Environmental Impact of Uranium Mine Waters in Eastern Serbia

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Abstract
The territory of Eastern Serbia is characterized by a number of natural occurrences and four deposits of nuclear mineral ores of uranium mineralization. Stara Planina Mountain represents a significant metal genetic area, with variety of mineral paragenesis formed, both of endogenetic or atmospheric/surphace origin. Particular points of interests are hercinyan orogeny ore deposits, such as uranium, gold, silver and bismuth deposits. Exploitation and processing of uranium ore started in late fifties of the twentieth century and ran until 1996, when all the mines were conservated. Two mines, "Mezdreja" and "Gabrovnica" exist within the study area together with number of exploratory galleries on the "Srneci Do" and "Aldina reka" locations. Uncontrolled mine waters leak out directly from the mentioned objects into the local streams. Registered concentrations of uranium in mine waters range up to 2,700 μg/l (uranium MAC in drinking waters in Serbia is 50 μg/l). During nineties of the twentieth century (several occasions in 1992 and 1997) and during 2008, concentrations of natural radioactive elements such as uranium, thorium, radium and radon in soil, water, river deposits and tailing dumps were investigated and measured. The main aim of investigation was to determine grade of water and soil vulnerability in the area. A number of different methods was used during research, such as radiometric and emanation measures, hydrogeochemical methods etc. Analyses of geological, hydrogeological and hydrogeochemical features of the study area as well as the most vulnerable level of environment and type, degree and causes of pollution are presented in this paper. The basic processes of mobility, transport and uranium deposition in water and soil are also explained.

Key words: uranium, mine waters, environmental protection

Introduction

There are several uranium deposits in Serbia. The occurrences of uranium mineralization are present at several localities in Central and Eastern Serbia. The exploration of those localities has been carried out since the middle of the last century, with some interruptions. The uranium ore was exploited only in Stara Planina Mountain in Eastern Serbia in the vicinity of the Bulgarian border (Fig. 1).

The first exploration of uranium in Eastern Serbia began in 1949. The first investigated location was "Aldina reka", while in 1951 uranium ore occurrences were discovered in "Mezdreja" [5]. From 1951 to 1956 intensive research of the terrain began where geological and geophysical investigation were carried out, as well as, the partial investigation of the Stara Planina Mountain granitoid complex. By not fully detailed prospecting of the terrain in 1957 the Grabovnica deposit was discovered, as well as several other locations which would serve later as orientation for further exploration. Further explorations were initiated again to a certain extent in 1960 and were related to the clearing up of the formed tailing dumps. During 1962 a structural geological map of uranium deposits was made 1:10.000 [1]. The Janja Granite Complex represents part of the study area where the explorations were the most extensive (in the period from 1949 to 1966 continually). During that period three deposits were discovered (Mezdreja, Gabrovnica and Srneći do), as well as several other radioactive occurrences. Thus the area surrounding the town of Kalna on Stara Planina Mountain in Eastern Serbia, represents a location characterised by the increased content of natural radioactive elements. The increased radioactivity is conditioned by the presence of mines where the uranium ore was exploited,

The latest investigations of uranium concentration in the waters of the abandoned mines and mine works were carried out to determine the present state of the environment in this area. The obtained results were compared with those of previous investigations which had been carried out systematically until 1996.

Figure 1 *Geographical position of the study area*

Applied methodology of exploration

The most detailed exploration carried out embraces the investigation of the uranium concentration at the Mezdreja and Gabrovnica locations (two most significant deposits) (fig. 2). Within these deposits, the exploration locations, which were supposed to be the biggest environmental pollutants, have been selected.

After the closing of the mine the quantity of natural radioactive substances increased through the time. A whole set of various methodological procedures was applied in order to determine the contamination of waters in the area of the abandoned mines. The determination of both concept and methodology of research was especially made on the basis of past results related to the state of environment [2,3,4]. Until the year 1997 geoecological, radiometric, geochemical, and hydro chemical investigations were carried out in the study area.

On the basis of the data analysis it was stated that the area close to the mine is of the highest contamination and that it decreases rapidly as the distance from the mine increases [3,4]. That was the reason to focus the sampling places in the interior and immediate surroundings in the abandoned Mezdreja and Gabrovnica pits, as well as of several downstream locations.

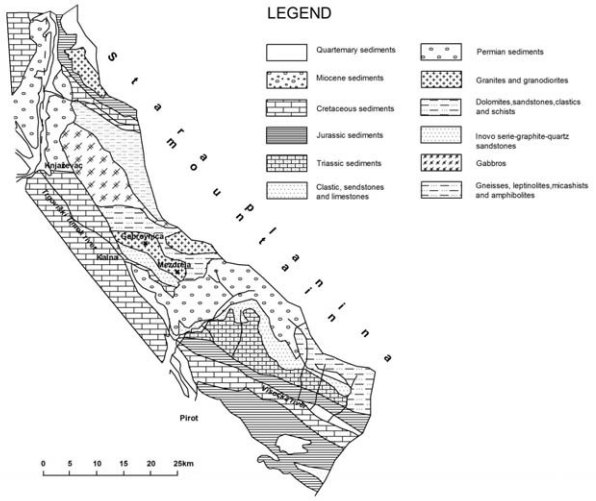
General geologic-hydrogeologic features of the study area

Stara Planina Mountain or Balkan belongs to the system of the Balkan mountains stretching from the Black Sea in the east to Vrška Čuka in the west. The length of this mountain system amounts 530 kilometres. This mountain represents part of the larger mountain wreath- Carpathian–Balkanic mountain chain (in Serbia, there is only minor western part). There are four deposits of uranium mineral raw materials in Stara Planina Mountain. Increased uranium concentrations were discovered mainly in the area of western slopes of Stara Planina Mountain. The altitudes within the study area range widely from 200 to 2169m. The area is characterised by a moderate continental climate with the mean annual precipitations of over 1000 mm, in the mountain area, while in the plain parts the level of precipitations amounts about 600mm [3,4]. The biggest settlement within the study area is the town of Kalna. The most significant uranium deposit is Janja (in the vicinity of Kalna) spatially limited to the granite massif bearing the same name in the western slopes of the central part of the Stara Planina Mountain. Within the Janja depost there are two mines, Mezdreja and Gabrovnica (fig.2).

The Mezdreja mine is situated on the right bank of the Debeštrička River. Within the Mezdreja mine, there was once, a minor plant for ore processing with the capacity of 60 t/day. Currently, 60 years after, there are only ruined concrete structures of the plant and two shafts in this location. The shaft of the Mezdreja mine is caved in, thus it is accessible 7 to 8 meters from the shaft entrance. There are three tailing dumps in front of the mine. On the basis of radiometric measuring in 1997, the increased concentration of radium in relation to uranium and thorium was determined [3,4]. Gabrovnica is

situated north from Mezdreja, on the left side of the Gabrovnička River at about 1.5 km from its running into the Timok River. The "Gabrovnica" mine had a plant processing about 200 t/day of ore. Complete ore from this location was exploited. The mine shaft of Gabrovnica is caved in.

Figure 2 *Geological setting of the study area*



On the basis of geological structure and various theories it is supposed that ore bodies within the study area are not the product of granite forming process on the terrain but the product of the action of crush zones in several occasions whereby the joints were filled with aplite, pegmatite and quartz veins. Significant uranium concentrations are related to deeper crash zones. Faults spread in all strikes within the Janja granites and there are present normal, reversible and horizontal ones. Joints where the deposition of uranium occurred were grouped within two systems. One system has the east-west strike and has vertical dip angle, while the other one has the northwest –southeast strike and is also with vertical dip angle. The thickness of formed veins is about 0.5m while their length is about 1 km. The uranium concentration is controlled with structures located in the vicinity of the granite-veinless rock contact. As the result of the occurrence of such a complex activity various deposits of granite complex uranium are formed [1].

In the study area a fissure type of an aquifer prevails. Ground water reserves within this aquifer have not been calculated so far. The maximum yield of the occurrences in the study area within this aquifer type is up to 1 l/s. On the basis of the element concentration in mine waters obtained on the basis of chemical analyses from the years 1992 and 1997 the concentrations of strontium and iron were raised [3,4].

The results of the investigations in the year 2008

During the year 2008 an investigation of uranium concentration in waters from the Mezdreja and Gabrovnica abandoned mines was conducted. On the basis of previous results it can be said that the uranium concentration in waters of the abandoned mines has been increased since 1992 till nowadays. The uranium concentrations have increased enormously in the invested locations. In the past 16 years it increased in the Mezdreja 30 times, in the Gabrovnica it increased 8 times while maximal allowed uranium concentration in drinking waters amounts 50 (μg/l) (Table 2, Fig. 3).

Conclusion

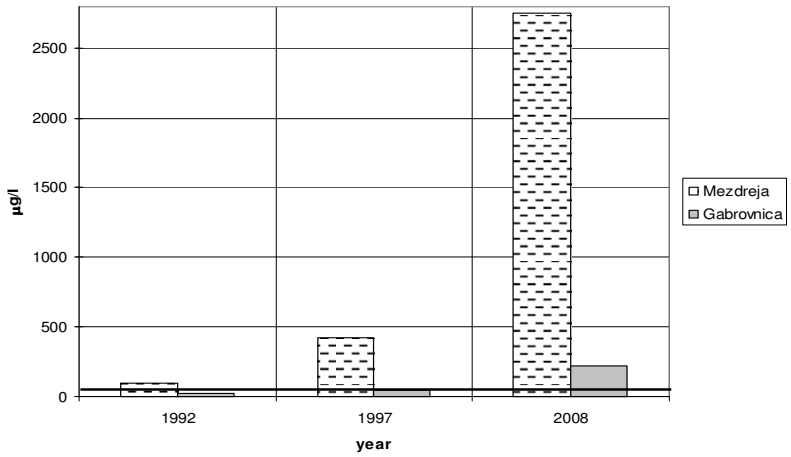
The goal of the investigations conducted in the year 2008 was to show how the uranium concentration was altered in mine waters in the past ten years. One of the ways of environmental protection is carrying out of various ecological investigations conducted in particular intervals. They are necessary for determining and monitoring of alterations within a disturbed environment. On the basis of the records obtained by investigations in the area of Mezdreja i Gabrovnica it was stated that the contamination in the vicinity of the mine plants was significantly increased in the past 10 years. On the

basis of the obtained results, the uranium concentration in mine waters has been increased 6.5 times in the Mezdreja location and 4.4 times in the Gabrovnica location. The explanation for such significant increase of uranium concentration in ground waters requires complex additional explorations in order to define completely the conditions of mine water discharge during the whole hydrologic year.

Table 2 *Uranium Concetration in investigated location (records for the years 1992 and 1997 taken from lit. 3 i 4)*

	Uranium (μg/l)		
	Mezdreja	**Gabrovnica**	**Debeštrička River**
1992	**93,8**	27,2	-
1997	**420**	50	2,2
2008	**2750**	**220**	4,5

Figure 3 *Uranium Concentration in investigated locations*



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