Evaluation of environmental hazards resulted from natural radioactivity in rocks from catchment area in Delta Tuban in Yemen

Emran Eisa Saleh[1], Ahmed Ali Al Nagashee[2] , Hesham Ibrahm El Kassas[3], Soad Abed Elmenem El Fiki[4],and Hanan Ahmed Diab[4]

[1] Physics Department, Faculty of Science, University of Aden
[2] Biology Dep., Faculty of Education Toor El baha, University of Aden
[3] Institute of Environmental Studies and Research, Ain Shams University, Egypt
[4] Physics Dep., Faculty of Science, Ain Shams University, Egypt
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Abstract

The knowledge of environmental hazards resulted from natural radioactivity and human activities are very important for monitoring environmental contamination. In this study the environmental hazards due to the natural radioactivity in rocks from catchment area of Tuban delta in Yemen were discussed and evaluated. Eight rocks samples were collected from the study area. The results showed that the mean activity concentrations of ^{238}U series (^{226}Ra), ^{232}Th, and ^{40}K were 29.52 ± 1.5, 32.29 ± 2.3, and 817.5 ± 30.1 Bq kg^{-1}, respectively. Also, the physical and chemical properties of some rock samples were examined and evaluated. Radiological parameter, such as absorbed dose rate in air, annually effective dose, the radium equivalent activity (Ra_{eq}), gamma index (I_γ), external hazard index (H_{ex}), and internal hazard index (H_{in}), were calculated and evaluated. The results were compared with those of literatures.

Keywords: Environmental hazards; Natural radioactivity; Human activities; Tuban delta

Introduction:

The natural environmental radiation mainly comes from radionuclides which are members of the natural radioactive series and ^{40}K. The members of radioactive decay series of ^{232}Th (14%), ^{235}U and ^{238}U (55.8%), along with ^{40}K (13.8%) are responsible for the main contributions to the dose from natural radiation (9).

The concentrations of (^{238}U and ^{232}Th) and radioactive isotope ^{40}K depend mainly on the geological and geographical conditions. The radioactivity of soils linked to the rocks from which it is derived, diminished by the leaching action of moving water, diluted by increased porosity and by added water and organic matter, and augmented by proportion and precipitation of radionuclides from incoming water.

Many natural rocks contain radioactive elements such as ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. Even though these radionuclides are widely distributed, they vary from place to place (2). Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks. There are exceptions, however, as some shale and phosphate rocks have relatively high content of radionuclides (31).

This paper presents the evaluation of environmental hazards resulting from natural radioactivity in rock samples collected from catchment area in Delta of Tuban, Yemen.

Materials and methods

Study area

The Republic of Yemen is located in the southern sector of the Arabian Peninsula. Yemen land is covered with rocks whose ages date back to an era prior to the Cambrian. Some Cambrian rocks even dated to a time before that era (that is, about 3 billion years ago). Geologically speaking, Yemen composes part of the Arabian Shield (3).

The Delta of Tuban is located in the southern part of Yemen. It extends along Lehg and Aden Governorates, the study areas are shown in Fig. (13).

The former wadis; Al-Kabir and Al-Saghir (Wadi Tuban) have large catchment areas of 5090 square kilometers. It is bordered in the north and the northeast by high mountain chains (from 700 to 1500 m) (5).

The large catchment area of wadi Tuban extends upward and drain high mountainous ground. However, the direct annual rainfall on Tuban Delta is very low and hardly goes beyond the 63 mm per year. The mean annual rainfall of Wadi Tuban is 530 mm. Such depth of rainfall constitutes an annual volume of water of 2700 million m^3(6).

Major floods usually occur in both summer and autumn seasons. Along with irrigation by flood water, also, groundwater (abstraction by hand dug wells and tube wells) has been used for irrigation in Tuban delta.

The Yemen Trap series flood basalts occur through the Upper Cretaceous and Lower Tertiary in the northwest part of the study area to the north of the study area, the Yemen Trap series is very extensive and thick (19). Associated with the flood basalts are a swarm of granitic and pegmatitic dykes that strike NW-SE. Several individual dykes with lengths exceeding 50 km (18).

Chemical analysis

1. Particle size distribution was carried out by the international Pipette method using sodium hexametaphosphate as a dispersing agent (25).
2. Calcium carbonate content was measured using the Collin's Calcimeter method, (26).
3.
4. Organic matter content was determined using the modified Walkley and black method as described by Jackson (16).
5. Cation exchange capacity (CEC) and the exchangeable sodium % (ESP) were determined using sodium acetate and ammonium acetate of pH 7, respectively (26).

Sampling and sample preparation for gamma spectrometry

A total of 8 rock samples were collected from the study area. The rock samples were crushed and ground to fine powder and homogenized. The samples were air-dried and dried in an oven at about 100° C. Samples of rocks were sealed in airtight plastic containers of 100 cm^3 and was left for more than one month, before counting by gamma-ray spectrometry, to allow secular equilibrium between ^{226}Ra and its decay products.

Radioactivity Measurements

One of the most valuable techniques for low-level radioactivity measurements is gamma ray spectrometry. The various systems, consisting of semiconductor detectors coupled to multichannel analyzers, provide for rapid simultaneous measurement of many radionuclides in the same sample.
In this work, each sample was measured using HPGe with 35% efficiency and 1.9 keV resolution. The spectrum was collected and analyzed using computer software called Maestro software. These measurements processes were carried out in the Egyptian Atomic Energy Authority Laboratory. The spectrometer was calibrated for efficiency and energy.

Efficiency calibration was done in two stages in the energy range from 186 to 2450 keV. In the first stage, the relative efficiency curve of the detector was obtained using a ^{226}Ra point source. The most intensities gamma rays of ^{226}Ra in equilibrium with its daughters were used. The relative intensities of the photopeaks, corresponding to these gamma-ray lines, were measured by the detector and calculated. The photopeak relative efficiency was obtained by dividing the relative intensity of the photopeak (27) i.e:

$$\varepsilon_{(E)} = I_M(E)/I_R(E) \qquad (2\text{-}1)$$

Where :

$\varepsilon_{(E)}$ is the relative efficiency at energy (E).

I_M is the relative intensity measured by the detector for the photopeak with energy (E), and I_R is the reference relative intensity of the same photopeak.

The relative efficiency curve of the detector was made of 16 different energy values covering the energy range from 186 keV to 1850 keV. Using the results, a curve (fifth order polynomial fitting) was made. The relative efficiency of the detector corresponding to any photopeak energy, can be obtained using this curve.

In the second stage, the relative efficiency curve of the detector was normalized to an absolute efficiency. The normalization has been done by standard solutions of potassium chloride. The radionuclide potassium-40, in the natural potassium, is perhaps the most widely used "standardized" low-level source for beta particle and gamma emitters. Naturally potassium, containing 0.0118% of potassium-40, has a specific activity of about 850 pCi/g (31.45 Bq/g).
Pure KCl is an excellent low-level reference source in many respects: environmental low-level specific activity, wide available at high purity and relatively simple branching decay (15).

Potassium chloride (KCl) has been used by a low-level standard source for efficiency calibration of gamma ray spectrometer used for measuring the large volume of low specific activity materials. The normalization was done using different concentrations of KCl for each geometrical configuration. The used concentrations were 8 g/l, 16 g/l, 32 g/l, and 64 g/l, which correspond to 261.8 Bq/l, 532.6 Bq/l, 1047.2 Bq/l, and 2094.4 Bq/l, respectively. Using these concentrations and the corresponding counting rates, a normalization factor for each measuring geometry was determined (22).

The normalization factor for any radionuclide can be calculated relatively to the potassium chloride solution normalizing factor using the following equation (6):

$$N.F(Y) = \frac{\text{R.E(1460 keV)} \times \text{B.R(K)}}{\text{R.E(Y)} \times \text{B.R(Y)}} \times N.F(K) \qquad (2\text{-}2)$$

Where:

N.F(Y) the normalization factor for (Y) radionuclide, R.E(1460 keV) the relative efficiency of radionuclide (Y), B.R(K) the percentage of photon per disintegration of ^{40}K, B.R(Y) the percentage of photon per disintegration of (Y) nuclide, N.F(K) the normalization factor of ^{40}K. it is calculated as:

$$\text{N.F(K)} = \text{weight of } ^{40}\text{K (in KCl)} \times 16.238/ \text{ count rate of } ^{40}\text{K} \qquad (2\text{-}3)$$

Table: (1) calculation of normalization factors of desired energy lines. The gamma transition for activity calculation of ^{40}K and ^{137}Cs are 1460 keV and 661.6 keV, respectively. For the ^{238}U series they are 351.9 keV (^{214}Pb), 609.3 keV (^{214}Bi) 1120.3 keV (^{214}Bi), and 1764.5 keV (^{214}Bi). For the ^{232}Th series, they are 338.4 keV (^{228}Ac), 583 keV (^{208}Tl), 911.1 keV (^{228}Ac), and 968.9 keV (^{228}Ac).

The activity concentrations of the natural radionuclides in the measured samples were computed using the following relation (15).

$$A_{EI} = NP/t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M \quad (\text{Bq kg}^{-1}) \qquad (2\text{-}4)$$

where NP is the number of counts in given peak area corrected for background peaks of a peak at energy E, $\varepsilon(E_\gamma)$ the detection efficiency at energy E, t is the counting lifetime, $I_\gamma(E_\gamma)$ the number of gamma rays per disintegration of this nuclide at energy E, and M the mass in kg of the measured sample.
The calculated activity concentrations were corrected for the sample density.

Calculation of the radiological parameters

To evaluate the radiation hazard of the measured ^{226}Ra, ^{232}Th and ^{40}K activities, many radiological parameters were calculated. The radium equivalent activity is a weighed sum of activities of the ^{226}Ra. ^{232}Th and ^{40}K radionuclides based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma ray dose rate (20). Radium equivalent activity can be calculated from the following relation suggested by Bertka and Mathew (8).

$$Ra_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \qquad (2\text{-}5)$$

where A_{Ra} is the activity concentration of ^{226}Ra in Bq kg^{-1}, A_{Th} is the activity concentration of ^{232}Th in Bq kg^{-1} and A_K is the activity concentration of ^{40}K in Bq kg^{-1}.

The second radiation parameter is called the external hazard index (H_{ex}). This criterion considers only the external exposure due to the emitted gamma-ray and corresponds to a maximum

Ra_{eq} of 370 Bq kg^{-1} for the materials. The value of this index must be less than unity for the radiation hazard to be negligible.

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad (2\text{-}6)$$

where A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K, respectively. The calculated average external hazard index was found to be less than unity.

In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs. To assess the internal exposure to ^{222}Ra gas and its daughter products the internal hazard index has been defined by Bertka and Mathew as:

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad (2\text{-}7)$$

where A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K, respectively. For the safe use of a material in the construction of dwelling, H_{in} should be less than unity.

In order to examine whether the samples meet these limits of dose criteria, another radiation hazard index, the representative level index, I_γ, were used to estimate the level of gamma-radiation hazard associated with the natural radionuclides in specific investigated samples, from the following equation (21):

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (2\text{-}8)$$

Where A_{Ra} , A_{Th} and A_k are the activity concentration of ^{226}Ra , ^{232}Th and ^{40}K, respectively, in Bq kg^{-1}.

The total air absorbed dose rate (nGy h^{-1}) due to the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}) can be calculated using the formula of (Beck, et al., 1972) (7) and (UNSCEAR, 1988) (30)

$$D = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.042\ A_K \quad (2\text{-}9)$$

where: A_{Ra}, A_{Th} and A_K are the mean activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K, respectively, in Bq kg^{-1}.

Beck et al. (7) derived this equation for calculating the absorbed dose rate in air at a height of 1.0 m above the ground from measured radionuclides concentrations in environmental materials.

In addition, the annual effective dose rates indoors (E) (measured in mSv y^{-1}) was calculated assuming a value of 0.7 Sv/Gy for the conversion factor from absorbed dose in air to annual effective dose received by adults and a 0.8 factor for the indoor occupancy (32). The formula used is:

$$E\ (\mu Sv\ y^{-1}) = d\ (nGy\ h^{-1}) \times 24\ h \times 365.25\ d \times 0.8 \times 0.7\ Sv/G\ y \times 10^{-6} \quad (2\text{-}10)$$

The annual effective dose of a member of the public by 0.3 mSv y^{-1} at the most, which is the excess gamma dose to that received outdoors. Within the European Union, doses exceeding 1 mSv y^{-1} should be taken into account from the radiation point of view (10).

Results and discussion

Physicochemical properties of rocks samples

Textural classes of the studied rocks samples

Textural analysis has been performed to classify the studied rocks into their main types (28). Table 2 shows the textural analysis of some rocks samples collected from the study area, these types are the silt loam, clay loam, silt clay, and silty clay loam.

Total salinity

Several classification systems were elaborated to set up an adequate standard for covering the measured EC of the rocks saturation extract into salinity classes. The approximate limits of salinity classes were defined in the Soil Survey Staff Manual (28), as in Table (3). As shown in Table (4) electrical conductivity of some samples saturation extracts (EC) of the rocks from catchment area of Tuban delta,

three samples fall in the Salt-free class, two samples fall in the slightly saline class and three samples fall in the moderately saline class.

Organic matter and Calcium Carbonate contents

Organic matter content in samples under study is extremely high (exceeding 6.1 g/kg) in all of the studied samples. Organic matter ranges from 0.52 to 1.22 % for rocks. Also, data in the Table (4) illustrate, that both calcium carbonate ($CaCO_3$) values range from 7.56 to 13.50 % for rock samples, these results reveals that these rocks samples are calcareous.

Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR), is defined by

$$SAR = \frac{Na^+}{\sqrt{0.5(Ca^{2+} + Mg^{2+})}} \quad (3\text{-}1)$$

where the concentration of the cations is in meq/l. It indicates the degree to which cation exchange reactions occur in the soil. As sodium replaces Ca and Mg on clays and colloids, it causes the expansion or "swelling" of clay particles and leads to a reduction in permeability and hardening of the soil. SAR should remain low enough so that Na occupies a low portion of the exchange complex. The structure and drainage properties of most soils remain good when SAR values remain below 10 (14).

The quality classification of rock samples, based on SAR value is given in Table (4).

Table (4) shows that rock sampled from the study area are 5 samples were high, 2 samples were low sodium hazard.

Cationic and Anionic composition

Table 4 shows the cationic and anionic composition of some rock samples, the soluble cat ions are often dominated at the studied samples with Ca^{2+}, Mg^{2+}, and Na^+ while K^+ is the least soluble cat ion.

Regarding the anionic distribution, CO_3^{2-} is absent in all of the studied samples. The distribution of the other anionic followed the descending order: $Cl^- > SO_4^{2-} > HCO_3^-$ for all studied samples.

Radioactivity concentrations

A summary of measurements for the activity concentrations (Bq kg^{-1}) of the natural radioactivity due to ^{238}U series(^{226}Ra), ^{232}Th, and ^{40}K of rocks samples are given in Table 5. From the table, the activity concentrations of ^{238}U series(^{226}Ra) ranged from 7.0 ± 0.5 (limestone rock) to 75.5 ± 3.3 (volcanic rock) with an average value 29.25 ± 1.5 Bq kg^{-1} . ^{232}Th activity concentrations in rock samples ranged from 10.12 ± 1.7 (limestone) to 58 ± 3.5 (volcanic) with an average value 32.29 ± 2.3 Bq kg^{-1}. ^{40}K values ranged from 307.7 ± 11.8 to 1465.3 ± 51.3 with an average value 817.5 ± 30.1 Bq kg^{-1}.

Volcanic rock samples show significantly higher concentrations of ^{238}U series(^{226}Ra), and ^{232}Th when compared with limestone rocks, while the high activity concentration of ^{40}K was found in samples (1 and 3) limestone rocks.

From the Tables 3-1 and 3-4 the increase of activity concentrations of ^{238}U series (^{226}Ra) and ^{232}Th was noticed with increase of percentage of clay in rocks, this may be due to the increase of clay minerals, montmorillonite and kaolinite.

The activity concentration of ^{40}K in rocks is higher than that of ^{238}U series(^{226}Ra) and ^{232}Th for all samples, this is also in accordance with the well-known fact that potassium in the earth's crust is of the order of percentage whereas uranium and thorium are in ppm level (30). The average concentrations of ^{40}K in samples under study are higher than the worldwide average concentrations of ^{40}K (412 Bq kg^{-1}) in soil(32) while the average activity concentrations of ^{226}Ra and ^{232}Th, for samples under study are agreed worldwide with the average concentrations of this radio nuclides in soil (32, 45 Bq kg^{-1}), respectively.

The results for the radium equivalent activity, gamma index, (external and internal) hazard index, absorbed dose rate in air, and annual effective dose of the present work are presented in Table 6. It is observed that the calculated radium equivalent in rocks is lower than the allowed maximum value of 370 Bq kg^{-1} (16). The calculated H_{ex} and H_{in} values for the samples under investigation do not exceed the upper limit for H_{ex} and H_{in} which is unity. The absorbed dose rate for rock samples exceeds the upper limit for absorbed dose rate and annual effective doses which is 59 nG h^{-1},

except samples (2 and 8) and the annual effective doses for rocks under study are lower than the allowed maximum value of 1 mSv y^{-1} (32).

Table 7 represents a comparison of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations Bq kg-1 for rocks in our study with those from Yemen and world studies. From the table, it can be seen that the average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in our study are lower than those from Assalamya-Alhomira area reported by El Kamel et at., (12) and higher than from Sana'a and in the same range with those from Juban area reported by El Mageed et al., (13) in Yemen. Also, it can be seen that ^{226}Ra average activity concentration in our study is lower than those obtained from studies in different rocks from Egypt (Bir El-Sid, Wadi El-Gemal, Gabal Elba and Qena), and higher than those in the other countries (India (Kaiga), Ghana (Shai hills), China (Shaanaxi) and Kenya, while ^{226}Ra obtained from our study area is in the same range with those in other countries (Brazil, Greece, Cyprus). ^{232}Th activity concentration obtained from our study is lower than those obtained from studies in different rocks from Egypt (Bir El-Sid, Wadi El-Gemal, Gabal Elba and Qena), China (Shaanaxi), Cyprus, Greece and Brazil and higher than from (Kenya, India (Kaiga), Ghana (Shai hills. ^{40}K activity concentration in our study is higher than those from India (Kaiga) and Ghana (Shai hills), and lower than that from other countries (Egypt (Bir El-Sid, Wadi El-Gemal, Gabal Elba, Qena), Kenya and Chaina (Shaanaxi), and in the same range with those from other countries Cyprus, Brazil and Greece.

Conclusion

1. Physical and chemical properties for some rock samples were discussed. The rocks under study are characterized by a texture mainly clay loam.

   The organic matter content in samples under study is extremely high (exceeding 6.1 g/kg) in all of the studied samples, also, calcium carbonate ($CaCO_3$) values in samples under study were high, this means that the rock samples under study are calcareous.

   The cationic and anionic composition of samples under study are dominated at the studied samples with Ca^{2+}, Mg^{2+}, and Na^{+} while K^{+} is the least soluble cat ion. For the soil $Na^{+} > Ca^{2+} > Mg^{2+}$, The predominance of Na^{+}, Ca^{2+}, and Mg^{2+} is a true reflection of the involvement of marine origin in soils formation.
2. Rock samples collected from catchment area in the Delta of Tuban in Yemen were evaluated for their radioactivity content. The results show that the mean concentration values of ^{238}U series (^{226}Ra), and ^{232}Th were 29.25 and 32.29, Bq kg^{-1}, respectively. These results are below the recommended levels by UNSCEAR report. The average activity concentration of ^{40}K is 817.5 Bq kg^{-1} which is higher than the recommended levels by UNSCEAR report.
3. The means of radium equivalent activity (Ra_{eq}), gamma index (I_γ), external hazard index and internal hazard index, for samples under investigation are 138.4 Bq kg^{-1} , 0.53 , 0.37 and 0.45,respectively, these values are below the recommended value reported by UNSCEAR.
4. The average absorbed dose rate and annually effective dose were 67.23 nGy y^{-1} and 0.46 mSv, respectively, these values are slightly higher than the recommended value reported by UNSCEAR which is 55 nGy y^{-1} and 1 mSv.

Table: (1) calculation of Normalization factors of desired energy lines

Efficiency	N. Factor	B. G	B.R	Energy (keV)	Daughter	Parent
0.00275	1865.844	0.00205	19.5	295	Pb-214	
0.00243	1107.373	0.002913	37.1	351	Pb-214	
0.00159	1363.256	0.00254	46.1	609	Bi-214	^{238}U
0.00099	6707.541	0.00145	15	1120	Bi-214	
0.00070	8980.364	0.00081	15.9	1764	Bi-214	
0.00274	3214.749	0	11.357	338	Ac-228	
0.00166	1966.21	0.00228	30.6	583	Tl-208	^{232}Th
0.00122	2957.553	0	27.7	911	Ac-228	
0.00126	5170.37	0	15.3	969	Ac-228	
0.00149	786.1248	0	85.1	661.6	^{137}Cs	^{137}Cs
0.00081	11535.89	0	10.7	1460.6	^{40}K	^{40}K

Table (2) Particle size distribution of the rocks under investigation

Gypsum (%)	Texture	Particle size distribution				S.No.
		Clay	Silt	F.Sand	C. Sand	
0.27	SL	23.92	64.55	8.56	2.97	R1
0.28	SL	21.58	64.30	10.52	3.51	R2
0.12	CL	26.82	52.28	18.77	2.13	R3
0.38	CL	38.58	44.63	14.81	1.98	R4
0.09	SL	16.02	69.08	12.75	2.15	R5
0.18	SCL	27.99	56.66	12.23	3.12	R6
0.30	SC	43.29	47.78	7.84	1.09	R7

SL=Silty loam, SCL= Silty clay loam, CL= Clay loam, SC= Silty clay.

Table (3) Classification of saline soils, (Soil Survey Staff Manual, 1951)

EC dSm^{-1} at 25ºC	Class Name	Soil class
0-4	Salt free	0
4-8	Slightly saline	1
8-15	Moderately saline	2
>15	Stroungly saline	3

Table 4 Physical and chemical analysis of the studied rocks samples

Soluble anions (mmole l^{-1})				Soluble cations ($mmolel^{-1}$)				ESP %	SAR %	Organic matter %	$CaCO_3$ %	EC (dS/m)	pH	Type of sample
SO_4^{2-}	Cl^-	HCO_3^-	CO_3^{2-}	K^+	Na^+	Mg^{2+}	Ca^{2+}							
48.8	150.0	3.0	*	1.60	100.0	30.2	15.0	22.99	21.10	0.52	10.27	14.82	8.40	R1
46.70	145.0	2.50	*	1.7	147.0	23.0	2.20	36.90	41.41	0.60	3.50	16.29	8.28	R2
8.10	40.00	2.0	*	0.40	41.0	3.80	4.9	21.73	19.71	0.64	7.56	4.61	7.80	R3
8.99	48.09	2.50	*	0.49	47.20	4.90	6.90	18.67	19.42	0.56	10.12	5.48	7.86	R4
3.70	7.00	3.00	*	0.10	7.20	2.00	4.40	4.16	3.80	0.65	9.52	1.31	8.96	R5
166.0	17.00	2.00	*	0.40	17.40	10.70	8.10	6.6	5.68	0.55	11.96	3.33	8.14	R6
24.85	71.0	2.5	*	0.85	72.5	5.20	19.80	22.45	20.48	1.22	9.33	8.51	7.74	R7

Table 5 The Activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs for rocks samples under study

Activity concentrations (Bq kg^{-1})			Location	Rock type	S.No.
^{40}K	^{232}Th	^{226}Ra			
1427.2±50.3	32.24±1.35	11.86±1.19	N	Limestone	1
770.1±30.8	27.6±2.4	9.8±0.9	N	Limestone	2
1465.3±51.3	38.1±1.5	8.8±1.2	N	Limestone	3
307.7±11.8	10.12±1.7	7.0±0.5	N	Limestone	4
582.3±25	17.6±1.12	63.7±2.8	NW	Basalt	5
661.5±23	50.76±4.9	26.7±1.13	NW	Basalt	6
512.5±21.7	23.9±3.3	75.5±3.1	NW	Basalt	7
813.7±28.7	58±3.5	30.7±1.8	NW	Basalt	8
817.5±30.1	32.29±2.3	29.25±1.5			Mean

Table 6 The calculated values of radium equivalent, gamma index, (external, internal) hazard index, total absorbed dose and annual effective dose in samples under investigation.

E (mSv y^{-1})	Dose rate (nGy h^{-1})	H_{in}	H_{ex}	I_γ	Ra_{eq} (Bq kg^{-1})	S. No.
0.59	85.4	0.49	0.45	0.68	167.9	R1
0.37	53.6	0.32	0.29	0.43	108.6	R2
0.61	89.1	0.50	0.48	0.71	176.1	R3
0.44	64.2	0.53	0.36	0.49	133.7	R4
0.48	70.1	0.48	0.41	0.56	150.2	R5
0.48	70.3	0.61	0.40	0.54	149.1	R6
0.57	82.7	0.56	0.48	0.66	176.3	R7
0.15	22.3	0.14	0.12	0.18	45.2	R8
0.46	**67.23**	**0.45**	**0.37**	**0.53**	**138.4**	**mean**

Table 7 Comparison of mean activity concentrations (Bq kg^{-1}) in rocks with other countries of the world

Reference	Activity concentrations Bq kg^{-1}			Country
	^{40}K	^{232}Th	^{226}Ra	
Present work	817.5±30.1	32.29±2.3	29.25±1.5	Tuban delta, Yemen Yemen
El Mageed et al., 2010. El Kamel et al., 2012.	399.4±16	19.15±2.6	22.4±3.	Yemen, Sana'a
	190.9±15-2341±78	22.3±2.9-127±6.7	32.1±3-55±4	Juban
	ND-1618±52	28.8±3.3-4125±124	48.68±6.7-769.5±39	Assalamya- Alhomira
	263.9±11-2208±91	12.5±3-148.5±12	7.5±1.5-118±7	Egypt (different Rocks)
Ahmed et el., 2006.	1041±76.6	53.4±5.4	57.4±4.5	Bir El-Sid, Egypt
	1031±75	47.9±5.1	39±3.2	Wadi El-Gemal, Egypt
Khaled., 2006	1430±47	107.9±9.5	162.8±11	Gabal Elba, Egypt
Ahmed., 2005	852	118	187	Qena, Egypt
Mustapha et al., 1997.	931.3	24.7	23.1	Kenya
Trortzis et al., 2004	50-1606	1-906	1-583	Cyprus
Xinwei et al., 2006	968.5	75.9	22	China (Shaanxi)
Papastefanou et al., 2005	49-1592	30-354	1.6-170	Greece
Anjos et al., 2005	190-2028	4.5-448.5	5.2-169	Brazil
Patra et al., 2006	349.6	8.1	4.3	India, Kaiga
Yeboah et al., 2001	86.3±10	9.9±1.3	1.6±0.2	Ghana, Shai hills

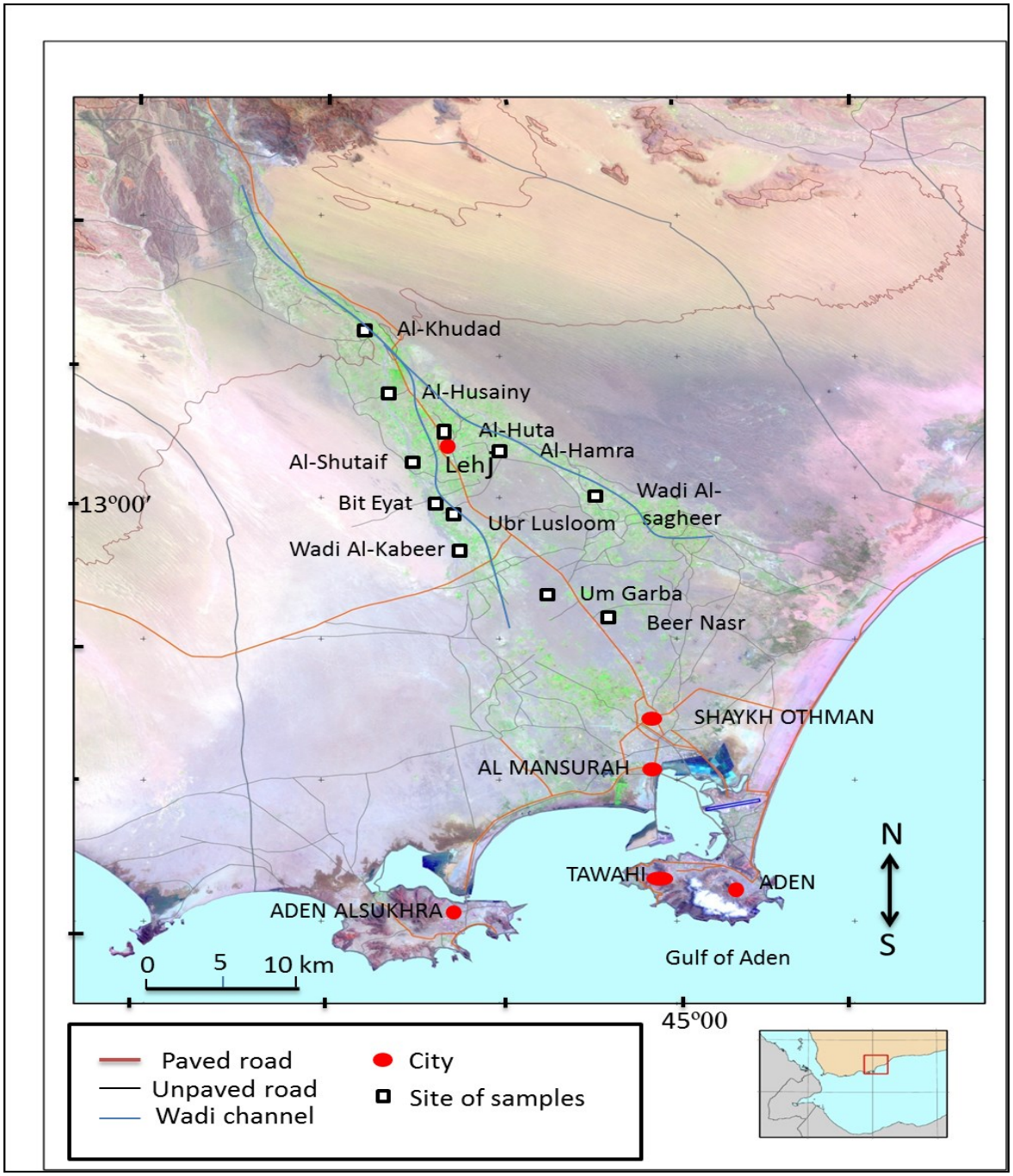

Figure 1 Base Map of the Tuban Delta, Rubablic of Yemen

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تقييم المخاطر البيئية الناتجة من النشاط الإشعاعي الطبيعي في الصخور من منطقة الاستجلاب لدلتا تبن في اليمن

عمران عيسى صالح[1] ، أحمد علي النجاشي[2]، هشام إبراهيم القصاص[3]، سعاد عبدالمنعم الفقيه[4] و حنان احمد دياب

قسم الفيزياء، كلية العلوم، جامعة عدن[1]

فسم الأحياء، كلية التربية – طور الباحة، جامعة عدن[2]

معهد الدراسات البيئية، جامعة عين شمس، مصر [3]

فسم الفيزياء ، كلية العلوم، جامعة عين شمس، مصر[4]

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الملخص

إنَّ معرفة ودراسة الاخطار البيئية الناتجة من النشاط الإشعاعي الطبيعي والانشطة الانسانية تعد مهمة من أجل رصد التلوث البيئي لأي منطقة في العالم. تهدف الدراسةِ الحالية إلى تقدير تركيز النشاط الإشعاعي للنظائر المُشعّة الراديوم-226 والثوريوم-232 والبوتاسيوم-40 في الصخور من منطقة وادي تبن، محافظة لحج في اليمن وتأثيرها على صحةِ الإنسان والبيئة الزراعية. استعمل للقياس مطياف جاما المكون من كاشف الجرمانيوم العالي النقاوة وذلك بمعامل الهيئة العامة للطاقة الذرية المصرية، والمتصل بمحلل عديد القنوات (8196 قناة). تمَّ جمع تسع عينات من الصخور من منطقة الدراسة (دلتا تبن) وتمَّ إعداد العينات لقياس النشاط الإشعاعي الطبيعي (الراديوم- 226 , الثوريوم-232 , البوتاسيوم-40) . أظهرت نتائج الدراسة أنَ متوسط تركيز النشاط الاشعاعي الطبيعي (الراديوم- 226 , الثوريوم-232 , البوتاسيوم-40) كانوا 29,52 ± 1,5، 32,29 ± 2,3 و 817,50 ± 30,1 بيكريل / كجم على التوالي. تم ايضاً حساب المخاطر والجرعات الإشعاعِية التي يتعرض لها الإنسان من هذه النويدات المشعة. ايضاً تم دراسة الخواص الفيزيائية والكيميائية لعينات الصخور من منطقة الدراسة. وتم مقارنة النتائج بالدراسات السابقة من مختلف البلدان في العالم.

الكلمات المفتاحية: أخطار بيئية، الإشعاع الطبيعي، الأنشطة البشرية، تبن لحج.