URANIUM (U) CONCENTRATIONS IN THE SOIL OF THE TUZLA'S URBAN AREA

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The paper presents the results of the pedological-geochemical researches of the soil in the Tuzla's urban area. The conducted researches, among the others, included the analysis of soil samples on radioactive element uranium (U). The research has required the few stages of research and application of different methods, such as literature analysis, the preparing of the work concept and the order of researches, terrain researches, analysis of the soil samples and drafting of the thematic maps and tables etc.
Increased concentrations of U in soil samples are registered in several local communities located mainly on west and southwest of the investigated area. The conducted research results indicated that increased concentrations of this radiotoxic and cancerogenous element in the analyzed area are mostly the consequence of human activities.

Key words: uranium (U), soil samples, increased concentrations, environment, Tuzla

INTRODUCTION

The area of Tuzla geographically belongs to the macroregion of the Peripanonian Bosnia, i.e. to the mesoregion of the northeastern Bosnia, and located between Panonian plain in the north and Dinarides mountain system at the south. From the regional-geographical aspect, the mentioned area belongs to the northern Bosnia, i.e. to the subregion of the Spreča-Majevica. The urban part of the Tuzla is mostly located in the valley of the Jala river, whose base is flattened and eroded by the fluvial erosion. South Majevica foothills, which is neotectonically uplifted at the basin borders, orographically closes the area from north, east and south. On the west, not far from the Šići settlement, the Tuzla's basin is morphologically merged with Donjosprečka valley.

The urban area of Tuzla is located between 18°56' and 18°79' E and 44°48 'and 44°60' N, at an altitude from 202 and 480 m. The urban area of Tuzla covers about 98.37 km^2 and it's located on the northern slopes of the Dinarides mountain system and is generally mildly tilted towards the Gornja Spreča valley (Stjepić Srkalović, 2015). There are about 110,979 inhabitants living in 66 settlements in this area (Census, 2013).

The geological structure of soil considers the rock surface, which is changed under the influence of a many factors and from which the soil is evolving and developing. Soil material can provide any rock, if it's on the surface and the subject of physical, chemical and biological impacts, that lead to the decomposition of its surface layer (Ćirić, 1991).

The urban and industrial development of Tuzla is based on the thick deposits of salt and coal. Recently, the Tuzla's area and its wider surrounding is marked by the processes of

urbanization and deruralization, industrialization and deagrarization, which are contributing mostly to the pollution, degradation and devastation of soil (Stjepić Srkalović, et al, 2016).

The main goal of the research was to determine to what extent the urban area of Tuzla is contaminated with the radioactive element uranium (U). Considering the defined goal, the detailed soil analyze for the presence of potentially toxic elements of the Tuzla's urban area, was carried out. On the research results basis of the presence and quantity of the mentioned element, it has been concluded that the uranium concentrations have been overly exceeded in the specific parts of the researched area.

Radioactive elements are dangerous for humans, plants and animals depending on their concentration, bioavailability and bioaccumulation.

GEOLOGICAL SETTINGS AND PEDOGEOGRAPHIC CHARACTERISTICS

Geological settings

The oldest structures belong to the Tuzla's lower Miocene formations in which organogenic limestones are prevailing ("slavinovićki" limestones and dolomites) with sporadic marls. Above them, the clasts were deposited with characteristic reddish coloring sandstones and conglomerates, building the "red" series. The continuation of sedimentation cycle is made of a "trakasta" series, where the salt formation with accompanying dolomite, anhydrite and tufts are developed. The organogenic limestones, clays, marly clays, sands and subsidiary conglomerates are belonging to the youngest Miocene products.

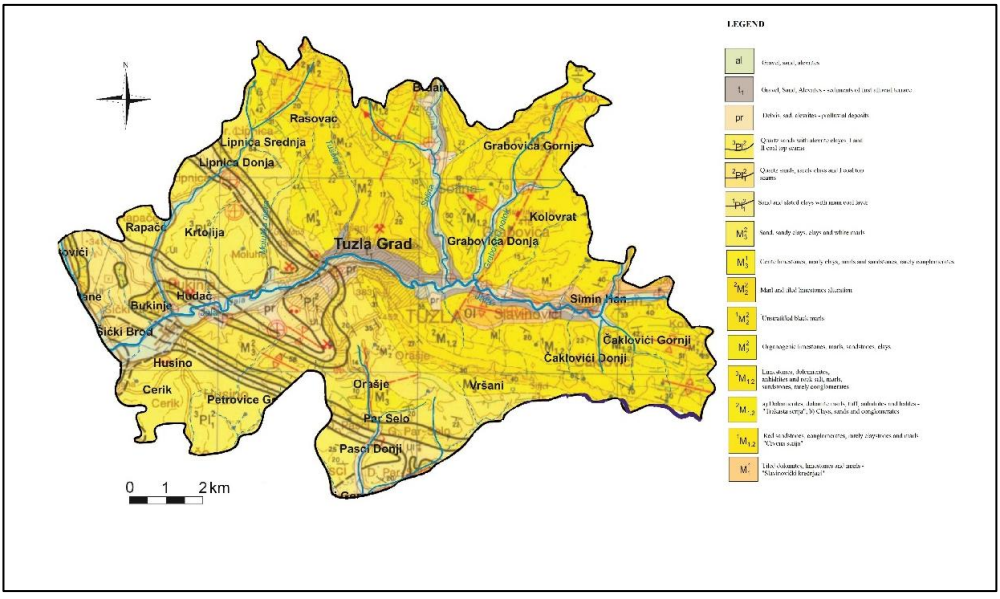

Fig. 1. Geological map of Tuzla's urban area (Čičić, 1988)

The development of the lower Pliocene is characterized by the deposition of several seams of lignite (main, base and top seams). Vertical development of the Pliocene formation has the characteristics of rhythmicity: quartz sand, clays (slate and alevrite) and lignite. Quaternary formations were developed along the streams in the form of proluvial depositions (debris) and as precipitated terrace and alluvial sediments (sand and pebbles) (Fig. 1) (Čičić, 1988, Stjepić Srkalović, et al. 2017).

Pedogeographic characteristics

On the pedological map (R = 1: 50 000) of the Tuzla's urban area, there are 16 (mostly automorphic) soil types (Ćirić, 1991; Stjepić Srkalović, 2015) (Fig. 2).

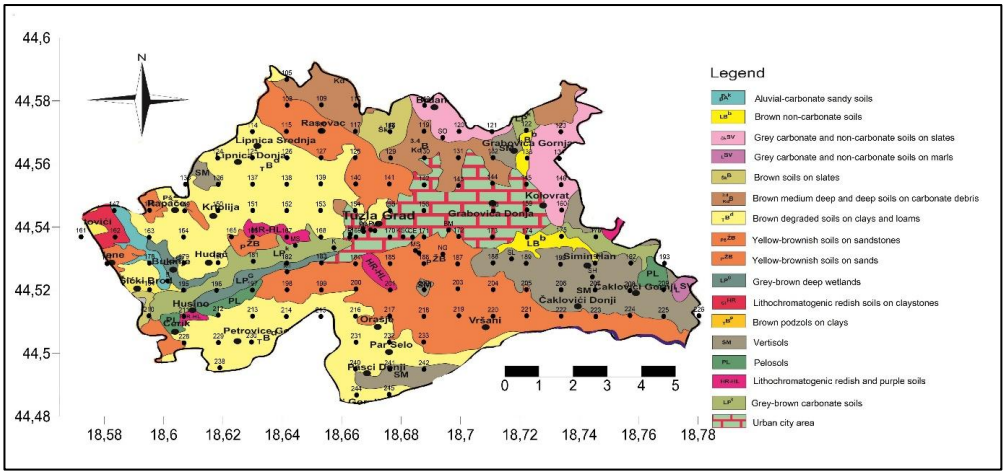

Fig. 2. Pedological map of Tuzla's urban area

The most common types of soil in the researched area are yellowish-brown soils on sands and sandstones, brown degraded soil on clays and loams, brown medium deep and deep soil on limestones, grey-brown carbonate soil, grey-brown deeply-soaked soils, pelosols and vertisols. It should be noted that high percentage of this soils is covered with urban infrastructure and isn't used for agricultural purposes.

METHODS AND RESEARCH RESULTS

Research methods

The methods of research and laboratory testing included the analysis of previous research findings, terrain observation, sample preparation for laboratory testing, laboratory research and textual and graphical processing of results.

Terrain work was based on soil sampling (129 samples) from the area of about 100 km^2 (urban part of Tuzla) (Fig. 3a). The samples were collected according the composite sampling scheme (Fig. 3b), i.e. 5 subsamples collected from the corners and the center of the

square made 1 sample. The samples were taken from a depth of about 30 cm and stored in PVC bags with the specified number, location, coordinates and other data.

Soil sampling was conducted according to the geochemical expert group (The Urban Geochemistry Project (URGE)) (Ottesen, et al, 2008).

Preparation of soil samples for laboratory analysis (sowing, drying, grinding, weighing) was carried out on the Faculty of mining, geology and civil engineering of the University of Tuzla.

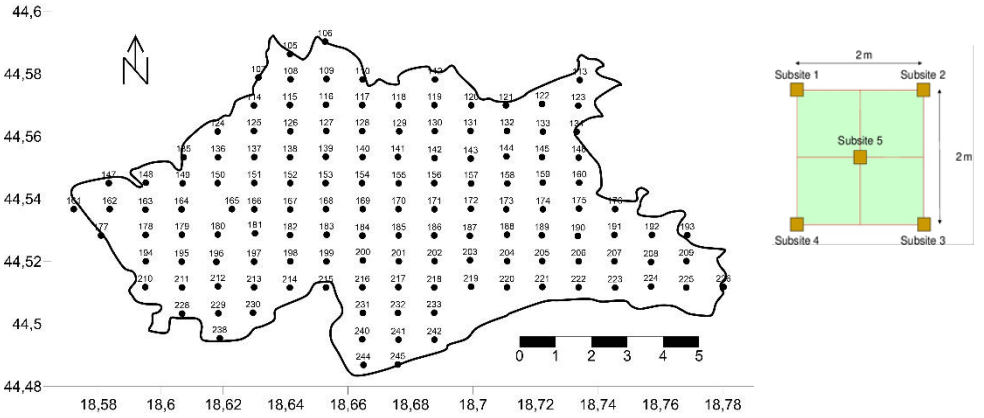

Fig. 3. a) Sample locations and b) soil sampling scheme

The laboratory analysis was performed at Bureau Veritas Commodities Canada Ltd., Laboratory in Vancouver - Canada, by Ultra trace ICP-MS method (Inductively Coupled Plasma - Mass Spectrometry), code MA250. The detection limit of this method for uranium is 0,1 – 4.000 ppm. The graphical processing of the results was made in the Golden Software Surfer 12 software package.

Research results

The uranium concentrations were analyzed in 129 soil samples, collected in the urban part of Tuzla and shown in Table 1. The graphic display of the uranium concentrations in the soil of the urban part of Tuzla is shown in Fig. 3.

Table 1: The concentration of uranium (U) in soil samples in researc
***the U concentrations are in ppm**

Sample No.	U	Sample No.	U	Sample No.	U	Sample No.	U	Sample No.	U	Sample No.	U	Sample No.	U
105	1.9	130	1.9	151	2.4	173	2.2	194	1.8	215	2.3	242	2.5
108	1.7	131	2.1	152	1.6	174	2.2	195	2.0	216	2.4	244	1.9
109	2.3	132	1.5	153	2.0	175	1.7	196	1.6	217	1.8	245	2.3
110	2.0	133	2.1	154	1.5	176	1.5	197	1.6	218	2.5		

112	2.5	134	1.8	155	1.7	177	1.3	198	1.8	219	2.8		
114	1.6	135	1.9	156	2.1	178	2.8	199	2.5	220	3.0		
115	1.9	136	1.7	158	1.8	179	3.4	200	3.0	221	2.7		
116	2.2	137	1.8	159	2.2	180	2.0	201	1.6	222	2.5		
117	1.6	138	2.1	160	2.2	181	2.0	202	2.8	223	1.7		
118	1.4	139	2.5	161	2.4	182	2.0	203	1.2	224	2.8		
119	2.4	140	2.0	162	2.6	183	2.6	204	1.9	225	1.8		
120	2.7	141	3.0	163	3.5	184	2.1	205	1.9	226	1.7		
121	2.3	142	2.2	164	2.0	185	1.8	206	1.6	228	3.3		
122	1.4	143	1.9	165	1.4	186	1.7	207	1.6	229	3.4		
123	2.0	144	1.9	166	2.0	187	1.4	208	2.7	230	2.9		
124	1.6	145	3.0	167	2.6	188	1.9	209	2.1	231	2.1		
125	1.2	146	2.2	168	1.8	189	1.1	210	2.0	232	2.1		
126	2.2	147	4.2	169	1.9	190	2.7	211	1.9	233	2.5		
127	1.9	148	2.6	170	2.2	191	1.8	212	2.9	238	2.7		
128	2.8	149	2.6	171	2.1	192	2.5	213	2.4	240	2.0	**Median**	2,1
129	2.3	150	2.4	172	2.1	193	2.1	214	4.5	241	2.4	**Avg.**	2,16

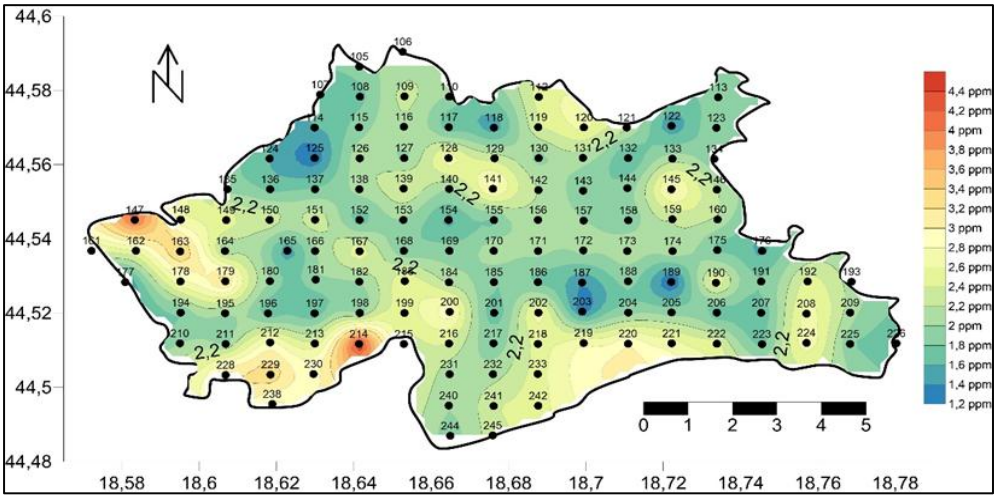

Fig. 3. Uranium concentration in Tuzla's urban area soil samples

DISCUSSION

The uranium is lithophile element. It is being enriched in the lithosphere by the growth of magma alkalinity. It's accompanying element of the thorium. The average content of uranium in magmatic rocks is 2.7 ppm, in sedimentary rocks (in slates) is 3.7 ppm, in carbonate rocks 2.2 ppm and in sandstones 0.45 ppm. In soils, the average uranium content varies from 1.2 to 11 ppm.

Uranium is chemotoxic, radiotoxic and cancerogenous. In addition to radioactive radiation, all uranium compounds are moderately poisonous to all organisms. Into the human organism it comes through food and accumulates in the lungs, kidneys, liver and bones. It is used as a fuel in nuclear power plants, in the military industry, and has been used for ceramic and glass dyeing. Into the environment uranium is dispersed by testing nuclear warheads and ammunition, atomic bombs, and by nuclear accidents. In addition, it gets into the soil by burning the fossil fuels and use of phosphate fertilizers (Šorša, Halamić, 2014).

According to data obtained during 1991. „In situ mjerenja gamafona u okolini termoelektrana na ugalj na području BiH", the specific U^{238} activity in the soil at 3-5 km distance from power plant "Tuzla" amounts to 1.74 ppm, in the immediate nearness of the power plant is 2, 0 ppm, 3-5 km after the powerplant is 2.49 ppm and on the power plant "Tuzla" depot is 2.12 ppm (Mihalj, et al, 1996).

The uranium concentrations in the soil samples is in the range of 1.2 to 4.2 ppm, with a median of 2.1 ppm. The maximum value was registered in the area of Plane, Bukinje and Rapače settlements with 4.5 ppm and in the area of Gornji Pasci with 4.2 ppm (Table 1, Fig. 3). Considering that the geological base in this area consists mainly of sand and sandstones (Fig. 1), it is evident that the increase of uranium in soil samples collected in these settlements is of anthropogenic origin. The settlements Plane, Bukinje, Rapače and Gornji Pasci are located in the immediate vicinity of the power plant "Tuzla".

On the map of spatial distribution, it is noticeable that uranium concentrations are increased in the soil samples near the thermal power plant "Tuzla", which can be explained by the wind particle transport in the northwest-southeast directions. Wind is an important climatic element, because the concentration and diffusion direction of the pollutants depends on its speed and intensity and can be considered as the basic parameter of the urban climate.

According to the annual values, the highest wind frequencies that are occurring in the area of Tuzla valley are the northeastern winds, which are represented by 17.5% and the southwestern winds with 13%. The annual frequencies of the quietude are dominant and amounts 30,6%. The recorded wind roses at the meteorological station "Tuzla", located at the Bukovčić (φ = 44°32' N, λ =18°41' E, 305 m a.s.l.) show that the average wind speed is 1,5 m/s, indicating that Tuzla's basin has a very low air circulation (Tab. 2) (Gutić, 2015).

Table 2: Frequencies and medium speeds of certain wind directions in the Tuzla's basin

Pravac	N	NE	E	SE	S	SW	W	NW	C
%	11,2	17,5	5,8	4,9	3,9	13,0	8,7	4,3	30,6
m/s	1,5	1,4	1,3	1,6	1,8	2,0	1,6	1,3	

Data source: Meteorološki godišnjaci, FHMZ, Sarajevo.

Not as significant increases can be seen in the areas of main roads and near the open pit mine "Dubrave". Undoubtedly, the elevated concentrations of the uranium in the soils are of anthropogenic origin.

CONCLUSION

The uranium concentrations were evaluated in 129 samples, gathered in the urban Tuzla area. The samples were sampled in a net 1x1 km, from the area of 100 km2. The results of the analyzed soil were processed in the Golden software Surfer 12 package and shown on the thematic map, where it can be seen that the uranium concentration vary in a range from 1,2 to 4,2 ppm, with a median of 2,1 ppm.

The maximum value is registered on the area of Plane, Bukinje and Rapače settlements, with 4,5 ppm and Gornji Pasci with 4,2 ppm. Considering the hodograph plot of wind vectors, it can be concluded that the elevated concentrations of uranium in the soil samples, it those areas, are anthropogenic - mainly caused by fossil fuel burning and the deposition of slug and ash in the nearby landfills. Additional researches on plants and agricultural crops need to be done, how the precise determination of uranium could be completed.

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