Levels of Outdoor Gamma Dose Rates in Selected Sites from Romania, Moldova and Greece

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Abstract

The study presents a synthesis of results obtained in the frame of international cross-border projects, implemented in partnership, for gamma radiation dose rates measured in outdoor environments in various sites in Romania, Moldova, Greece, including urban, rural, touristic and protection areas. The selected sites (n=41) are found in the Eastern Carpathians Mountains, Lower Danube basin, Danube Delta, Lower Prut River Reserve, Dniester River, as well as Black Sea and Northern Aegean Sea basins. The data recorded for targeted spots using portable dosimeters highlight an hourly and daily variation of the outdoor gamma dose rate and the specificity of the geological background and terrain utilization. The mean values of outdoor gamma radiation dose rate, calculated for 50 measurements per each site, are ranging between 71 nGy/h (Vama Veche, Constanta County, Black Sea coast, Romania) and 394 nGy/h (Nea Peramos, Ammolofoi beach, Northern Aegean Sea, Greece), with a minimum of 41 nGy/h in Vama Veche and a maximum of 489 nGy/h in Ammolofoi beach. A comparison is made with legislated values and other world places. The measurements performed at water surface during boat expeditions (n=21) on Danube River and Danube Delta lakes and channels point out lower values of dose rate, due to the weak influence of gamma rays' emission from bottom sediments. The data of the dose rate temporal variations will be used for the target regions as a base in further investigations and preparation of maps of gamma dose rates (terrestrial and cosmic), and calculation of the health risk for inhabitants and tourists.

Keywords: outdoor gamma dose rates, danube delta, romania, moldova, greece

Introduction

Life on Earth evolved in the presence of cosmic radiations coming from outer space or those produced because of the presence of radioactive materials spread in the earth's crust with a high geographic variability. Three-quarters of the radioactivity in the environment comes from natural elements [1–3]. Due to the destructive effects on humans and other living organisms, measurement of the ionizing radiation doses in the environmental compartments in various regions of the world is very important, besides the monitoring of various classes of toxicants [4].

Taking into consideration the strong penetration power of gamma radiations, the absorbed dose rate measurement in ambient air is considered as significant. The study presents a synthesis of results obtained in the frame of cross-border projects such as Romania-Ukraine-Republic of Moldova and Black Sea Basin, and JINR-Romania international grants, implemented in partnership by teams from Romania (RO), Moldova (MD), Greece (GR) and Ukraine (UA), for gamma radiation dose rates measured in outdoor environments in various sites in Romania, Moldova, Greece, including urban, rural, touristic, protection areas and natural reserves. The targeted sites are found in the Eastern Carpathians Mountains, Lower Danube basin, Danube Delta, Lower Prut River Reserve, Dniester River, as well as the Black Sea and Northern Aegean Sea basins (Figure 1). The information will be used to complete the data for mapping the environmental radioactivity [5,6] in SE Europe and to compare with real-time monitoring data provided by the European Commission [7].

Methodology

Ambient gamma dose rates were recorded during field trips organized in the period 2014–2022 in the selected sites with various geological backgrounds and land use presented in Figure 1, from Black Sea coast in RO (sites nos. 1–8, map part A), Danube Delta Biosphere Reserve (sites nos. 9-15, map part B), Lower Danube basin (sites nos. 16–18, general map and part B), Lower Prut River Reserve (sites nos. 21–23 in RO and 31,32 in MD, map part C), Dniester River (site no. 33, MD, general map), the Eastern Carpathians Mountains (sites nos. 24–30 in RO, map part D), and Northern Aegean Sea (sites nos. 34–41 in GR, map part E). Supplementary measurements in the region marked with B in Figure 1 were performed at water surface during boat expeditions (n=21) on the Danube River (sites D1–D7) and Danube Delta lakes and channels (sites D8–D21), many of them being in the RO-UA border area of Lower Danube Euroregion and Chilia branch of the Danube (Figure 2). The site description is shown in Tables 1 (field trips) and 2 (aquatic trips). To highlight the temporal variation of outdoor gamma dose rate, 20 places were selected in Cahul town all over the urban territory (Figure 3), and the measurements were recorded in various days and at different day moments during April 2015.

The gamma dose rate measurements were carried out with Digilert 100 and Inspector Alert handheld survey meters, placed at height of 1 meter from ground level. 50 measurements were carried out at each site and the data were compiled using Microsoft Excel 2019.

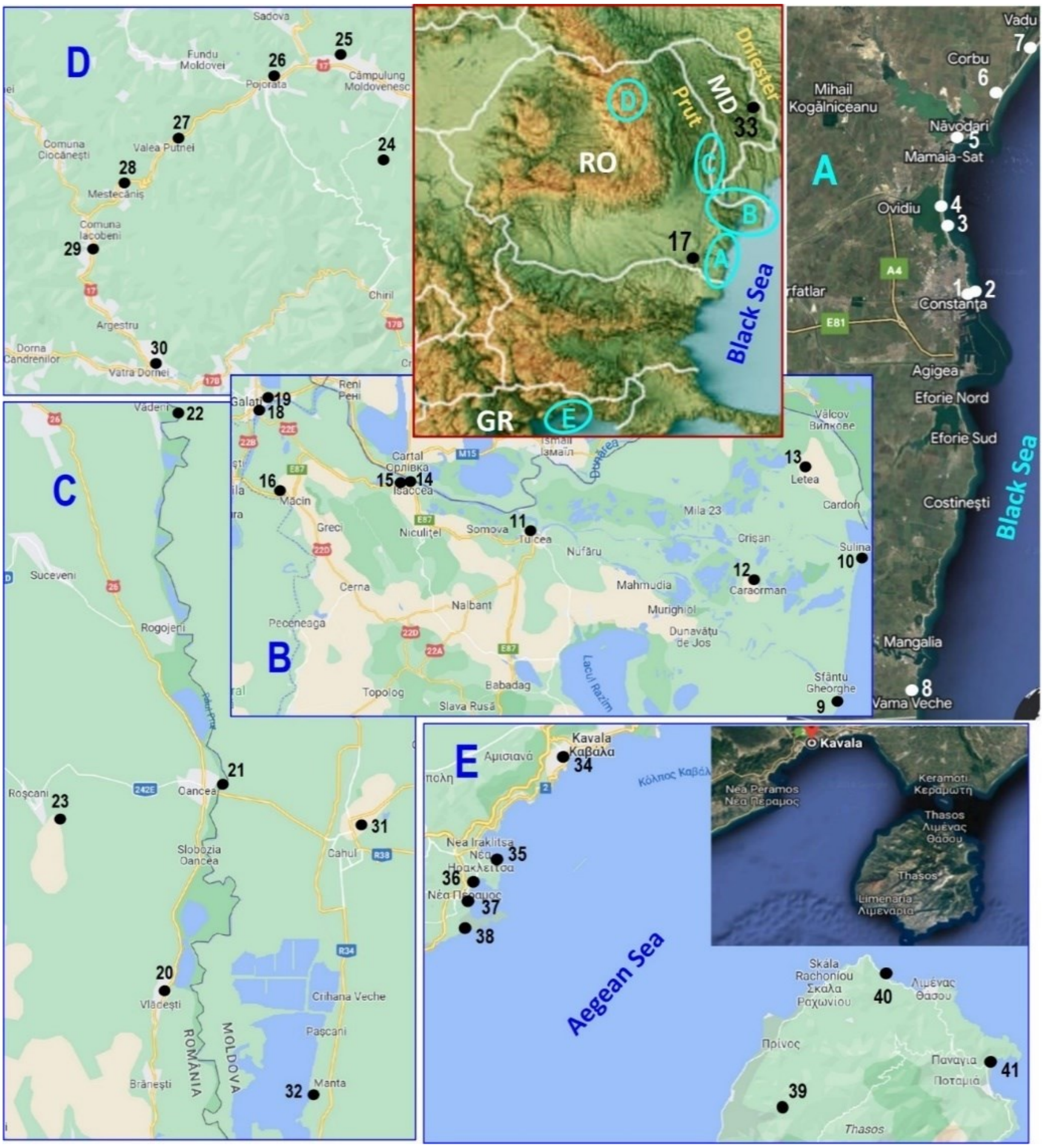

Fig. 1. Map of study area and field monitoring sites.

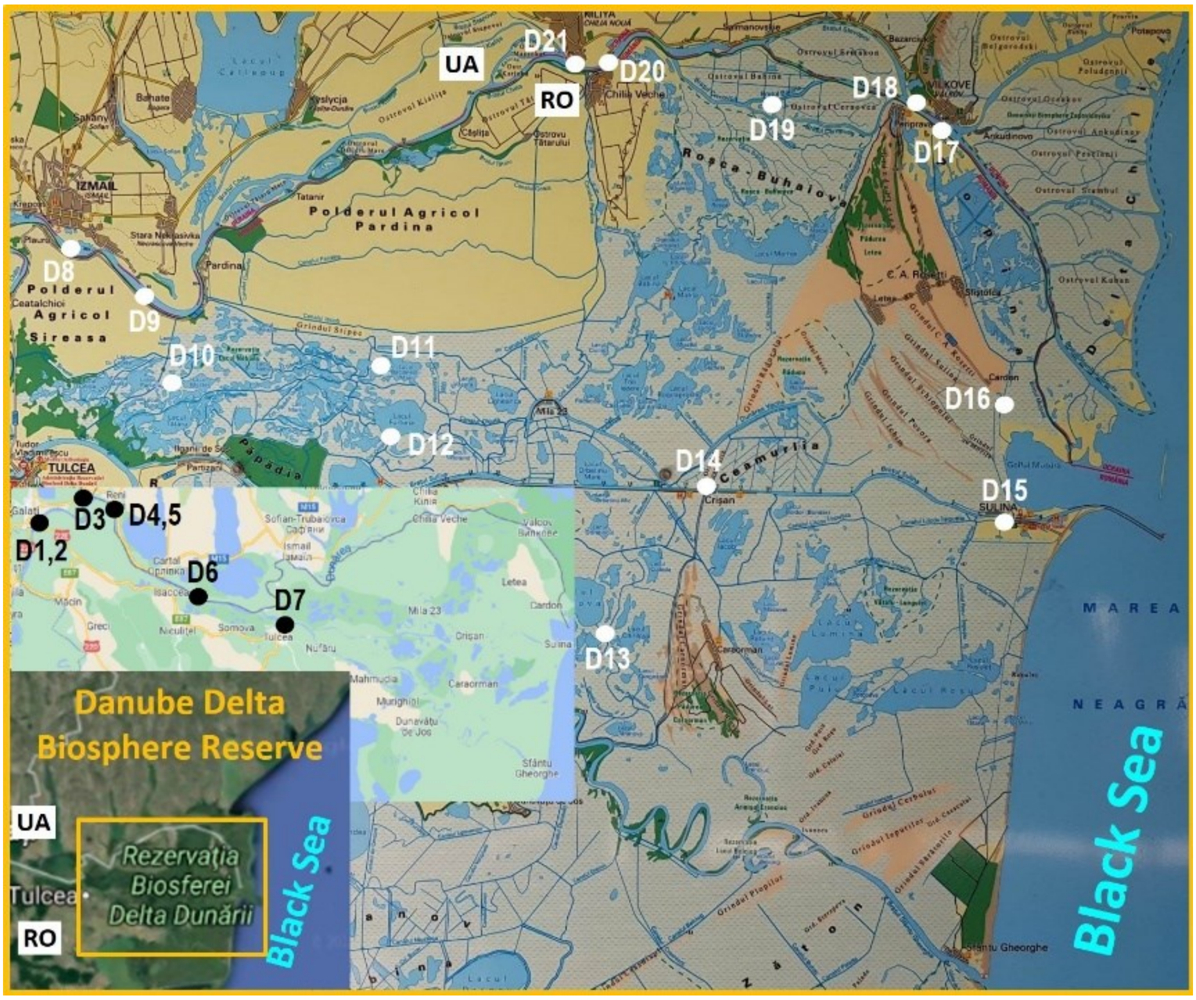

Fig. 2. Boat trips sites in Danube River basin and Danube Delta.

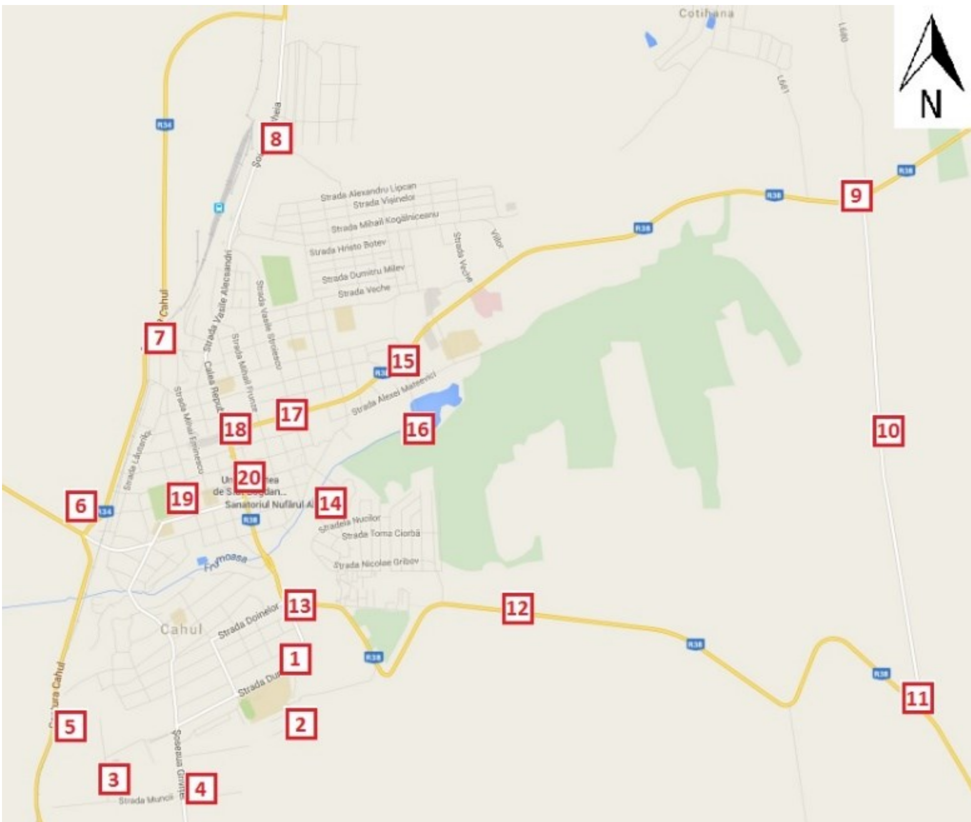

Fig. 3. Monitoring sites in Cahul town, Lower Prut River, Republic of Moldova.

Results and Discussion

The average (AVE) values of the outdoor gamma radiation dose rate, in nGy/h, calculated for 50 measurements per each site, together with the values of standard deviation (SD), coefficient of variation (%), minimum (MIN), maximum (MAX), median (MED) and geometric mean (GM) are presented in Tables 1 and 2, for field and boat expeditions, respectively.

The data recorded for targeted spots using portable dosimeters highlight a spatial and temporal (daily, hourly) variation of the outdoor gamma dose rate and the specificity of the geographical location.

Tab. 1. Gamma dose rates (nGy/h) recorded during the field trips carried out in the target sites in Romania, Moldova, Greece

Site no.	Site code	Location	Site description[a]	AVE	SD	CV (%)	MIN	MAX	MED	GM
1	CT1	Constanta (RO)	Town, Modern beach	75	12	16.7	51	103	72	74
2	CT2	Constanta (RO)	Beach, rocks formation	123	41	33.5	62	228	124	116
3	M1	Mamaia (RO)	Central part beach, CT	142	33	23.5	93	240	135	139
4	M2	Mamaia (RO)	Tomis hotel beach, CT	111	25	22.3	51	155	114	108
5	NV1	Navodari (RO)	Beach, CT	152	14	9.0	135	198	154	152
6	CR1	Corbu (RO)	Wild beach, CT	195	37	19.0	145	259	192	191
7	VU1	Vadu (RO)	Wild beach, CT	133	45	33.7	72	228	115	126
8	VV1	Vama Veche (RO)	Beach, BS, CT	71	22	30.3	41	114	72	68
9	SG1	Sf. Gheorghe (RO)	Beach, DD-BS, TL	145	29	20.1	83	207	145	142
10	SG1	Sulina (RO)	Beach, DD-BS, TL	130	14	11.0	114	155	130	129
11	TL1	Tulcea (RO)	Tulcea town, TL	142	33	23.4	83	191	149	138
12	Cr1	Caraorman (RO)	Forest, DD, TL	124	39	31.3	83	249	114	120
13	LT1	Letea (RO)	Dune sands, DD	103	28	27.1	62	155	93	99
14	IS1	Isaccea (RO)	Quarry lake, TL	265	101	38.2	113	479	239	246
15	IS2	Isaccea (RO)	Municipality park, TL	139	28	20.3	89	185	143	136
16	MC1	Macin (RO)	Danube banks, TL	139	32	23.0	72	197	145	135
17	OS1	Ostrov (RO)	Danube banks, CT	151	17	11.3	105	186	150	150
18	GL1	Galati (RO)	Danube banks, GL	144	40	28.1	51	218	145	137
19	GL2	Galati (RO)	Park, granite sidewalks	258	46	17.6	186	391	249	254
20	VL1	Vladesti (RO)	Ravene, Prut R., GL	208	37	17.7	119	281	203	204
21	OA1	Oancea (RO)	Prut R., RO-MD border	154	28	18.3	95	209	155	151
22	VAD1	Vadeni (RO)	Prut R., RO-MD border	139	23	16.7	95	213	137	137
23	RS1	Roscani (RO)	Roscani forest, GL	157	18	11.6	119	191	161	156
24	RR1	Rarau (RO)	Lodge, Carpathians Mts.	183	35	19.4	83	238	186	179
25	CM1	C-lung Mold. (RO)	E part of town, SV	182	26	14.3	135	249	176	180
26	PJ1	Pojorata (RO)	Village, SV	209	40	19.0	135	290	207	205
27	VP1	Valea Putnei (RO)	Parking, SV	255	40	15.5	184	342	249	252
28	ME1	Mestecanis (RO)	Parking, SV	183	30	16.3	114	228	186	181
29	IA1	Iacobeni (RO)	Old U mine railway, SV	213	32	14.9	155	270	219	211
30	VT1	Vatra Dornei (RO)	Central park, SV	163	24	14.5	124	218	155	162
31	CH1	Cahul (MD)	South part of town	86	17	19.9	59	113	86	85
32	LM1	Manta (MD)	Lake, Prut reserve	137	25	18.3	83	185	137	134
33	DN1	Molovata (MD)	Dniester River	118	32	26.9	72	186	109	115
34	KA1	Kavala (GR)	Public beach	206	39	18.9	114	283	197	202
35	NI1	Nea Iraklitsa (GR)	South beach	238	42	17.5	155	321	228	234
36	NP1	Nea Peramos (GR)	Central beach	243	43	17.5	107	342	238	239
37	NP2	Nea Peramos (GR)	South beach	371	62	16.7	207	456	394	365
38	NP3	Nea Peramos (GR)	Ammolofoi beach	394	45	11.5	311	498	384	392
39	SO1	Sotiras (GR)	Platanas square, Thassos	153	28	18.1	89	209	155	150
40	LI1	Limenas (GR)	Glikadi beach, Thassos	100	40	39.8	51	186	83	93
41	SP1	Skala Panagia (GR)	Chrysi Ammoudia beach	145	50	34.6	51	238	150	135

[a] Abbreviations: DD=Danube Delta; BS=Black Sea; CT, SV, TL, GL=Constanta, Suceava, Tulcea, Galati counties.

The mean values of outdoor gamma radiation dose rate are ranging between 71 nGy/h (Vama Veche, Black Sea coast, Romania) and 394 nGy/h (Nea Peramos, Ammolofoi beach, Northern Aegean Sea, Greece), with a recorded minimum of 41 nGy/h and a maximum of 489 nGy/h in these touristic places, respectively (Table 1).

The measurements performed at water surface during boat expeditions (n=21) on Danube River and Danube Delta lakes and channels point out lower values of dose rate (Table 2), due to the weak influence of gamma rays' emission from bottom sediments.

Tab. 2. Gamma dose rates recorded during boat trips on the Danube River and Danube Delta

Site no.	Location	AVE	SD	CV (%)	MIN	MAX	MED	GM
D1	Galati, middle channel	72	15	21.0	41	101	71	70
D2	Galati, left bank	81	19	22.9	41	126	77	79
D3	Giurgiulesti, MD border	86	20	23.2	41	125	89	83
D4	Reni, middle channel	77	20	26.5	25	113	77	74
D5	Reni, left bank	87	23	26.7	47	137	83	84
D6	Isaccea, midddle channel	66	25	38.0	17	119	65	61
D7	Tulcea	84	27	31.7	41	131	89	80
D8	Ismail, RO bank	78	24	30.4	41	125	77	74
D9	Ismail, ore harbor	88	20	23.0	53	125	89	85
D10	Sireasa channel	80	23	28.5	29	125	80	76
D11	Baclanesti lake	74	21	29.0	29	119	71	70
D12	Furtuna lake	79	27	33.9	29	143	83	74
D13	Perivolovca channel	75	21	28.0	29	119	77	72
D14	Crisan	75	13	17.4	41	101	77	73
D15	Sulina	86	20	22.9	41	131	83	84
D16	Musura channel	73	21	28.1	29	113	71	70
D17	Periprava, RO bank	94	24	25.4	47	143	95	90
D18	Vylcovo, middle channel	76	20	25.7	41	125	77	74
D19	Babina branch	86	29	33.9	29	143	83	81
D20	Chilia veche, RO bank	91	24	26.9	35	143	95	87
D21	Kiliya (Chilia noua), middle channel	77	19	24.2	29	113	77	74

Among the urban sites, Constanta town (RO) exhibits the minimum value of the average gamma dose rate of 75 nGy/h, followed by Cahul town (MD) with 86 nGy/h. In most of the locations (Tables 1,2), the dose rates values fall in the normal range of 52–163 nGy/h given in the 2008 Report of United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Compared with the official reports for external gamma dose, our results registered in the period 2014–2022 are lower than the attention limit of 250 nGy/h, except for several beaches in Greece, and mountain areas and urban sites in Romania (Table 1). The reason of high value of dose rate in Greek touristic sites resides probably from the existence of sands rich in heavy minerals such as allanite, monazite and zircon, which control the contents of natural radioactive elements uranium and thorium in the Kavala pluton [8]. The presence of radionuclides from base rock [9] and building materials, such as granites [10–13], used for urban sidewalks construction, might increase the values of dose rate, as resulted from the measurements performed in Isaccea old quarry and Galati town park, Romania. The Eastern Carpathian Mts. region in Romania also has a relatively high level of radioactivity, due to the composition of its granitic rocks (Valea Putnei, Pojorata) or former uranium mining activities (Iacobeni, RO). Slight exceeding of the limit value of 250 nGy/h is observed in Vladesti village (Galati County) in a ravene area having clay as main geological background and in Corbu wild beach (Black Sea littoral), a region characterized by mining and processing of zircon sand which is one of the major sources responsible for naturally occurring radionuclides in the earth's crust [14].

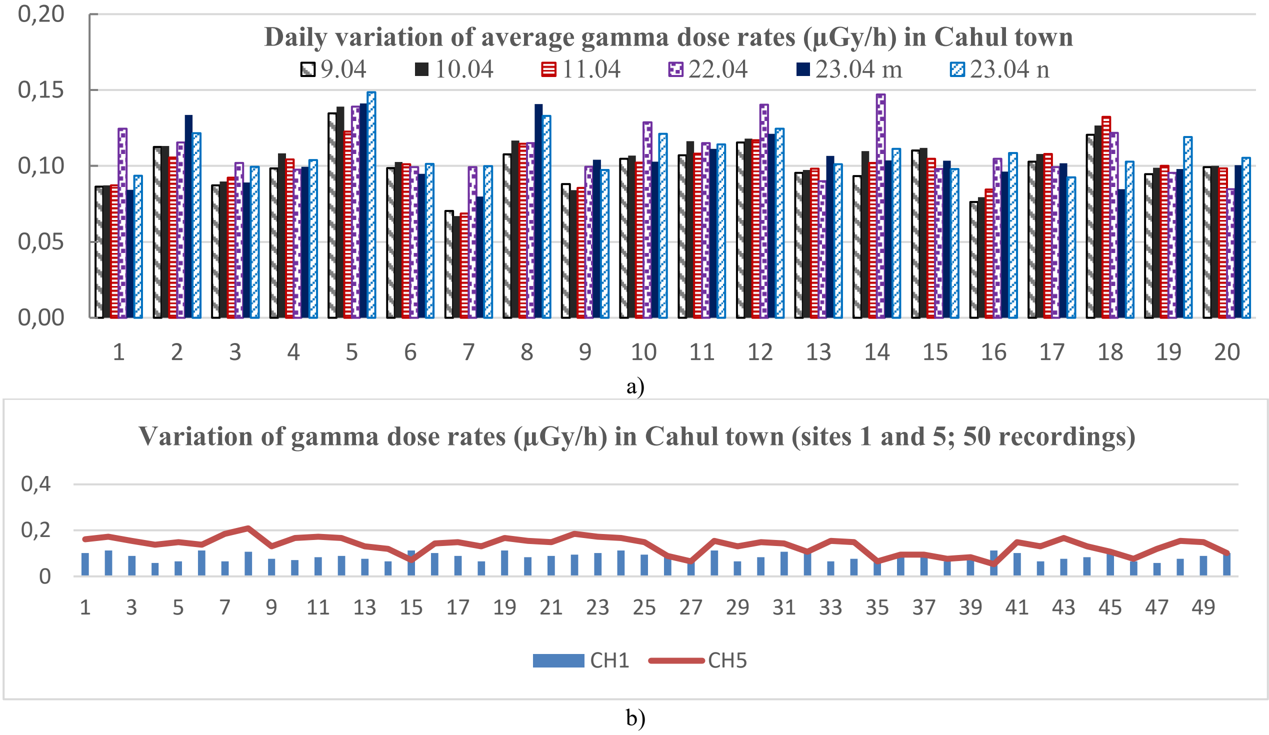

Fig. 4. Temporal variation of outdoor gamma dose rate in Cahul town in April 2015: a) average dose rate (20 sites, 5 days: m=morning, n=night); b) dose rate in sites 1 (south part) road and 5 (near national road).

For Cahul town in Moldova, the results of the measurements carried out in each of the 20 selected locations in 5 different days in April 2015 (Figure 4) point out a clear spatial and temporal variation of ambient gamma dose rate. The values vary with site, day and hour, and might be influenced by the temporal fluctuations of terrestrial and cosmogenic radioactivity, meteorological conditions and presence of radiation emitted by building materials.

The data of the dose rate temporal variations will be used for the target regions as a base in further investigations and preparation of maps of gamma dose rates (terrestrial and cosmic) [3], and calculation of the health risk for inhabitants and tourists.

Conclusion

The investigation of the level of environmental radioactivity and assessing the health risk of gamma-emitting radionuclides are of great importance in environmental management and evaluation of radiological hazards for population health and ecosystems.

The monitoring of different regions and detection of the presence of radioactive anomalies in certain areas makes the problem of assessing the radioactivity of objects and territories relevant. Such studies make it possible to determine the natural gamma background of the studied areas, to assess the radiation doses of the population from natural sources of gamma radiation and to identify those territories unsuitable for human activity and areas which require the organization of radioecological monitoring.

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