Radiation Study, Summary and Conclusions

The surveys carried out in Struma motorway, Lot 3.2 area on the gamma radiation dose intensity along with the analysis of the specific activity of naturally occurring radionuclides' **have shown some alarming results:**

1. At T5; T11; T12; T14; T17; T18 and T19 spot locations have been measured higher values of gamma radiation dose intensity in comparison to those of the naturally background radiation. All these higher levels of gamma radiation are directly related to fault zones, i.e. the one near Devilska river and the one around Yavorov fault, leading through paleogenic granite massifs.
   Such higher levels of gamma radiation are common for areas of former sites of uranium mining activities, as is the case with Krupnik No. 70 site (as per Decree No. 74 of the Council of Ministers, SG No. 39/ 1998).
   Higher levels of gamma radiation dose intensity have also been measured at T23 and T24 spot locations in the area of Gorna Breznitsa village, related to another type of volcanic formation – dacites.

These results confirm the theory that Krupnik uranium field and to a certain degree the accumulation of radionuclides in the area of Gorna Breznitsa village are related to the migration of radioactive elements from granite and dacite massifs along existing fault zones towards the graben-like tectonic structures – Krupnik and Kresna.

1. Results **from the analysis of the specific activity of naturally occurring radionuclides' through gamma spectrometry** of the complex soil and rock samples are presented in inspection protocols No. No. GR172/ 2015.08.27 to No. GR178/ 2015.08.27, and in *Table No.1*. as well

Table No.1.

SPECIFIC ACTIVITY OF NATURALLY OCCURRING RADIONUCLIDES									
					TESTED SAMPLES				
SAMPLES	REFERENCE VALUES FROM THE UNSCEAR report*	BACK-GROUND SAMPLES **	No. GR 172/20 15.08.27	No. GR 173/20 15.08.27	No. GR 174/20 15.08.29	No. GR 175/20 15.08.30	No. GR 176/20 15.08.31	No. GR 177/20 15.08.32	No. GR 178/20 15.08.33
^{40}**K** specific activity **[Bq/kg]**	**400**	**570**	1160	959	991	920	1126	1185	570
^{40}**K** comb. stand. uncertainty (1σ) [Bq/kg]			30	25	26	32	30	30	16
^{210}**Pb** specific activity **[Bq/kg]**			95,8	45,8	46,1	51,5	59,1	39,1	28,4
^{210}**Pb** comb. stand. uncertainty (1σ) [Bq/kg]			4	2,5	2,1	4,2	3,4	1,6	2,3
^{226}**Ra** specific activity **[Bq/kg]**	**45**	**35,9**	112	62	44,8	76	80	65	35,9
^{226}**Ra** comb. stand. uncertainty (1σ) [Bq/kg]			10	6	1,1	6	7	6	1,0
^{232}**Th** specific activity **[Bq/kg]**	**30**	**29,7**	77,3	50,2	59,5	56,2	76,4	88,2	29,7
^{232}**Th** comb. stand. uncertainty (1σ) [Bq/kg]			3,4	1,5	2,1	1,8	2,4	2,5	1,3
^{235}**U** specific activity **[Bq/kg]**			3,1	1,46	1,99	2,27	2,58	3,66	1,81
^{235}**U** comb. stand. uncertainty (1σ) [Bq/kg]			0,6	0,3	0,18	0,31	0,35	0,37	0,20
^{238}**U** specific activity **[Bq/kg]**	**40**	**39,2**	68	32	43,2	49	56	80	39,2
^{238}**U** comb. stand. uncertainty (1σ) [Bq/kg]			13	7	3,9	7	8	8	4,4
*UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation									

** Background samples measured in the vicinity of Oshtava village

It's evident from the results presented in *Table №* 1 **that the concentration levels of naturally occurring radionuclides are higher than both the typical values for Bulgaria**, published in UNSCEAR's report (2000) and **the background/ reference sample** taken outside the surveyed area, in the vicinity of Oshtava village.

The soil sample, taken from the surface layer in the **area of Krupnik village** (starting point of Lot 3.2) contained **the highest amounts of uranium** (^{238}U – 68 Bq/kg) **and radium** (^{226}Ra – 112 Bq/kg)**.** Such values are common for former uranium mining sites (Krupnik No. 70 site and Eleshnitsa site (Druzhba 1 and Druzhba 2), No. 1 and No. 2 respectively, as per Decree No. 74 of the Council of Ministers, SG No. 39/ 1998). The specific concentration of ^{226}Ra in the rock samples varies between 44.8 Bq/kg and 80 Bq/kg, while the concentration of ^{235}Th – from 50.2 Bq/kg to 88.2 Bq/kg, which **exceeds twice the measured background values.**

2. During a potential boring of a long tunnel in Struma motorway Lot 3.2 section, the underground excavations around the tunnel tubes will be with variable gradients and will inevitably pass through areas with increased presence of **uranium and radium.** If these amounts are within the boundaries of the measured concentrations, conduction of construction works will be possible, provided that relevant specialized precautions have been undertaken. Regardless of such measures however, there's a potential risk that if separate radioactive particles are inhaled by construction workers and engineers, after certain time this may result in various cancer diseases.
3. During a potential implementation of the construction works, around the two tunnel tubes will be created ground water drainage areas and the collected water will have to be drained via parallel drainage pipes. Such change in the ground water routes will create prerequisites for increased leaching of radioactive elements from the massif and will predetermine the necessity for treatment of such water. The leaching itself will constitute an additional issue during a potential tunnel construction.
4. A lot more complicated is the issue with the deposit areas for excavated rock material from the two tunnel pipes, with approximate volume exceeding 6 000 000 $м^3$. When the pyrite minerals from the granites come into contact with the infiltrated rain water they will be oxidized and a leaching process will commence, affecting not only the radioactive elements, but all heavy metals as well. This in turn will require drainage of all infiltrated water amounts passing through the deposited crushed rock material. For this reason the deposit area (or rather areas) will have to be supplied with comprehensive drainage systems, including the relevant water treatment facilities.
5. The deposited excavated material will have to be covered with natural or artificial anti-filtration screens. These screens, along with the above-mentioned drainage systems, will significantly raise the costs for construction of the deposit areas. Finally, there are no alternative variants for utilization of the excavated from the tunnel tubes material during the construction of road embankments.

Conclusion

The provided summary of the findings from the radiation dose intensity surveys and the analysis of the **specific activity of naturally occurring radionuclides, reaching concentrations which exceed two to three times the background concentration values,** indicate that naturally occurring radionuclides **will constitute a serious hazard** during a potential construction of a long tunnel with two tubes. Furthermore, the excavated rock material from the tunnels will have to be deposited at supplied with suitable drainage facilities deposit areas, with the water running out of this areas being subject pursuant to the provisions of the Bulgarian legislation to treatment with regard to the presence of radionuclides. Additionally, the deposit areas will have to be covered with natural or artificial anti-filtration screens, which will significantly raise the costs for construction of a long tunnel.

All of the above-mentioned issues related to the potential construction of a long tunnel are of minor significance in the alternative variant solution when the same section of Struma motorway Lot 3.2 is implemented as a combination of open expressways, viaducts and short tunnels. For these reasons we categorically do not recommend the construction of a long tunnel with two tubes, associated with high risk potential.