ENVIRONMENTAL RADIOACTIVITY OF CHITUC SANDBANK

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Chituc is a sand bank which separates the waters of Lake Sinoe and the Black Sea. It was established as protected area of national interest [1]. Sand samples were taken on the surface of the sand bank in order to assess the radioactivity between Corbu village (south) and channel Periboina (north). Samples were measured by high-resolution gamma spectrometry in the underground laboratory of IFIN-HH from Unirea salt mine, Slanic-Prahova [2]. It is to mention that the radiation background in the detector shield is reduced about 3,600 times (the radiation dose rate in underground in average is < 2nSv/h) [3, 4]. Samples were proved to be very low radioactive, compared with other samples taken from the entire seashore area of Black Sea by different researchers who issued their sand and soil measurements in the journal articles. Results show that the activity concentrations of the principal radionuclides contained in the samples are: ^{228}Ac (7.5 ÷18.7 Bq/kg), ^{226}Ra (6.2÷21.3 Bq/kg), ^{137}Cs (0.3 ÷1.53 Bq/kg) and ^{40}K (169÷362 Bq/kg).

Keywords: environmental radioactivity, high-resolution gamma ray spectrometry, underground laboratory

1. Introduction

The results shown in the paper present the measurements of activity of the natural radiation background from different sand samples belonging to Chituc sandbank, Constanta County, Romania.

Chituc sandbank, an area with a surface of 7,700 ha, which belongs to Lake Sinoe, is situated in Constanta county on the administrative teritory belonging to Corbu village. Main of the surface of Chituc sandbank is covered with deposits composed from marine coarse sand rich in calcium carbonate, mica

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and max. 2% clay. The first layer of 20 cm of soil contains sand and only at most 5 % clay.

The analyse of samples of soil taken out untill 100 cm depth shows the fact that the beaches of the Lake Sinoe are formed from a mixture of paralel and alternative layers of high salinity soils. These layers are orientated from the South-West to North-East direction. In the North shores of the lake the molic psamo-soils and moor coal soils (semi-submerged or swampy) prevail. In the South area there is a wide band consisting in carbonated semi-fastened sands. In the rest of the areas there are swampy psamo-soils, glaised psamo-soils, carbonated soils and surface saline soils with a high content of salts. Alongside the shores there are conched mobile sands [5].

The results refer to radioactive measurements consisting, firstly, in recording of absorbed dose rates in situ and, secondly, gamma spectrometry analyses accomplished in Unirea underground laboratory on the sand samples extracted from the surface layer of the sand.

The following specialized equipment was used for measurements in the sandbank area and in the underground laboratory: universal monitor Berthold Umo LB 123 and Canberra spectrometric gamma system with HPGe detector for the measurement of the activity of gamma emitting nuclides found in samples.

2. Materials and method

The underground IFIN-HH laboratory, where the samples were analyzed, is situated at a depth of 208 m under the level of the entrance in the Unirea salt mine from Slanic Prahova.

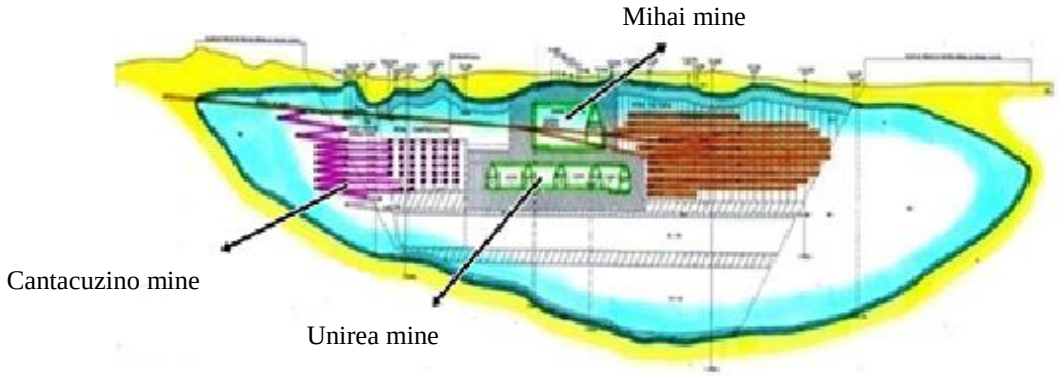

Fig. 1. Section through salt lens in Slanic Prahova with highlight of mining zone [6]

Unirea mine is characterized by the following features shown in the table:

Table 1

The environmental main characteristics of Unirea salt mine Slanic Prahova

No.crt.	Characteristics	Value
1	Temperature	12.0 ÷ 13.0 ºC
2	Humidity	65 ÷70 %
3	Excavated volume	2.9 x 10^6 m^3
4	Surface	~70000 m^2
5	High	52 ÷ 57 m

Gamma ray spectrometry represents an analytical method that allows the identification and quantification of gamma emitting isotopes in a variety of matrices. In one single measurement and with little sample preparation, gamma ray spectrometry allows detecting several gamma emitting radio nuclei in the sample [7].

Inside Unirea laboratory there are two gamma high resolution HPGe detectors produced by Canberra. The first has a 22 % relative efficiency, and, the second, 120%. The pictures of the two detectors are presented below in the figures no. 3 and 4. Each detector has its own shield build in accordance with the user's specifications. The first detector has a shield build from three layers, first layer, from interior to exterior, consisting in OFHC copper 5 cm thick, the second, old lead with a content of Pb-210 under 25 Bq/kg 5 cm thick and the last layer, at the exterior, 10 cm of fresh lead. The second detector has, also, three layers disposed in the same way: first layer, OFHC copper 2 cm thick, the second, old lead with a content of Pb-210 under 25 Bq/kg 5 cm thick and the third layer, 10 cm of fresh lead. Gamma radiation shielding factor is, for the two shields, aprox. 3.600 [8].

Fig. 2 120 % relative efficiency HPGe detector

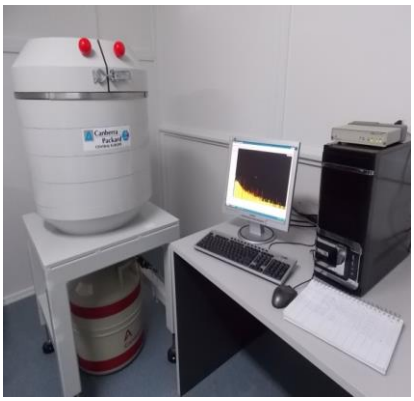

Fig. 3 22 % relative efficiency HPGe detector

The HPGe detectors are cooled with liquid nitrogen (Dewar vessel). The sensitive surfaces of the detector are protected from the humidity and other contaminants. The detector is anchored through a brace, electrically isolated, but thermically connected to a so-named "cold finger" made from copper. This "cold finger" transfers the heat from the detector system to the liquid nitrogen reservoir. The brace of the detector, the cover and the cowl of the vacuum chamber are thin in order to avoid the attenuation of the low energy photons. Usually, the brace is made from aluminum 1 mm thick, the cowl, from the same material, and has 1.5 mm thick. The surface of the detector is situated from aprox. 5 mm distance to the cowl of the vacuum chamber.

Canberra InSpector 2000 is the state-of-the-art gamma spectroscopy device based on digital signal processing named DSP technology. The applications of these equipments include all HPGe, NaI and Cd(Zn)Te detectors used in characterization of environment radioactivity and other nuclear applications [9].

InSpector 2000 is a portable multi-channel analyzer which offers the possibility to function at a very good counting rate and an improved resolution.

Genie-2000, software especially designed for gamma ray spectroscopy domain, works under Windows operating system [10].

The measurements carried out in the underground laboratory established a global reduction of the absorbed dose due to natural factors of about 80 times compared to level on the surface. The distribution of the external dose rate within the Unirea salt mine, host of the Low-Level Background Laboratory was determined and compared with calculated values based on the experimentally determined content of natural radioactive elements in the mine wall. The average external dose rate was found to be 1.4 ± 0.3 nSv/h. The total gamma background spectrum between 40 keV and 3 MeV is 80 times smaller at laboratory level with respect to the same spectrum recorded at surface, in open field [2].

Our results strengthens the hypothesis that the radionuclides belonging to the natural series, i.e. Ac-228 from Th-232 series and Ra-226 from U-238 series are associated with heavy minerals resistant to specific environment conditions. These isotopes exist within minerals in secular equilibrium.

The formula for calculating the activity is:

$$A = \frac{A_n}{Ta \cdot m \cdot Eff \cdot Int} \quad (1)$$

where:
A = activity (Bq / kg), An = net area,
Ta = collecting time (s) m = mass (kg),
Eff = efficiency, Int. = gamma ray intensity (yield).

3. Results and discutions

The places where the samples were taken are presented in the figure

below:

Fig. 4 The sampling places from Chituc sandbank

Fig. 5 The sampling places from Chituc sandbank shown at an accurate view containing the measurement points from reference [4]

The sand samples were taken with the help of a grubbing hoe in quantities of aprox. 500 g in each place. Then, the sand samples were inserted in

polyethylene boxes and tagged with number of sample and the geographical coordinates. The six sand samples were transported to laboratory, dried, separated from impurities and sieved through a 0.5 mm sizer, and then, quantities of 100 grams from each sample were introduced in a polyethylene cylindrical box, special manufactured for the geometry of the detector.

The initial dose rates measurements in situ relieved values from 40 to 200 nSv/h.

Dose rates measurements and sand sampling took place in June 2015.

The HPGe Canberra gamma detector with a relative efficiency of 120 %, described above, was used to measure the conditioned samples. The time for measurement of each sample was around 24 hours.

The results of the samples measurements are presented in the table below:

Table 2

The results of the measurements of Chituc sandbank samples

			Cs 137		K 40		Ra 226		Ac 228	
Sample number	Lat. N	Long. E	Acti-vity Bq/kg	Uncertainty Bq/kg	Acti-vity Bq/kg	Uncertainty Bq/kg	Acti-vity Bq/kg	Uncertainty Bq/kg	Acti-vity Bq/kg	Uncertainty Bq/kg
1	44.37287	28.7066	1.53	0.2	224	18	21.3	1.7	18.7	1.3
2	44.39287	28.7066	1.07	0.1	245	19	11.3	0.9	8.7	0.6
3	44.46535	28.80742	1.04	0.1	224	18	15.5	1.2	14.3	1.0
4	44.49533	28.84122	0.75	0.2	169	16	6.2	0.5	7.5	0.9
5	44.54235	28.88173	0.55	0.2	272	25	11.6	0.9	10.4	1.1
6	44.56963	28.90052	0.30	0.1	362	29	19.6	1.5	14.5	1.0

In the table below we show a comparison of the specific activities on other beaches:

Table 3

The comparative table between Chituc sandbank specific activity values and the values reported in different periods on the beaches around the world

	K40	Cs137	Ra226	Reference
Chituc, Romania	169-362	0,3-1,53	6,2-21,3	-
Ghana	68,3-183,9	-	10,9-103,7	H. Lawluvi, E.O. Darko, C. Schandorf, A. Fannu, A.R. Awudu and D.O. Kpeglo2011[11]
Brazil	47-527	-	6-180	Freitas and Alencar (2004)[12]
India	158-405	-	36-400	Sunta (1993)[13], Kalyani et al. (1990)[14], Narayana et al. (1994) [15]
Spain	136-1087	-	5-19	Rosell et al. (1991) [16]
Egypt	96-1011	-	32.2-105.6	El-Mamoney and Khater (2004)[17] Ibraheim et al. (1993) [18]
North Sinai	77	-	108	Seddeek et al. (2005) [19]
Hong Kong	1210	-	27,7	Yu et al. (1992) [20]
Iran	140-1172	-	-	Abdi et al. (2006) [21]

Pakistan	680-784	-	36.9-51.9	Khan et al. (2005) [22]
Bulgaria	1200	-	460	Peev and Mitov (1999) [23]
Inani, Bangladesh	182,39-642,27	-	12,52 - 31,76	M. M. Ahmed, S. K. Das, M. A. Haydar, M. M. H. Bhuiyan, M. I. Ali, D. Paul (2014)[24]
Ulcinj, Montenegro	174-450	0,34-2,84	6,4-17,9	Mirjana B. Radenkovićsaeed, Masaud Alshikh, Velibor B. Andrić and Šćepan S. Miljanić (2009) [25]
Patara Beach, Xanthos,Turkey	48,5-60,5	< 0,3	9,6-12	
Manhattan Beach,USA	3,9-6,1	0,49-0,81	413-501	
Copacabana, Rio de Janeiro, Brazil	16,5-21,3	< 0,3	1,88-2,6	

4. Conclusions

The activity concentrations of the principal radionuclides contained in our samples, namely Ac-228 (7.5 ÷18.7 Bq/kg), Ra-226 (6.2÷21.3 Bq/kg), Cs-137 (0.3 ÷1.53 Bq/kg) and K-40 (169÷362 Bq/kg) are among the lowest values found on the beaches in the world reported on the journal articles.

Cs-137 activity concentrations, due to Chernobyl accident, are at very low values.

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