26 ± 0.88 to 31.21 ± 0.09 , 10.32 ± 0.80 to 20.33 ± 0.08 , 0.783 ± 0.07 to 0.990 ± 0.23 , and 562.04 ± 0.62 to 1804.63 ± 0.45 with mean values of 14.22 ± 0.65 , 23.77 ± 0.30 , 14.00 ± 0.45 , 0.763 ± 0.11 , and 968.19 ± 0.14 Bq/kg respectively. Also, for ten samples at 0.50 m depth, the activity concentrations in Bq/kg dry weight ranged from 10.27 ± 0.27 to 25.31 ± 0.05 , 17.96 ± 0.04 to 30.78 ± 0.04 , 10.74 ± 0.15 to 28.02 ± 0.16 , 0.570 ± 0.14 to 1.320 ± 0.24 , and 367.45 ± 0.65 to 1855.72 ± 0.71 with mean values of 17.01 ± 0.15 , 24.34 ± 0.12 , 17.30 ± 0.15 , 0.911 ± 0.19 , 934.45 ± 0.61 Bq/kg respectively. The radium equivalent activity Bq/kg varied from 081.60 to 182.29 Bq/kg with mean values 118.33 Bq/kg for the samples on the ground surface, and from 071.77 to 196.96 Bq/kg with mean value 120.40 Bq/kg, for the samples at 0.50m depth. The Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSv/h), External Hazard Index for the ground surface samples ranged from 40.06 to 93.15, 0.049 to 0.114, and 0.220 to 0.492 with mean values 59.13, 0.073, and 0.320, while for the samples at 0.50m depth the values ranged from 34.75 to 99.85, 0.043 to 0.123, and 0.194 to 0.532 with mean values 59.67, 0.073, and 0.325. These calculated values were lower than the estimated world –averaged values.

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1. Introduction

The Red Sea is a large marine ecosystem, it is less perturbed by human activities than the Arabian Gulf. Jeddah city is located in west of Saudi Arabia on the eastern cost of the Red sea. Jeddah is considered one of the biggest cities in Saudi Arabia after Riyadh, where there is a beach located on the western part of the city and it stretches for almost 100 km along the Red Sea coastline. The beach is a major tourist attraction, but also locals are very likely to be seen there. The landscaping and development of coastline concentrated on three areas: The central beach, an open-areas, the northern beach which, due to private ownership along the coast, and the southern beach, where the project involves construction of a desalination plant. The plant will have desalination capacity of 3 million gallons a day (Amal Al-Sheikh, 2011). So, Knowledge on the distribution and activity concentrations of naturally occurring radionuclides from uranium and thorium series and ^{40}K on tourism beaches are of particular concern, since they provided the main gamma radiation exposures to visitors and people living by the beaches. This knowledge would enable the estimation of radiation hazard to be made, and suggest mitigation steps if needed. There are

many literatures on the concentrations of naturally radionuclides in marine environment from different regions in the world [Price *et al.*, 1998, Higgy, 1999, Sroor *et al*, 2001, Santawamaitre, 2010, Ahmad Saat, 2011, ObhoXa's, 2012].

In the present study, sand samples were collected from south beach in Jeddah. Gamma, activities of radionuclides in the samples were measured using a HPGe spectrometer and the related radium equivalent, the external hazard index, the absorbed dose, and the annual effective dose were calculated to make base line map for the study area, to be compared with future studies for any environmental and geological changes.

Geographic Location Of Study Area

The Red Sea is unique among the seas of the world as no river flows into it. Occasionally sediment is brought into the Red Sea via a number of *Wadis* (with seasonal streams) especially in the south. Since there is absence of rivers and permanent streams, sand and dirt is only brought to the Red Sea by rain and wind. The coastal sediment is mostly composed of carbonate material from coral fragments, coralline algae and mollusks. The sediments vary in size from gravel to sand with occasional fine sediments at

places. Saudi Arabia's Red Sea coastline stretches about 1,760 kilometers. This coastline is of great economic, recreational, tourist, and water resources (desalination plants located on Red Sea beach), so any contamination especially radioactive one may affect the people health. It is quite important to

develop database for marine radioactivity for determining any future contaminations. (Abou Ouf and Geith, 1997).

Fig. 1: shows the location map of the collected samples.



Fig. 1: Location Map of the Collected Samples.

2. Material and Methods

I. Sample collection and preparation

Twenty marine sediment samples were collected (ten samples from the ground surface down to ten samples at depth of 0.50 m at the same locations) in mars 2012 covering 15 km of south Jeddah coast as shown in Fig. 1. For each sample, the exact GPS coordinates have been recorded. Samples were grounded, sieved by 1mm x 1mm, then dried to 95°C for 24 hours in order not to lose the volatile Polonium or Cesium. The dried fine grained samples were packed in polyethylene Marinelli beakers for gamma spectroscopy, and then stored for up to four month to reach secular equilibrium between ^{238}U and ^{232}Th and their progenies.

II. Experimental techniques

Ten gms. of the dried samples were analyzed by XRD model Burker XR-D D8 Advance for the chemical and mineral compositions. Samples were analyzed for concentrations of ^{238}U , ^{232}Th series and ^{40}K using the gamma spectrometer based on Canberra hyper pure germanium detector "HPGe" coaxial detector with relative efficiency of 20% and FWHM

4.2 keV at 1461 keV, the measurements were done for a time period of twenty four hours.

III. Calculations

For ^{238}U , a gamma-ray line of energy 1001.03 keV, of $^{234\text{m}}\text{Pa}$, was used to find the concentrations. Gamma-ray lines of energies 295.09, 351.87, 609.31, 1120.27, and 1764.49 keV resulting from the decay of daughters ^{214}Pb and ^{214}Bi radionuclides were used to determine the activity concentrations of ^{226}Ra which it is in secular radioactivity equilibrium with its short half – life daughters; the gamma-ray lines at 911.07, 968.97, 583.10, and 2614.48 keV from the decay of short half – life daughters ^{228}Ac and ^{208}Tl were used to determine the activity concentrations of ^{232}Th respectively (since there is secular radioactivity equilibrium in ^{232}Th series); while the 1460.80 transition was used to determine the activity concentrations of ^{40}K . ^{235}U and ^{226}Ra emit gamma-rays of energy 185.7 keV (57.2%) and 186.2 keV (3.6%), respectively. The detector energy resolution is not sufficient to easily separate these peaks. Therefore, the concentrations of ^{235}U was calculated

by subtracting the fraction of ^{226}Ra using equation (1) (Y.Y.EBAID,2010):

$$A_{U-235} = [1.75(CR_{T,186}) / \epsilon_{186}] - 0.063A_{Ra-226} \quad (1)$$

Where: CR_T : is the total count rate (counts. sec⁻¹) in the 186 keV energy peak.

ϵ : is the detection efficiency.

A_{Ra-226} : activity concentration of ^{226}Ra .

Determination of activity concentrations in Bq/kg was calculated using the equation (2) (Amrani D., Tahtat M.,2001).

$$A = \frac{C}{M \beta \epsilon} \quad (2)$$

Where: C is the net peak area of specific gamma ray energy (count per second).

M is the mass of the samples (kg).

β is the transition probability of gamma-decay.

ϵ is the detector efficiency at the specific gamma-ray energy.

Exposure to radiation has been defined in terms of the radium equivalent Ra_{eq} in Bq/kg which is calculated from equation (3) (Tufail *et al.*, 2006).

$$Ra_{eq} = C_{Ra} + (C_{Th} \times 1.43) + (C_K \times 0.077) \quad (3)$$

Where:

C_{Ra} , C_{Th} and C_K are the concentrations Bq/kg for radium, thorium and potassium respectively.

Besides the radium equivalent activity, the total air absorbed dose rate (nGy h⁻¹) in the outdoor air at 1 m above the ground due to the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K (Bq/ kg) dry weight was calculated using the equation (4) (UNSCEAR 2000; Veiga *et al.*, 2006)

$$D(\text{nGyh}^{-1}) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_K \quad (4)$$

Where:

C_{Ra} , C_{Th} , and C_K are the specific activities (concentrations) of ^{226}Ra , ^{232}Th and ^{40}K in Bq /kg respectively.

By using a conversion factor of 0.7 SvGy⁻¹ and outdoor occupancy factor of 0.2 (people spend about 20% of their life outdoor) the Annual Effective Dose (in mSvy-1) received by population can be calculated using equation :

$$D_{\text{eff}} (\text{mSvy}^{-1}) = D (\text{nGh}^{-1}) \times 8,766 \text{ h} \times 0.7 (\text{SvGy}^{-1}) \times 0.2 \times 10^{-6} \quad (5)$$

Where: D (nGh⁻¹) is the total air absorbed dose rate in the outdoor.

8,766 h is the number of hours in 1 year.

10⁻⁶ is conversion factor of nano and milli.

From Ra_{eq} an external hazard index, H_{ex} can be computed by the supposition that the maximum value allowed for the index is 1, that corresponds to $Ra_{eq} = 370$ Bq/kg. Thus it can be calculated in Bq/kg by (Beretka and Mathew, 1985):

$$H_{ex} = C_{Ra} / 370 + C_{Th} / 259 + C_K / 4810 \quad (6)$$

3. Results and Discussion

Table (1) and table (2) represent XRD analysis results for twenty samples (ten samples from the ground surface down to ten samples at depth of 0.50 m at the same locations) of the marine sediments, results show that the samples are composed of different minerals in decreasing order of their abundances. In table (1), the major concentrations for the samples are ALBITE (NaCaAlSi₃O₈), ARAGONITE (CaCO₃), MICROLINE (KAlSi₃O₈), and QUARTZ (SiO₂) (in all samples) and in table (2), the major minerals concentrations are ALBITE(NaCaAl Si₃O₈), ARAGONITE(CaCO₃), AUGITE (Ca,Na) (Mg,Fe,Al,Ti) (Si,Al)₂O₆, and QUARTZ(SiO₂) (in all samples), with minor and trace concentrations.

Table (1): The mineral constituents of ten samples from surface marine sediments analyzed by XRD spectrometer, (Leet *et al.*, 1982, and Mineral Data, 2012).

SAM NO.	MAJOR	MINOR	TRACE
1-S	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , CALCITE(CaCO ₃), CLINOCHLORE (MgFe ²⁺) ₃ Si ₃ Al ₂ O ₁₀ (OH) ₈ , HALITE(NaCl),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), GYPSUM Ca(SO ₄)•2(H ₂ O), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROCLINE(KAlSi ₃ O ₈), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
2-S	ARAGONITE(CaCO ₃), QUARTZ(SiO ₂),	ALBITE(NaCaAl Si ₃ O ₈), AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , CALCITE(CaCO ₃),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CLINOCHLORE(MgFe ²⁺) ₃ Si ₃ Al ₂ O ₁₀ (OH) ₈ , HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
3-S	ALBITE(NaCaAl Si ₃ O ₈), QUARTZ(SiO ₂)	ARAGONITE(CaCO ₃), MICROLINE(KAlSi ₃ O ₈),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₃ Si ₃ Al ₂ O ₁₀ (OH) ₈ , DIOPSIDE CaMg(Si ₂ O ₆), GYPSUM Ca(SO ₄)•2(H ₂ O), HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
4-S	ARAGONITE(CaCO ₃),	ALBITE(NaCaAl Si ₃ O ₈),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂),

	QUARTZ(SiO ₂)	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , HALITE(NaCl), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ .	CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROLINE(KAISi ₃ O ₈), PARTHEITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
5-S	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , HALITE(NaCl), MICROLINE(KAISi ₃ O ₈), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , GYPSUM Ca(SO ₄)•2(H ₂ O), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
6-S	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), MICROCLINE(KAISi ₃ O ₈), QUARTZ(SiO ₂)	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , CALCITE(CaCO ₃), HALITE(NaCl),	BIOTITE (K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CLINOCHLORE (MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , GYPSUM Ca(SO ₄)•2(H ₂ O) , MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
7-S	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , DIOPSIDE CaMg(Si ₂ O ₆ , MICROCLINE(KAISi ₃ O ₈), TREMOLITE Ca ₂ Mg ₅ (Si ₈ O ₂₂)(OH) ₂	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), GYPSUM Ca(SO ₄)•2(H ₂ O), HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
8-S	ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	ALBITE(NaCaAl Si ₃ O ₈), AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , HALITE(NaCl)	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , GYPSUM Ca(SO ₄)•2(H ₂ O), AGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROLINE(KAISi ₃ O ₈), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
9-S	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , HALITE(NaCl), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), CLINOCHLORE (MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , GYPSUM Ca(SO ₄)•2(H ₂ O), MAGNETITE (Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROLINE(KAISi ₃ O ₈), SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
10-S	ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	ALBITE(NaCaAl Si ₃ O ₈), AUGITE (Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , CALCITE(CaCO ₃), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CLINOCHLORE (MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , HALITE(NaCl), MAGNETITE (Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROLINE(KAISi ₃ O ₈), SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)

The main sources of the Red Sea beach sediments are terrestrial deposits transported from the fringing mountains during the occasional runoffs through the numerous Wadis, the Middle Miocene, and later biogenic carbonate sediments. In addition, the constructions waste disposal adds ecological

stresses on the Red Sea beach environment (El Mamoney and Khater, 2004). The minor and trace concentrations of the samples from the ground surface samples down to the at depth of 0.50 m samples show similarity in most elements.

Table (2): The mineral constituents of ten samples at depth 0.50 m in the same locations marine sediments analyzed by XRD spectrometer, (Leet *et al.*, 1982, and Mineral Data, 2012).

SAM. NO.	MAJOR	MINOR	TRACE
1-D	ARAGONITE(CaCO ₃), AUGITE(Ca,Na)(Mg,Fe,Al ,Ti)(Si,Al) ₂ O ₆ , QUARTZ(SiO ₂)	ALBITE(NaCaAl Si ₃ O ₈), CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (O H) ₈ , HALITE(NaCl),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), GYPSUM Ca(SO ₄)•2(H ₂ O), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O), TREMOLITE Ca ₂ Mg ₅ (Si ₈ O ₂₂)(OH) ₂
2-D	ARAGONITE(CaCO ₃), QUARTZ(SiO ₂)	ALBITE(NaCaAl Si ₃ O ₈), AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , CALCITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (O H) ₈ , HALITE(NaCl),	GYPSUM Ca(SO ₄)•2(H ₂ O), ,MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), OFFRETITE K ₁ Ca ₁ Mg _{0.7} Al _{5.2} Si _{12.8} O ₃₆ •15.2(H ₂ O), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , SAPONITE CaNa(MgFe ²⁺) ₃ Si ₃ AlO ₁₀ (OH) ₂ •4(H ₂ O)
3-D	QUARTZ(SiO ₂)	ALBITE(NaCaAl Si ₃ O ₈), ARAGONITE(CaCO ₃), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (O H) ₈ , MICROLINE(KAISi ₃ O ₈)	ANKERITE CaFe ²⁺ _{0.6} Mg _{0.3} Mn ²⁺ _{0.1} (CO ₃) ₂ , AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ , BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH F) ₂), CALCITE(CaCO ₃), HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄),,

			PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
4-D	ARAGONITE(CaCO_3), QUARTZ(SiO_2)	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), CALCITE(CaCO_3), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), FERRARISITE $\text{Ca}_5(\text{AsO}_3\text{OH})_2(\text{AsO}_4)_2 \cdot 9(\text{H}_2\text{O})$, GYPSUM $\text{Ca}(\text{SO}_4) \cdot 2(\text{H}_2\text{O})$, MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
5-D	ARAGONITE(CaCO_3), QUARTZ(SiO_2)	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), HALITE(NaCl), MICROLINE(KAISi_3O_8)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CALCITE(CaCO_3), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
6-D	ARAGONITE(CaCO_3), QUARTZ(SiO_2)	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CALCITE(CaCO_3), HALITE(NaCl), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), MICROCLINE(KAISi_3O_8), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
7-D	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), ARAGONITE(CaCO_3), QUARTZ(SiO_2)	AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), HALITE(NaCl), MICROLINE(KAISi_3O_8)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CALCITE(CaCO_3), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
8-D	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), ARAGONITE(CaCO_3), QUARTZ(SiO_2)	AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), MICROLINE(KAISi_3O_8)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CALCITE(CaCO_3), HALITE(NaCl), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
9-D	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), ARAGONITE(CaCO_3), QUARTZ(SiO_2)	AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), PARGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CALCITE(CaCO_3), HALITE(NaCl), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), MICROCLINE(KAISi_3O_8), SAPONITE $\text{CaNa}(\text{MgFe}^{2+})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
10-D	ARAGONITE(CaCO_3), QUARTZ(SiO_2)	ALBITE($\text{NaCaAl Si}_3\text{O}_8$), AUGITE($\text{Ca,Na}(\text{Mg,Fe,Al,Ti})(\text{Si,Al})_2\text{O}_6$), CALCITE(CaCO_3), HALITE(NaCl)	BIOTITE($\text{K}(\text{MgFe}^{2+})_3\text{AlSi}_3\text{O}_{10}(\text{OH F})_2$), CLINOCHLORE($\text{MgFe}^{2+})_5\text{Si}_3\text{Al}_2\text{O}_{10}(\text{OH})_8$), MAGNETITE($\text{Fe}^{3+}_2\text{Fe}^{2+}\text{O}_4$), PRGASITE $\text{NaCa}_2\text{Mg}_3\text{Fe}^{2+}\text{Si}_6\text{Al}_3\text{O}_{22}(\text{OH})_2$, ZEOPHYLLITE $\text{Ca}_4.2\text{Na}_0.1\text{Si}_{3.1}\text{Al}_{0.2}\text{O}_9\text{F}_2 \cdot 6.2(\text{H}_2\text{O})$

The activity concentrations in Bq/kg dry weight of ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U , and ^{40}K for ten samples from the ground surface of Red Sea coast are represented in table (3) and found in the range of 09.43 ± 0.76 to 18.32 ± 0.75 , 20.26 ± 0.88 to 31.21 ± 0.09 , 10.32 ± 0.80 to 20.33 ± 0.08 , 0.783 ± 0.07 to 0.990 ± 0.23 , and 562.04 ± 0.62 to 1804.63 ± 0.45 with mean values of 14.22 ± 0.65 , 23.77 ± 0.30 , 14.00 ± 0.45 , 0.763 ± 0.11 , and 968.19 ± 0.14 Bq/kg respectively.

The ground surface samples have ^{226}Ra activity concentrations in Bq/kg dry weight higher than ^{238}U activity concentrations in Bq/kg dry weight which means a state of disequilibrium between ^{226}Ra and ^{238}U can be explained by the leaching out of uranium during the processes of alterations, ^{226}Ra has lower solubility in water than ^{238}U , and the difference in the geochemical properties between radium and uranium. Thorium was found to vary with variation of sample types and the same behavior of ^{40}K .

Table (3): The activities concentrations Bq/.kg dry weight of the ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U and ^{40}K for the measured samples at surface.

Samp. No.	Lat. and Long.	^{238}U	^{226}Ra	^{232}Th	^{235}U	^{40}K
1S	N:21° 19' 55.8" E:39° 07' 08.4"	17.38 ± 0.21	22.25 ± 0.44	14.34 ± 0.66	0.990 ± 0.07	644.67 ± 0.05
2S	N:21° 19' 51.6" E:39° 41' 52.8"	09.86 ± 0.07	31.21 ± 0.09	12.65 ± 0.43	0.549 ± 0.09	583.79 ± 0.03

3S	N:21° 19' 51.6" E:39° 06' 39.6"	09.56±0.09	21.71±0.11	15.12±0.08	0.478±0.32	1804.63±0.45
4S	N:21° 20' 18.0" E:39° 06' 30.6"	14.68±0.70	20.91±0.09	12.18±0.08	0.783±0.07	562.04±0.62
5S	N:21° 19' 36.6" E:39° 06' 22.8"	16.08±0.47	20.48±0.33	20.33±0.08	0.848±0.19	1273.02±0.03
6S	N:21° 19' 19.8" E:39° 06' 21.6"	17.30±0.52	22.73±0.10	14.37±0.08	0.976±0.13	1156.70±0.45
7S	N:21° 18' 55.2" E:39° 06' 0.4"	15.90±0.67	20.26±0.88	19.27±0.09	0.831±0.41	1013.20±0.61
8S	N:21° 18' 13.2" E:39° 06' 6.8"	18.32±0.75	20.64±0.10	10.32±0.80	0.990±0.23	1053.42±0.13
9S	N:21° 17' 46.2" E:39° 06' 32.4"	09.43±0.76	27.77±0.05	11.04±0.08	0.497±0.28	988.20±0.32
10S	N:21° 17' 28.8" E:39° 06' 46.8"	13.69±0.73	29.46±0.07	10.39±0.28	0.675±0.21	602.27±0.71
Min.		09.43±0.76	20.26±0.88	10.32±0.80	0.783±0.07	562.04±0.62
Max.		18.32±0.75	31.21±0.09	20.33±0.08	0.990±0.23	1804.63±0.45
Mean		14.22±0.65	23.77±0.30	14.00±0.45	0.763±0.11	968.19±0.14

The activities concentrations Bq/kg dry weight of the ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U and ^{40}K for the measured samples at 0.50 m depth are represented in table (4), The activities concentrations Bq/kg dry weight ranged from 10.27 ± 0.27 to 25.31 ± 0.05 , 17.96 ± 0.04 to 30.78 ± 0.04 , 10.74 ± 0.15 to 28.02 ± 0.16 , 0.570 ± 0.14 to 1.320 ± 0.24 , 367.45 ± 0.65 to 1855.72 ± 0.71 with mean values of 17.01 ± 0.15 , 24.34 ± 0.12 , 17.30 ± 0.15 , 0.911 ± 0.19 , 934.45 ± 0.61 Bq/kg respectively. The results show

that, there is disequilibrium between ^{226}Ra and ^{238}U . Samples 1D, 2D, 3D, 5D, 7D, 8D, and 9D have ^{226}Ra activity concentrations in Bq/kg dry weight higher than ^{238}U activity concentrations in Bq/kg dry weight which can be explained as mentioned above, while samples 4D, 6D, and 10D have ^{226}Ra activity concentrations in Bq/kg dry weight lower than ^{238}U activity concentrations in Bq/kg dry weight because of the escape of radon gas which leads to lower the values of concentrations.

Table (4): The activities concentrations Bq/kg dry weight of the ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U and ^{40}K for the measured samples at 0.50 m depth.

Samp. No.	Lat. and Long.	^{238}U	^{226}Ra	^{232}Th	^{235}U	^{40}K
1D	N:21° 19' 55.8" E:39° 07' 08.4"	14.87±0.07	28.04±0.09	11.14±0.16	0.800±0.91	367.45±0.65
2D	N:21° 19' 51.6" E:39° 41' 52.8"	11.68±0.16	30.78±0.04	28.02±0.16	0.620±0.12	531.60±0.46
3D	N:21° 19' 51.6" E:39° 06' 39.6"	10.27±0.27	23.48±0.03	21.39±0.15	0.590±0.08	1855.72±0.71
4D	N:21° 20' 18.0" E:39° 06' 30.6"	24.68±0.16	21.34±0.03	10.74±0.15	1.320±0.07	455.51±0.03
5D	N:21° 19' 36.6" E:39° 06' 22.8"	12.10±0.07	25.16±0.09	15.85±0.19	0.630±0.08	1120.83±0.04
6D	N:21° 19' 19.8" E:39° 06' 21.6"	24.52±0.15	17.96±0.04	13.50±0.15	1.210±0.08	933.84±0.03
7D	N:21° 18' 55.2" E:39° 06' 0.4"	18.07±0.32	21.27±0.33	14.62±0.16	1.010±0.23	1115.39±0.03
8D	N:21° 18' 13.2" E:39° 06' 6.8"	18.27±0.06	24.85±0.08	19.30±0.12	1.040±0.09	1133.87±0.46
9D	N:21° 17' 46.2" E:39° 06' 32.4"	10.31±0.24	29.15±0.13	19.53±0.15	0.570±0.14	1173.01±0.04

10D	N:21° 17' 28.8" E:39° 06' 46.8"	25.31±0.05	21.34±0.16	18.94±0.16	1.320±0.24	575.09±0.33
Min.		10.27±0.27	17.96±0.04	10.74±0.15	0.570±0.14	367.45±0.65
Max.		25.31±0.05	30.78±0.04	28.02±0.16	1.320±0.24	1855.72±0.71
Mean		17.01±0.15	24.34±0.12	17.30±0.15	0.911±0.19	934.45±0.61

Table (5) and table (6) represent the Radium Equivalent (Bq/kg), Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSvy/h), External Hazard Index for ten samples on the ground surface down to ten samples at depth of 0.50 m.

Table (5): The Radium Equivalent (Bq/kg), Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSvy/h), External Hazard Index for samples on the surface.

Samp. No.	Ra _{Eq} (Bq/kg)	D(nGy/h)	D _{eff} (mSv/y)	H _{ex}
1S	092.53	45.43	0.056	0.250
2S	094.24	45.99	0.056	0.255
3S	182.29	93.15	0.114	0.492
4S	081.61	40.06	0.049	0.220
5S	147.57	73.94	0.091	0.399
6S	132.35	66.61	0.082	0.357
7S	125.83	62.54	0.077	0.340
8S	116.51	58.96	0.072	0.315
9S	119.65	60.01	0.074	0.323
10S	090.69	44.58	0.055	0.245
Min.	081.60	40.06	0.049	0.220
Max.	182.29	93.15	0.114	0.492
Mean	118.33	59.13	0.073	0.320

Table (6): The Radium Equivalent (Bq/kg), Absorbed Dose Rate (nGy/h), Annual Effective Dose, (mSvy/h) External Hazard Index for samples at 0.50m depth.

Samp. No.	Ra _{Eq} (Bq/kg)	D(nGy/h)	D _{eff} (mSv/y)	H _{ex}
1D	072.26	35.02	0.043	0.195
2D	111.78	52.94	0.065	0.302
3D	196.96	99.85	0.123	0.532
4D	071.77	34.75	0.043	0.194
5D	134.13	67.15	0.082	0.362
6D	109.17	54.74	0.067	0.295
7D	128.06	64.39	0.079	0.346
8D	139.76	69.63	0.086	0.377
9D	147.40	73.36	0.090	0.398
10D	092.71	44.88	0.055	0.250
Min.	071.77	34.75	0.043	0.194
Max.	196.96	99.85	0.123	0.532
Mean	120.40	59.67	0.073	0.325

The radium equivalent activity Bq/kg varied from 081.60 to 182.29 Bq/kg with mean values 118.33 Bq/kg for the samples on the ground surface, and from 071.77 to 196.96 Bq/kg with mean value 120.40 Bq/kg, for the samples at 0.50m depth. The radium equivalent activity for all samples are below the internationally accepted value 370 Bq/kg (UNSCEAR, 2000). The Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSvy/h), External Hazard Index for the ground surface samples ranged from 40.06 to 93.15, 0.049 to 0.114, and 0.220 to 0.492 with mean values 59.13, 0.073, and 0.320. For

the samples at 0.50m depth the Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSvy/h), External Hazard Index ranged from 34.75 to 99.85, 0.043 to 0.123, and 0.194 to 0.532 with mean values 59.67, 0.073, and 0.325. These calculated values were lower than the estimated world –averaged values (≤ 1 for D_{eff} (mSv/y) and H_{ex}).

4. Conclusion

The results of analyzed twenty marine sediment samples from south Jeddah coast show that, the major concentrations for the samples are

ALBITE, ARAGONITE, MICROLIN , AUGITE, and QUARTZ. The activity concentrations values of ^{238}U , ^{232}Th series and ^{40}K are within the international limits. There is disequilibrium between ^{226}Ra and ^{238}U in all samples while the equilibrium between ^{226}Ra daughters is clear, also there is equilibrium between ^{232}Th daughters. The Radium Equivalent (Bq/kg), Absorbed Dose Rate (nGy/h), Annual Effective Dose (mSv/h), External Hazard Index are lower than the respective world's average. The results can be considered as base values for distribution of natural radionuclides in the area and will be used as reference information for determining any future changes.

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