RADIOACTIVITY LEVELS AND RADIATION HAZARD IN SANDS FROM CUBAN BEACHES

NIVELES DE RADIACTIVIDAD Y PELIGROSIDAD POR RADIACION EN ARENAS DE PLAYAS CUBANAS

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The natural radionuclides ^{238}U, ^{232}Th and ^{40}K are called primordial radionuclides, because they are present on the Earth since the creation of the planet. The nonuniform distribution of natural radionuclides has been observed in various environmental matrices such as soil, sand, water, air, sediment, etc. Natural radionuclides often reach these matrices by the weathering process of rocks and other materials.

The purpose of the present study was to determine the levels of natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K) on the sands of some Cuban white sand beaches (Fig. 1), in order to assess the potential radiological risks to their users.

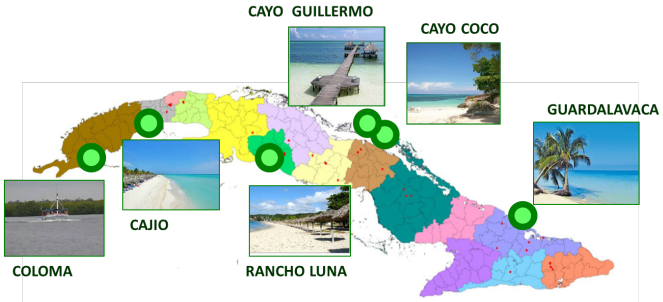

Figure 1. Location of the studied sand beaches

Beach sand samples, which reached equilibrium at the end of a time of one month, were counted for 48 hours on a well calibrated HPGe gamma spectrometer at the Center for Environmental Studies at Cienfuegos, Cuba [1]. In the study, while ^{40}K activity concentrations were determined directly based on 1460 keV gamma ray, the ^{238}U and ^{232}Th activity concentrations were indirectly determined from the daughter nuclides of these radionuclides. The ^{214}Pb or ^{214}Bi activity concentrations of the samples need to be accepted as a measure of the ^{226}Ra content rather than ^{238}U itself [2] . That is, in the analysis of the samples, for ^{226}Ra activity, ^{214}Bi's 609 keV and ^{214}Pb's 352 keV gamma transitions were used, while for ^{232}Th activity, ^{228}Ac's 911 keV gamma transition was used. The activity concentrations of natural radionuclides for beach sand samples under study, and some reported worldwide, are presented in Table 1. The measured activities are directly related to natural gamma radiation and represent the geological background of the rock settings. The only exception is the activity of ^{232}Th measured on the beach sand of La Coloma, with a mean activity slightly higher than the mean concentration of ^{232}Th worldwide (30 Bq $\cdot$ kg^{-1} [3]).

Table 1. Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (main ± SD, in Bq $\cdot$ kg^{-1}) in Cuban and worldwide beach sands.

Beach	**^{226}Ra**	**^{232}Th**	**^{40}K**
La Coloma, Cuba	19 ± 1	37 ± 1	40 ± 8
Cajio, Cuba	6 ± 1	6 ± 3	47 ± 7
Rancho Luna, Cuba	4.5 ± 0.7	2.6 ± 0.5	274 ± 12
Cayo Coco, Cuba	12 ± 1	4.6 ± 0.6	10.6 ± 0.7
Cayo Guillermo, Cuba	5.7±0.7	2.1±0.4	135±8
Guardalavaca, Cuba	2.1±0.7	1.5±0.4	15±1
Xiamen, China [4]	15±4	11±8	396±75
Zonguldak, Turkey [5]	23±1	20±2	245±14
Ao Phrao, Thailand [6]	11±2	6.4±0.8	174±67
Tamil Nadu, India [7]	13±4	6±1	379±40
El Ingles, Spain [8]	23±1	31±2	726±32
Penang, Malaysia [9]	31±8	36±6	369±17
UNSCEAR [3]	35	30	400

Radiological parameters such as *radium equivalent* activity (R_{aeq}), *absorbed dose rate* (D_R) and *gamma index* (I_γ) were calculated (Table 2) using the following standard formulas:

$$R_{aeq}(\mathrm{Bq \cdot kg^{-1}}) = C_U + 1.43C_{Th} + 0.0077C_K \quad (1)$$

$$D_R(\mathrm{nGy \cdot h^{-1}}) = 0.462C_U + 0.604C_{Th} + 0.0042C_K \quad (2)$$

$$I_\gamma = \frac{C_U}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (3)$$

where, C_U, C_{Th} and C_K, (given in $\mathrm{Bq \cdot kg^{-1}}$), are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively. The safety value for this I_γ index is ≤ 2 [3].

Table 2. Radiological indexes.

Beach	$\mathbf{R_{aeq}}$ ($\mathrm{Bq \cdot kg^{-1}}$)	$\mathbf{D_R}$ ($\mathrm{nGy \cdot h^{-1}}$)	$\mathbf{I_\gamma}$
La Coloma, Cuba	72	33	0.52
Cajio, Cuba	15	8	0.13
Rancho Luna, Cuba	10	15	0.24
Cayo Coco, Cuba	19	9	0.13
Cayo Guillermo, Cuba	10	10	0.15
Guardalavaca, Cuba	4	3	0.04
Xiamen, China [4]	34	30	0.47
Zonguldak, Turkey [5]	53	33	0.52
Ao Phrao, Thailand [6]	21	16	0.25
Tamil Nadu, India [7]	24	26	0.40
El Ingles, Spain [8]	73	60	0.95
Penang, Malaysia [9]	85	52	0.81
World average [3]	81	59	2

The calculated R_{aeq} values varied from 4 to 72 $\mathrm{Bq \cdot kg^{-1}}$, showing that all studied sands show activity lower than the recommended safety limit. The dose rate varied from 3 to 33 $\mathrm{nGy \cdot h^{-1}}$, all they are also lower than the worldwide average value of 59 $\mathrm{nGy \cdot h^{-1}}$.

Finally, the estimated values of gamma representative level index ranged from 0.04 to 0.52, confirming that mean values are lower than the recommended safety limits. We recommend performing a similar study of beach sands from other important Cuban resorts.

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