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Assessment of Radioactivity Levels and Annual Dose Intake from Water Consumption in Sohag Governorate, Egypt

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ABSTRACT

In this study, the activity levels of ^{226}Ra, ^{232}Th and ^{40}K in (*Bq/l*), the associated total dose intake in (*mSv/y*) and lifetime cancer risk have been analyzed and discussed in water samples collected from different locations in Sohag governorate, Egypt. All the samples were measured at the Radiation Protection Department in the Egyptian Nuclear and Radiological Regulatory Authority using N-type HPGe detector. The average activity concentrations for all samples were 0.27, 0.06 and 1.61 (*Bq/l*) with maximum values 0.38, 0.19 and 2.53 (*Bq/l*) for ^{226}Ra and ^{232}Th and ^{40}K respectively. The total dose intake scored for water consumption for different age groups for all samples is lower than that recommended by WHO. Lifetime cancer risk, as a result of ingestion of radionuclides by adults from the sampled area, shows that an average of 185.8 out of 1,000,000 may go through some of the fatality cancer developing and 6.7 out of 1,000,000 may go through some of the hereditary effects.

INTRODUCTION

Radionuclides of natural origin exist in varying amounts in water [1] which is strongly related to the common naturally occurring radionuclides in the two primordial radioactive series (Uranium-238 and Thorium-232 series) and radioactive potassium-40 [2]. The parent elements (^{238}U and ^{232}Th) of the two natural radioactive series generate radioactive progenies by alpha or beta particle decays and gamma rays' emission of chemical properties, solubility, mobility, half-life and physical features different from those of the parent elements. The mobility of radionuclides in water strongly depends upon the radionuclide's solubility and geochemical behavior which may be different from the parent element [3]. Many radionuclides in the radioactive decay series of ^{238}U are highly radiotoxic, where the most radiotoxic among them is radium, which is known as a carcinogen [4]. The two natural isotopes of radium that are considered of high concern in water supplies are ^{226}Ra, an alpha emitter produced through the ^{238}U disintegration, and ^{228}Ra, beta-emitter which is produced directly by ^{232}Th decay. The distributions of ^{226}Ra and ^{228}Ra in water are a function of the ^{238}U and ^{232}Th contents. The metabolic behavior of radium in the human body is similar to calcium [5]. When humans ingest radium, about 20% is absorbed into the bloodstream and initially distributed to soft tissues and bone [6]. ^{40}K is the primary radioactive isotope of potassium [5]. The concentration of ^{40}K in the body is kept under control by hemostatic balance [2]. The ingestion of natural radionuclides depends on the consumption rates of water and the radionuclide concentrations. Of absorbed uranium, 66% is rapidly rejected by urine while the residual is distributed and may be accumulated in the kidney, bone and soft tissues. The net of expelling of such radionuclide from the tissue and organ counts on the biological half-life [3]. The accumulative lifetime risk to 1 million persons from intake 5 *pCi/l* of ^{226}Ra a day was 9 bone and 12 head cancers and for ^{228}Ra was 22 bone cancers per million persons and for ^{238}U could lead to 1.5 more bone cancers per million persons [3]. ^{226}Ra activity concentration as recommended by the WHO is 1 *Bq/l* [4] and the assigned reference for the annual effective dose is 0.1 *mSv/y* for water consumption [4].

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In the present paper, a study was performed to measure the activity levels of ^{226}Ra, ^{232}Th, and ^{40}K and calculate the dose intake from water consumption. The study also aims to assess the cancers developing and the heavy metals and physical and chemical properties for water samples taken from different locations in Sohag governorate, Egypt.

Samples collection and preparation

Different water samples were collected from 10 wells of varying depths (35-55m) scattered in different locations in Sohag governorate. 5 liters plastic containers capacity were used for collecting the samples. Each container was filled to the brim and a tight cap was pressed on so that the container became air free. The water was then taken to the laboratory and processed through evaporation to 1-liter volume. Marinelli beakers of 1-liter volume capacity, previously washed, rinsed with dilute acid, were filled with the water of each sample and firmly sealed. The samples were stored for 30 days to allow the state of equilibrium to be reached before radiometric analysis was performed.

Gamma counting

All the samples were measured at the Radiation Protection Department in the Nuclear and Radiological Regulatory Authority, Egypt using a closed end-coaxial Canberra N-type HPGe detector of vertical configuration, with 40% relative efficiency and 2.0 KeV energy resolution at 1.33 MeV photons of ^{60}Co. The detector is shielded by a lead shield detector with an outer jacket of 9.5 mm thick of low carbon steel, a bulk shield of 10 cm thick and a graded lining of 1 mm tin and 1.6 mm copper. The spectra were analyzed using CANBERRA (Genie 2000) program. The detector was calibrated by radioactive standards of known energies. The background was measured under the same conditions to correct the calculated sample activity concentrations. Validation of the accuracy of the calibration by using Lab SOCS software for mathematical efficiency calibration of Ge detectors for laboratory samples with the same geometry shape was verified. Quality assurance was carried out by analysis of IAEA-381 and SOIL 6 reference materials with a known concentration. The activity of ^{226}Ra was determined from the photo peaks of ^{214}Pb (295.22, 351.93 KeV) and ^{214}Bi (609.31, 1120.29, 1764.49 KeV). The transition lines of ^{228}Ac (911.2, 968.97 KeV), ^{212}Pb (238.63 KeV), and ^{208}Ti (583.19, 2614 KeV) were used to determine the activity of ^{232}Th while ^{40}K was determined from the 1460.8 KeV photopeak.

The activity concentration

The activity levels (A_S) in (*Bq/l)* of the ^{226}Ra, ^{232}Th and ^{40}K radionuclides in the samples was calculated using the equation [7].

$$A_s = \frac{C_a}{\varepsilon_\gamma \times M_s \times t_c \times p_\gamma} \quad \textbf{(1)}$$

Where A_s is the sample levels, C_a is the net count, ε_γ is the efficiency of the detector, M_s is the sample volume, t_c is the total counting time and p_γ is the Abundance of the γ-line.

Radiation health hazard indices

Radium equivalent *(Ra_{eq})*

The activity levels of samples having different levels of ^{226}Ra, ^{232}Th and ^{40}K have been indicated in terms of radium equivalent (Ra_{eq}) in (*Bq/l)* which is calculated as follows [8].

$$Ra_{eq}\ (Bq/l) = A_{s(Ra)} + 1.43\ A_{s(Th)} + 0.077\ A_{s(K)} \quad \textbf{(2)}$$

Where $A_{s(Ra)}$, $A_{s(Th)}$ and $A_{s(K)}$ are the activity levels of ^{226}Ra, ^{232}Th and ^{40}K in (*Bq/l)* respectively.

Total dose intake

The total dose intake of ^{226}Ra, ^{232}Th and ^{40}K from drinking water were measured for different age groups as follows [5].

$$D_{(eff)} = A_s(W) \times C_R(W) \times C_F(W) \quad \textbf{(3)}$$

Where $D_{(eff)}$ is the dose intake *(Sv/y)*, $A_S(W)$ is the activity levels of radionuclides in the ingested drinking water *(Bq/l)* and $C_R(W)$ is the annual intake of drinking water *(l/y)* which is 150, 350, and 500 l for infants, children and adults respectively and $C_F(W)$ is the ingested dose conversion factor for related radionuclide *(Sv/Bq)* [5].

Table (1): The conversion factors C_F *(W)* of the related radionuclides [5]

Age Group	^{226}*Ra* × 10^{-7}*(Sv/Bq)*	^{232}*Th* × 10^{-7}*(Sv/Bq)*	^{40}*K*× 10^{-7}*(Sv/Bq)*
Infants	9.6	4.5	5
Children	8	2.9	5
Adults	2.8	2.3	5

Cancer Risk

The radiation effects from water taking were estimated in adults using the (ICRP) cancer risk methodology [9].

In this study, the health risks to individuals as a result of exposure to low-dose radiation were estimated as follows [7, 9].

$$L_{FC} = D_{(eff)}\,(Sv)\times C_F \times L_E \quad \textbf{(5)}$$

$$L_{FH} = D_{(eff)}\,(Sv)\times C_H \times L_E \quad \textbf{(6)}$$

Where L_{FC} is the lifetime cancer fatality risk and L_{FH} is the lifetime cancer hereditary risk and C_F and C_H are caner effect coefficients of 5.5×10^{-2} and 0.2×10^{-2} (Sv^{-1}) for fatality and hereditary risk respectively reported by ICRP and L_E *is the* lifetime of continuous exposure of the population to low-level radiation which assumed to be 70 years [7, 9].

RESULTS AND DISCUSSIONS

The activity levels of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the water samples were calculated using equation (1). The measured activity levels of ^{226}Ra, ^{232}Th and ^{40}K in (*Bq/l)* for the samples are listed in Table (2) and Fig. (1). From the data listed in Table (2), the average activity concentrations were 0.27, 0.06 and 1.61 (*Bq/l)* with maximum values 0.38, 0.19 and 2.53 (*Bq/l)* for ^{226}Ra and ^{232}Th and ^{40}K respectively. The ^{40}K concentrations in all samples are higher than that of ^{226}Ra and ^{232}Th and the activity levels of ^{226}Ra, ^{232}Th and ^{40}K radionuclides have the following order ^{40}K>^{226}Ra>^{232}Th.

By comparing data of the present study with available similar studies for other countries it is clear that, ^{226}Ra activity concentrations of the present study match with the values reported by Isam, et al. of 0.016 to 4.9 (*Bq/l)* in Sweden [10], Godoy, et al. of 0.01 to 3.79 *(Bq/l)* in brazil [11], the values reported by Ahmed of an average 0.08 *Bq/l* in Qena and 0.01 *Bq/l* in Safaga - Quseir [12], Salonen of 0.01 to 49 (*Bq/l)* in Finland [13], Hany El-Gamal et al. of 0.19 to 0.25 (*Bq/l)* in Assiut [5] and lower than the values reported by L. I. Nwankwo of an average 3.7 *Bq/l* in Nigeria [14] and those reported by Najat K. Mohammed et al. of 2.1 to 2.5 (*Bq/l)* in Tanzania [15]. ^{232}Th values of water samples for the present study match with the values reported by El-Arabi, et al. of .21 to 0.79 (*Bq/l)* [16] in Egypt, Ahmed of an average 0.04 *Bq/l* in Qena and 0.05 *Bq/l* Safaga – Quseir and are lower than the values reported by Saqan, et al. of 1.42 to 2.37 (*Bq/l)* in Jordan [17], Najat K. Mohammed et al. of an average 1.9 and 1.8 (*Bq/l)* in Tanzania [8] and those reported by Hany El-Gamal et al. of 0.058 to 0.1 *(Bq/l)* in Assiut [5].

Table (2): The activity concentration, Radium equivalent, Total dose intake and life time cancer risk of natural radionuclide ^{238}U, ^{232}Th and ^{40}K for water samples of different locations

Samples ID	Activity concentration *(Bq/l)*			Ra_{eq} *(Bq/l)*	Total dose intake *(mSv/y)*			Lifetime cancer risk × 10^{-6}	
	^{226}Ra	^{232}Th	^{40}K		Infants	Children	Adult	Fatality risk	Hereditary risk
A_1	0.28	---	0.50	0.32	0.041	0.079	0.040	155.194	5.643
A_2	0.14	0.15	2.49	0.54	0.031	0.057	0.042	162.355	5.904
A_3	0.33	0.12	2.26	0.67	0.057	0.108	0.065	249.971	9.090
A_4	0.29	0.16	2.29	0.70	0.054	0.102	0.065	250.106	9.095
A_5	0.17	---	0.26	0.19	0.025	0.049	0.025	90.631	3.502
A_6	0.38	---	0.50	0.42	0.054	0.107	0.054	209.094	7.603
A_7	0.20	0.19	2.20	0.63	0.043	0.078	0.054	209.796	7.629
A_8	0.30	---	2.26	0.47	0.044	0.087	0.047	180.786	6.574
A_9	0.36	---	0.80	0.42	0.052	0.102	0.052	201.740	7.336
A_{10}	0.22	---	2.53	0.41	0.034	0.066	0.037	142.883	5.196
MAX.	0.38	0.19	2.53	0.70	0.057	0.108	0.065	250.106	9.095
Average	0.27	0.06	1.61	0.48	0.044	0.083	0.048	185.824	6.757

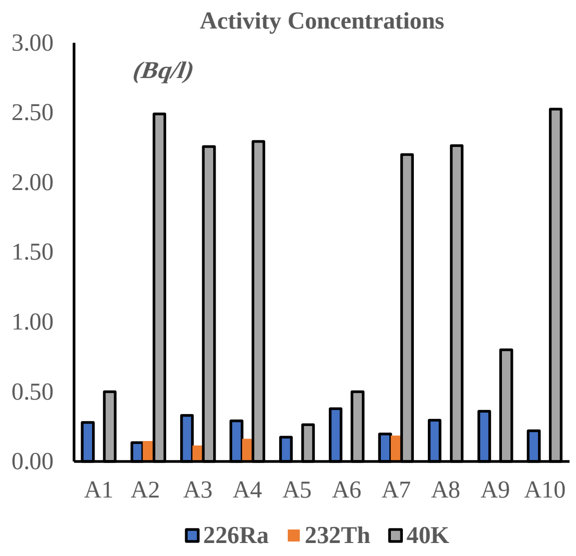

Fig. (1): Activity concentrations in (*Bq/l*) for water sample of different locations

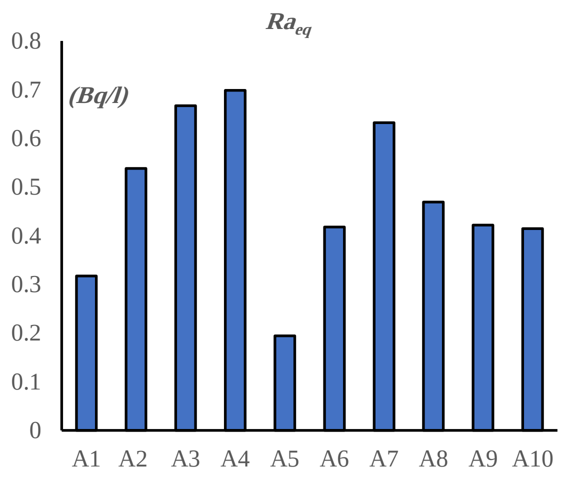

Fig. (2): Radium equivalent in (*Bq/l)* for water sample of different locations

^{40}K values of the present study are lower than the values reported by Saqan, et al. *of* 23.2 to 34.8 *(Bq/l)* in Jordan [17], El-Arabi, et al. of. 9.7 to 23 *(Bq/l)* in Egypt [16] and matches with those reported by Hany El-Gamal et al. of 0.6 to 0.9 *(Bq/l)* in Assiut [5].

From the results listed in Table (2) and Fig. (2), Ra_{eq} in (*Bq/l)* varied from 0.19 to 0.7 (*Bq/l)* with an average value of 0.48 *Bq/l* for water samples of different locations.

Table 2 and Fig. 3 summarizes the different values of the total dose intake for different age groups, where the values of the total dose intake of different locations varied from 0.031 to 0.057 *(mSv/y)* with an average value of 0,044 *mSv/y* for infants, 0.049 to 0.108 (*mSv/y)* with an average value of 0.083 *mSv/y* for children and from 0.037 to 0.065 (*mSv/y)* with an average value of 0.048 *mSv/y* for adult. from table 2 and Fig. 3, It can be noticed that the total dose intake *in (mSv/y)* received by children is higher than that received by infants and adults for all water samples of different locations. The total dose intake *in (mSv/y)* scored for the water consumption of the mentioned locations for infants, children and adults is lower than that recommended by WHO [18] and UNSCEAR [19].

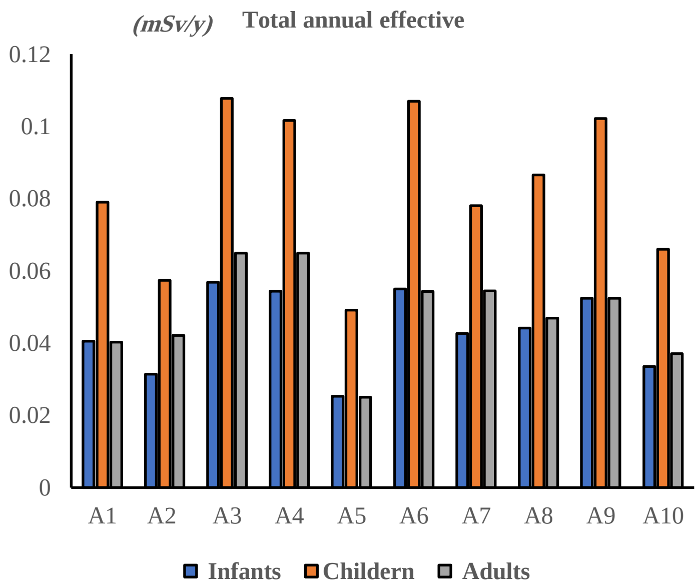

Fig. (3): Total annual effective dose in (*mSv/y)* of water consumption for different locations

According to results in Table (1), lifetime fatality cancer varied from 142.88×10^{-6} to 250.11×10^{-6} with an average value of 185.82×10^{-6}, while the lifetime hereditary effects in adults varied from 3.50×10^{-6} to 9.09×10^{-6} with an average value of 6.76×10^{-6}. The findings show that an average of 185.8 out of 1,000,000 may go through some of the fatality cancer developing and 6.7 out of 1,000,000 may go through some of the hereditary effects.

Table (3): Cations and heavy metal content of water samples of different locations

Samples ID	Element in *(Mg/l)*								
	Cd	Fe	K	Mg	Na	Cu	Zn	Mn	Ca
A_1	0.006	---	14.39	129.10	56	0.008	---	0.012	45.6
A_2	0.008	---	9.49	78.60	136	0.002	---	0.005	328
A_3	0.009	---	12.26	111.60	138	0.009	0.006	0.001	89.9
A_4	0.010	---	9.85	93.00	14	---	---	0.004	35.7
A_5	0.009	---	4.56	96.00	19	0.036	---	0.002	220
A_6	0.014	---	15.79	220.00	100	0.006	0.002	0.131	2390
A_7	0.009	---	10.94	900.00	435	---	---	0.014	13.1
A_8	0.010	---	13.86	985.00	775	---	---	0.002	29.2
A_9	0.090	---	9.69	930.00	505	---	---	0.004	0.34
A_{10}	0.010	---	9.14	485.00	80	---	---	0.14	0.23

Table (4): Anions and physical properties of water samples of different locations

Samples ID	*TDS*	*pH*	*Cl*	*SO_4*	*NH_4*	*NO_3*	*HCO_3*
A_1	1615	9.22	127	206	0.89	0.64	430
A_2	2440	9.21	301	55.08	0.15	0.10	470
A_3	2860	9.31	213	72	0.45	3.10	500
A_4	3170	9.18	211	86	0.38	3.50	750
A_5	1707	9.26	97	219.3	0.39	31.95	500
A_6	6670	6.86	751	101.4	1.44	7.54	230
A_7	1383	9.14	79	765	0.17	34.22	320
A_8	1645	9.18	230	106	0.49	22.95	250
A_9	1125	9.23	96	95	0.45	3.54	380
A_{10}	874	9.11	42	153	3.86	28.44	275

Cations, anions and heavy metal content analyses for the water samples for different locations of the study area were preformed to determine the quality of water related to the permissible limits of concentration and the results were listed in Tables (3 and 4). The findings in Tables (3 and 4) show that the major cations and anions found in water samples for different locations of the study area include Calcium, Magnesium, Cadmium, Sodium, Potassium, Nitrate, Sulphate, Bicarbonate, Ammonium and Chloride.

CONCLUSION

In this work, the activity levels of ^{226}Ra, ^{232}Th and ^{40}K have been calculated in water samples collected from 10 wells of varying depths (35-55m) scattered in different locations in Sohag governorate, Egypt using N-type HPGe detector. Furthermore, the dose intake as a result of the ingestion of natural radionuclides through drinking water consumption and the estimated cancer risk were analyzed and discussed. The findings show that the activity levels in the water samples of this work were similar to those reported for other similar studies of different countries and the estimated total doses intake through water consumption are lower than those recommended by the WHO.

REFERENCES

[1] Nuccetelli, C., Rusconi, R., & Forte, M. (2012). Radioactivity in drinking water: regulations, monitoring results and radiation protection issues. *Annali dell'Istituto superiore di sanità, 48,* 362-373.

[2] Pintilie-Nicolov, V., Georgescu, P. L., Iticescu, C., Moraru, D. I., & Pintilie, A. G. (2021). The assessment of the annual effective dose due to ingestion of radionuclides from drinking water consumption: calculation methods. *Journal of Radioanalytical and Nuclear Chemistry, 327*(1), 49-58.

[3] Zapecza, O. S., & Szabo, Z. (1988). 50 National Water Summary 1986–Ground-Water Quality: HYDROLOGIC CONDITIONS AND EVENTS NATURAL RADIOACTIVITY IN GROUND WATER-A REVIEW. *National Water Summary 1986: Hydrologic Events and Ground-water Quality, 2325,* 50.

[4] Awawdeh, K. M. (2012). Determination of natural radioactivity concentrations in natural water

resources of Hebron Province, Palestine. *Hebron University Research Journal-A, Natural Sciences*, *6*(1), 2.

[5] El-Gamal, H., Sefelnasr, A., & Salaheldin, G. (2019). Determination of natural radionuclides for water resources on the west bank of the Nile River, Assiut Governorate, Egypt. *Water*, *11*(2), 311.

[6] de Oliveira, J., Mazzilli, B. P., de Oliveira Sampa, M. H., & Bambalas, E. (2001). Natural radionuclides in drinking water supplies of Sao Paulo State, Brazil and consequent population doses. *Journal of environmental radioactivity*, *53*(1), 99-109.

[7] Mahmoud, M., & El-Zohry, M. (2020). The Natural Background Activity Concentration of (226Ra, 232Th and 40K) and the Annual Effective Dose from Different Water Sources Consumption in Phosphate Polluted Area. *Egyptian Journal of Physics*, *48*(1), 19-26.

[8] Mahmoud, M. H. (2021). Study of Hazard Indices and Radiological Doses in Phosphate Samples from El-Mahamid Area, Upper-Egypt. *Egyptian Journal of Physics*, *49*(1), 49-58.

[9] Ononugbo, C. P., & Nwaka, B. U. (2017). Natural radioactivity and radiological risk estimation of drinking water from Okposi and Uburu salt lake area, Ebonyi state, Nigeria. *Physical Science International Journal*, 1-15.

[10] Iqbal, M., Tufail, M., & Mirza, S. M. (2000). Measurement of natural radioactivity in marble found in Pakistan using a NaI (Tl) gamma-ray spectrometer. *Journal of Environmental Radioactivity*, *51*(2), 255-265.

[11] Godoy, J. M., & Godoy, M. L. (2006). Natural radioactivity in Brazilian groundwater. *Journal of environmental radioactivity*, *85*(1), 71-83.

[12] Ahmed, N. K. (2004). Natural radioactivity of ground and drinking water in some areas of upper Egypt. *Turkish Journal of Engineering and Environmental Sciences*, *28*(6), 345-354.

[13] Salonen L., 1994. U series radionuclides as a source of increased radioactivity in ground water originating from Finnish bedrock.Proceedings of the Helsinki Conference,.22, 71-84.

[14] Nwankwo, L. I. (2013). Determination of natural radioactivity in groundwater in Tanke-Ilorin, Nigeria. *West African Journal of Applied Ecology*, *21*(1), 111-120.

[15] Mohammed, N. K., & Mazunga, M. S. (2013). Natural radioactivity in soil and water from Likuyu village in the neighborhood of Mkuju uranium deposit. *International Journal of Analytical Chemistry*, *2013*.

[16] Arabi, A. E., Ahmed, N. K., & Salahel Din, K. (2006). Natural radionuclides and dose estimation in natural water resources from Elba protective area, Egypt. *Radiation protection dosimetry*, *121*(3), 284-292.

[17] Saqan, S. A., Kullab, M. K., & Ismail, A. M. (2001). Radionuclides in hot mineral spring waters in Jordan. *Journal of environmental radioactivity*, *52*(1), 99-107.

[18] Ndontchueng, M. M., Simo, A., Nguelem, E. J. M., Beyala, J. F., & Kryeziu, D. (2013). Preliminary study of natural radioactivity and radiological risk assessment in some mineral bottled water produced in Cameroon. *International Journal of Science and Technology*, *3*(12), 372-377.

[19] Noorddin, I. (1999). Natural activities of U, Th and K in building materials. J. Environ. Radioactivity, 43, 255–258.