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Levels and effects of natural radionuclides in sediment banks of Rhumel River (Northeast Algeria)

Ghania BOUHILA[1*], Fatima BENRACHI[1], Mourad RAMDHANE[2]

[1]*Frères Mentouri Constantine University, Laboratory* of *Mathematical* and *Subatomic Physics* (*LPMS*), *ALGERIA*

[2]*LPSC, Université Grenoble Alpes, CNRS/IN2P3, Institut Nationale Polytechnique de Grenoble, Grenoble Cedex FRANCE*

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Abstract: Activity concentrations of natural radionuclides in Boumerzoug River sediment (the main tributary of Rhumel river) have been measured using high resolution HPGe detector. The activity concentrations of the samples were range from 16.66±2.32 Bq/kg to 43.48±4.03 Bq/kg with mean value of 26.64±1.33 Bq/kg for ^{226}Ra, 20.01±1.98 Bq/kg to 32.71±3.85 Bq/kg with the mean value 25.95±1.46 Bq/kg for ^{232}Th and 81.70±33.59 Bq/kg to 259.20±38.80 Bq/kg with the mean value 164.50±11.30 Bq/kg for ^{40}K. These values were used to estimate the radiation hazard indices. The absorbed dose and annual effective dose were evaluated to assess the radiation risk due to the use of these sediments.

Keywords: River sediment, Natural Radioactivity, HPGe Detector, Radiation Hazards

Rhumel Nehrinin (Kuzeydoğu Cezayir) çökelti kümelerinde doğal radyonüklidlerin seviyeleri ve etkileri

Özet: Boumerzoug nehri tortusunda (Rhumel nehrinin ana kolu) doğal radyonüklidlerin aktivite konsantrasyonları, yüksek çözünürlüklü HPGe detektörü kullanılarak ölçülmüştür. Örneklerin aktivite konsantrasyonları, ^{226}Ra için 16,66±2,32 Bq/kg ile 43,48±4,03 Bq/kg arasında olup ortalama değer 26,64 ± 1,33 Bq/kg , ^{232}Th için 20,01±1,98 Bq/kg ile 32,71±3,85 Bq/kg arasında olup ortalama değer 25,95±1,46 Bq/kg, son olarak ^{40}K için 81,70±33,59 Bq/kg ile 259,20±38,80 Bq/kg arasında olup ortalama değeri 164,50±11,30 Bq/kg'dir. Bu değerler radyasyon tehlikesi endekslerini tahmin etmek için kullanılmıştır. Bu tortuların kullanımına bağlı radyasyon riskini değerlendirmek için emilen doz ve yıllık etkili doz değerlendirilmiştir.

Anahtar Kelimeler: Nehir çökeltisi, Doğal Radyoaktivite, HPGe Dedektörü, Radyasyon Tehlikesi

1. INTRODUCTION

Among the different geological formations in environment, sediment plays an important role in aquatic radioecology, since it acts as a medium of migration for the transfer of radionuclides to the biological systems [1-2]. Also, sediment is the most important source of continuous radiation exposure for human. For this reason, sediment is regarded the basic indicator of radiological contamination in the environment [1-3].

* Corresponding author. *Email address: bouhilaghania@yahoo.fr*

Most of the sediments that settle in river were formed when the rock and organic materials are broken into small pieces by moving in the water [3]. Therefore, the natural radionuclides concentration in the rock would affect radioactivity level of the river sediment because the breaking of a rock into pieces does not change its chemical composition [1-4]. In addition, some human activities can enhance the levels of radioactivity in river sediments, because it may be regarded as environmental host for many of the waste products discharged by society [5]. The presence of natural radionuclides in sediment by high levels may be lead to radiological risks to the human health, since these radioactive elements in sediment dissolve in water over time and may be transferred to water resources, plants and animals, then to human.

The knowledge of radionuclides distributions in the sediments acts an essential part in monitoring of environmental contamination and assessment of radiological hazard arising from natural sources. For this purpose, in the recent years many studies give an importance to the measurements of the activity concentrations of natural radionuclides and their hazard on human health [1-14].

In several areas of Algeria, especially in the big cities, rivers have been polluted by industrial and agricultural human activities, or waste disposal. Among the watercourse in northeast of Algeria; Rhumel River is a very important aquatic ecosystem in the region. This stream has a vital role, since it feeds Beni Haroun dam; the largest dam in Algeria. In addition, the waters of the river are exploited to irrigate the agricultural lands neighboring of stream.

This river represents the main rivers in the east of Algeria. Originates at around 1160 in the southern margins of Tell, North-West of Balaâ (125 km from El-Eulma, Setif), Rhumel River flows through high plain of Constantine. It drains an orientation South-West -North-East, after that it crosses the rock Constinoise deeply sinking (200 m in level) into gorge of limestone. Then, it suddenly changes the direction and turns to the right and flows obliquely towards the northwest, it confluences with Oued Endja around Sidi Merouene in Mila town. Its length is of 200 km and covers an area of 5315km^2 [15]. The river basin climate is a semiarid type; characterized by wet winters and dry and hot summers [15-16].

The main tributary of the river is Oued Boumerzoug which drains industrial and urban zones. Along of its path, the river basin includes several agricultural lands where the farmers use often the fertilizers. Although the importance of this watercourse in northeast of Algeria, no studies are found concerning the level of natural radioactivity about this aquatic ecosystem. This work aims to evaluate the radioactivity concentrations in some sediment samples collected of Rhumel River as well as assessment of radiological parameters.

2. MATERIALS and METHODS

2.1. Sample collection and Measurement

In order to evaluate the natural radioactivity levels, the sediment samples were collected from several locations along the Boumerzoug River (tributary of Rhumel River) at a depth of 5 -10 cm from the top surface layer. In the first and second locations (SRBD), (SRBB) in El Djedour city, the river passes through several farming fields in these areas. The third region (SRBH) is located near Industrial Zone (oued Hamimime). The fourth site (SRBQ) is located near Boumerzoug city and the fifth (SRBM) is located under the El Mouzina Bridge in El khroub city (Fig.1).

The samples were dried, pulverized, homogenized, weighed and packed into small cylindrical plastic containers approximately for 30 days (~7 half-lives) to reach secular equilibrium between the ^{238}U and ^{232}Th series and their respective progeny before measurements [11,17]. The natural radioactivity of samples was measured at low activity laboratory (LBA/LPSC-Grenoble) which has two HPGe detectors. Both detectors are surrounded by 2 cm of archeological lead and by 15 cm of purified lead. The two detectors and the lead plate are placed at the center of a two meter high cube; each face of this cube being constituted with a liquid scintillation detector. These detectors proceed as dynamic veto stopping the acquisition of data during the passage of a cosmic ray.

The data acquisition and analysis use two PCs equipped with the "Interwinner" (ITECH-instruments) software. The detectors have a relative efficiency of 20% and the energy resolution was of 0.78 and 1.85 keV at 122 keV (^{57}Co) and 1332 keV (^{60}Co) gamma lines, respectively [18]. IAEA-RGU-1 and IAEA-RGTh-1, in powder form, installed in the same position and plastic bottle as the samples, were used to determine the detectors efficiency curves. The activities of the natural-series were 4940±30 Bq/kg for ^{238}U and 228±2 Bq/kg for ^{235}U in IAEA-RGU-1 and 3250±10 Bq/kg for ^{232}Th in IAEA-RGTh-1 [19].

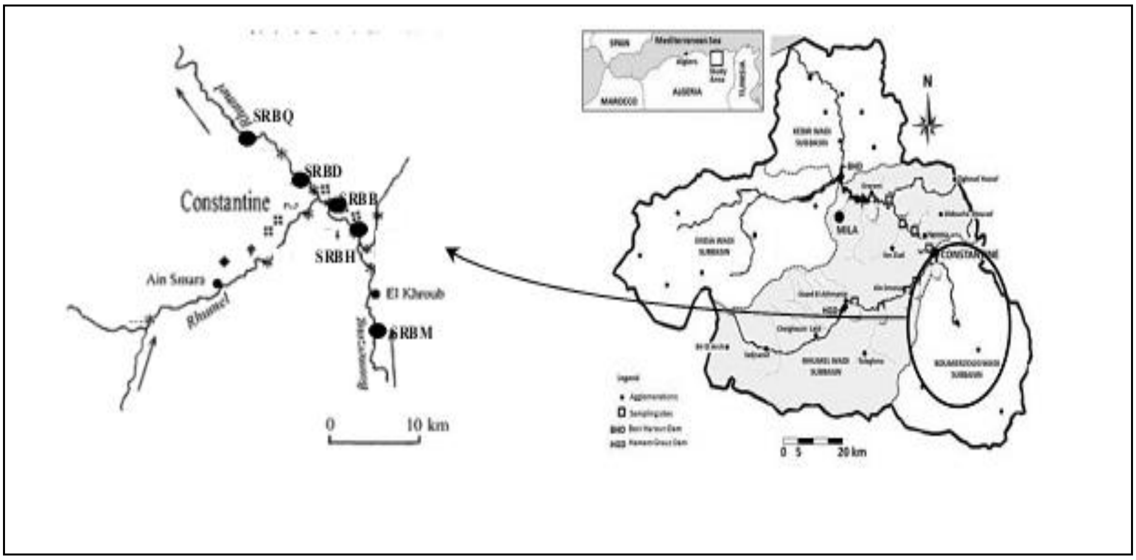

Figure 1. Sampling locations in Rhumel basin.

Each sample was measured for 48 hours. The measured prominent gamma-ray lines from both the Uranium and Thorium decay series were used for sample analysis to determine the activity concentration after correcting by background counts. The activity concentrations were determined for ^{232}Th assuming secular equilibrium with their decay products. The gamma-ray transitions of ^{228}Ac (338.4, 911.2 keV), ^{212}Pb (238.6 keV) and ^{208}Tl (583.1 keV) were used. The activity concentrations of ^{226}Ra were measured from gamma-ray transition of ^{214}Pb (351.9 keV) and ^{214}Bi (609.3 keV). ^{40}K was determined from the 1460.8 keV peak. The activity concentrations for the natural radionuclides in the measured samples were evaluated using the relation:

$$A_s = \frac{N_E}{\varepsilon_E\, ptm} \qquad (1)$$

Where: N_E and ε_E are the net peak area and the detection efficiency at energy E, p is the branching ratio of radionuclide of interest; t is the counting time (s); m is the mass of the measured sample in *kg*.

2.2. Radiation hazard indexes and Dose Estimation

In order to compare the activity concentration and radiological affects of sediment samples, which contain ^{226}Ra, ^{232}Th and ^{40}K, the radium equivalent activity (Ra_{eq}) as common index has been introduced [20]:

$$Ra_{eq} = 0.077A_k + 1.43A_{Th} + A_{Ra} \quad (2)$$

Where A_k, A_{Th} et A_{Ra} are the concentrations of ^{40}K, ^{232}Th and ^{226}Ra respectively.

Many other significant factors are dependent on the evaluation of the activity concentrations of ^{226}Ra. The first factor is named Internal Hazard Index H_{in} which represents radiation hazard to respiratory organs due to ^{222}Rn and ^{220}Rn and their progenies. This index is defined as follows [20]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

The second factor is named External Hazard Index H_{ex} reflecting the external exposure, which is given by [20]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

The values of the indices (H_{in}, H_{ex}) must be less than unity for the radiation hazard to be negligible.

Another radiation hazard index called the representative level index I_γ is defined by [21]:

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (5)$$

To assess the absorbed dose rates in outdoor (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the studied samples the following equation is used [22]:

$$D(nGyh^{-1}) = 0.462\,A_{Ra} + 0.621\,A_{Th} + 0.041\,A_K \quad (6)$$

The conversion factors used to compute absorbed γ dose rate (D) in air per unit activity concentration in Bq/kg (dry-weight) correspond to 0.462 $nGyh^{-1}$ for ^{226}Ra (of U- series), 0.621 $nGyh^{-1}$ for ^{232}Th and 0.0417 $nGyh^{-1}$ for ^{40}K. To estimate the annual effective dose rates (AED) , the conversion coefficient from absorbed dose in air to effective dose (0.7) and outdoor occupancy factor (0.2) proposed by UNSCEAR [22] were used. Therefore, the annual effective dose rate (μSv yr^{-1}) was calculated by the formula:

$$AED(\mu Svy^{-1}) = D(nGy.h^{-1}) \times 8760\,h \times 0.7\,SvGy^{-1} \times 10^{-3} \times 0.2 \quad (7)$$

3. RESULTS and DISCUSSION

Radionuclides activity concentrations measured in the sediment samples are presented in (Fig.2) which shows that the concentrations varied from site to site because the river sediment can exhibit large variation in composition [4]. Also, it can be seen that the ^{40}K activity is the largest contributor to the total activity for all the samples with the mean value of 164.50 ± 11.3 Bq/kg, this due to the presence of clays in these locations. In general, the clays and shales contain relatively high concentration of radioactive isotopes, notably potassium [23]. The mean activity concentrations of ^{226}Ra and ^{232}Th in the river samples are 26.64±1.33 and 25.95±1.46 Bq/kg respectively, as shown in (Table. 1). However, no artificial radionuclide was detected at any studied site.

The radiological hazard parameters are calculated from the measured activity concentrations of three main radionuclides in all sediment samples and are listed in (Table.1). It can be seen that the values Ra_{eq} of all sediment samples in the present work are lower than the accepted safety limit value of 370 Bq/kg [22]. The results obtained for internal and external hazard indexes (H_{in}, H_{ex}) are below than the limit of unity and the I_γ values of the measured samples are within the limit. Also, the estimated absorbed dose and the annual effective dose rates for the investigated samples ranged from 24,28±1.95 to 50,46±3.69 $nGyh^{-1}$ and 29.79±2.40 to 61.93±4.54 $\mu Svyr^{-1}$ respectively, with the mean values of 35,00±3.69 $nGyh^{-1}$ and 40.64± 4.54 $\mu Svyr^{-1}$. The obtained values are less than the world average values of 59 $nGyh^{-1}$ and 70 $\mu Svyr^{-1}$ given by UNSCEAR [22].

(Fig.3) shows the linear correlation between ^{226}Ra and ^{232}Th activity concentrations, to know the extent of the existence of these radionuclides together in study area. Positive correlation was observed between the activities of radionuclides. These results indicate that the samples collected from this region are geochemically coherent; which means that the individual result for any one of the radionuclide concentration in this pair is a good predictor of the concentration of the other and they belong to same source [24].

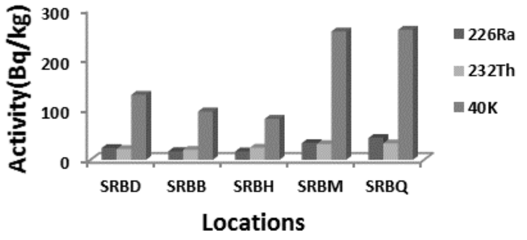

Figure 2. Comparison of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in study location.

Table 1. The activity of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg) and Radiation hazard parameters.

Locations	Concentration (Bq/Kg)			Radiation hazard indexes				Dose estimation	
	^{226}Ra	^{232}Th	^{40}K	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	I_γ	D ($nGyh^{-1}$)	AED ($\mu Svyr^{-1}$)
SRBD	23.33±2.54	21.38±2.30	129.50±28.70	63.87±5.44	0.17±0.03	0.24±0.02	0.46±0.01	29.24±2.19	35.88±2.68
SRBB	17.19±2.17	20.01±1.98	96.31±27.80	53.35±4.16	0.14±0.01	0.19±0.02	0.38±0.03	24.28±1.95	29.79±2.39
SRBH	16.66±2.32	24.19±3.59	81.70±33.59	57.54±6.19	0.16±0.02	0.20±0.02	0.41±0.05	25.99±2.83	31.89±3.47
SRBM	33.23±3.39	31.37±3.60	255.80±41.10	97.79±6.93	0.26±0.02	0.35±0.02	0.71±0.05	45.07±3.21	55.31±3.92
SRBQ	43.48±4.03	32.71±3.85	259.20±38.80	109.55±7.45	0.30±0.02	0.41±0.02	0.79±0.05	50.46±3.42	61.93±4.19
Mean	26.64±1.33	25.95±1.46	164.50±11.30	76.42±7.45	0.21±0.03	0.28±0.02	0.55±0.05	35.00±3.42	40.64± 4.19

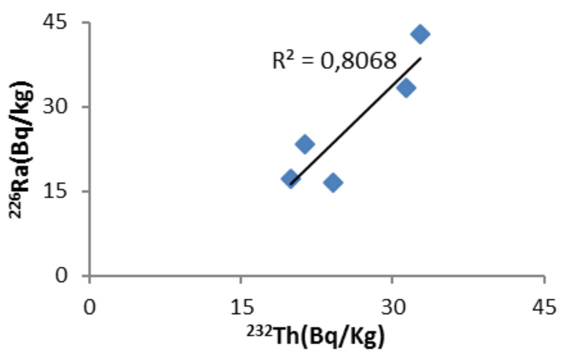

Figure 3. Correlation between ^{226}Ra and ^{232}Th in the study area.

The average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in sediment samples from studies area were compared with similar investigations in other countries and summary of results is given in (Table 2).

The measured values of ^{226}Ra, ^{232}Th and ^{40}K concentrations in the present work were within the world average according to UNSCEAR (2000) report.

Table 2. Comparison of natural radionuclides concentrations in sediment samples under investigation with those in other countries.

Locations	^{226}Ra	^{232}Th	^{40}K	References
Algeria	26.64±1.33	25.95±1.46	164.50±11.30	Present work
Italy	72.00±31.00	48.00±8.90	617.00±150.00	[25]
Thailand	60.20 ± 0.50	64.97± 0.50	431.87 ± 5.90	[26]
Turkey	18.90±1.20	27.20±1.70	524.0±24.30	[13]
Egypt	16.30± 9.22	12.49±6.23	200.21±52.94	[7]
Sudan	22.83±4.03	25.11±4.96	284.31±80.45	[27]
Ghana	16.02 ± 9.99	20.31±16.39	195.01±116.49	[28]
Nigeria	180.59±15.04	187.12±54.82	329.00±19.00	[29]
World average	35	30	400	[22]

As shown in (Table 2), it can be seen that the mean value of ^{40}K in investigation area is lower than the other countries. ^{226}Ra concentration is slightly higher than Ghana, Egypt and Turkey, but it is lower than the other countries. While ^{232}Th mean value is close to Ghana, Sudan and Egypt, however, it is less than Nigeria, Italy and Thailand.

4. CONCLUSION

The present study has been carried out to establish baseline data regarding concentration levels of naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K in Boumerzoug River sediments the main tributary of Rhumel River. The measurements showed that natural radionuclides of ^{238}U and ^{232}Th chains and ^{40}K are present in all samples where the results obtained for activity concentrations are lower than the world wide average identified by UNSCEAR [22]. The values of the radiation hazard parameters of these sediment samples are not high compared to the world averages. Also, the estimated dose and the annual effective dose rates in the studied area are less than the recommended values. Hence, the results in this current study can be used as a baseline for the observation of any possible change in the future.

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