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# Extended Abstracts

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title: # Restoration and revitilization of the area of the abandoned mine pit Suvo Rudiste on Kopaonik, based on the example of the construction of the water intake and water collector for multipurpose use of the mining waters

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## INTRODUCTION

Kopaonik, a mountain in the central part of southwest Serbia (280 km from Belgrade) and the belonging protected area of the National Park (established in 1989) represent a unique natural whole. However, in spite of the fact that Kopaonik was given priority in regards to new development of mountainous area in Serbia and the fact that it deservedly carries the epithet of the 'first' mountain that has the necessary spatial capacity to enable the return of humans to nature, upon which we have returned en masse, it has in return received a powerful blow or clearly stated, has experienced grave consequences. Namely, on the roof of Kopaonik, more precisely below its highest peak, the peak of Pančić (2017m a.s.l.) and in the immediate vicinity of the tourist resort, lies an abandoned surface and underground excavation site "Suvo Rudište" (1970 m a.s.l.), upon which, after an extensive ore exploitation, all the activities have died down about twenty years ago. The previous mining activities in the greater area of the Suvo Rudište mine have devastated the immediate area of the extensive exploitation in its entirety, as well as the surrounding area that has been, due to its current state and appearance, excluded from the current borders of the NP Kopaonik. At the height of 1740 m a.s.l., in the vicinity of the tourist resort, the mining waters are flowing out from the underground part of the pit in the quantity of 10–30 l/s, polluted with iron, manganese, copper, zinc, nickel and cadmium. The mining stream, since the abandoning of the mine, has been completely devoid of all living things, because the proscribed restoration and revitalization of the underground facilities and hallways has not been done. However, it is of import to note, that during the time of the active mining operations, the same groundwaters were used, and their quality regularly inspected, for the fulfillment of needs for drinking water of the mine personnel and the two nearby hotels. This directly implies that the groundwater quality within the mining facility at the place of operation complied with the Act of water quality.

Due to the all aforementioned and the growing needs to bring the analyzed area back to its purpose a Study of feasibility and the Project of restoration and revitalization of the abandoned mine Suvo Rudište was done. The project stipulated the restoration of the surface dig and the part of the underground facilities, the intake of the mining waters from the underground area of the dig, their treatment until the desired quality was achieved, and then the pumping into the area of the surface dig Suvo Rudište, which would serve as a multi-purpose water collector, of volume 300.000–350.00 $m^3$.

## THE DESIGN SOLUTION FOR THE SYSTEM OF WATER INTAKE STRUCTURE AND THE WATERCOLLECTOR

The ore deposit "Suvo Rudište" on Kopaonik during the phase of intensive exploitation was mined in two different ways, and consisted of the surface dig and the underground pit exploitation.

The underground part of the mine was opened with a main mine at the height of 1740 m a.s.l. (simultaneously the lowest point), divided vertically into five basic horizons that are linked by a system of transport and transit haulway rooms, a network of roads on the horizon itself, a network of exploratory hallways, bars for the transport of mined materials, and a network of trimming hallways and other auxiliary rooms. The main transport mine — horizon at 1740 m a.s.l., is simultaneously a main road, a room for drainage, a hallway of the main entry air current for ventilation, a room for fixtures, telecommunications etc. Apart from the main mine there were four other links – surface exits. The entire length of the pit facilities at the level of mine at

1740 m a.s.l. (the mine and the lateral hallways) is around 1820 m, of an average width of 2.2 m, respectively of the entire area of 4004 $m^2$ or volume 8808 $m^3$. The general assessment, based on the conducted research, is that the underground facility is stable and secure and there are no significant cave-ins. At the end of the mine and the lateral hallways several exploratory wells were done in the effort to define and follow the body of the ore. The groundwaters under pressure and further free fall towards the exit are the ones that stand out from all the wells with a full profile. An important characteristic connected to the phenomena of the presence of groundwaters within the mine, is that the body of ore was grasped by the mine that is simultaneously the lowest point in the underground, so that the entire drainage is gravitational, without pumps and energy utilization. The present quantities of groundwaters that are flowing out from the underground hallway at the height of 1740 m, are originating from the water sources along the cut sediment zones as well as the mentioned research wells. In the mine, at five points, there are appearances of permanent sources of groundwaters, and three have been regulated and smaller reservoirs with the volume of around 3 $m^3$ have been built, from where the intake waters were transported by a set-up pipeline to the one-time consumers at the surface of the mine, two nearby hotels, and for the pit, more precisely the mining drilling and blasting, with the aim of reducing dust. The flow of groundwaters within the main mine varied within the limits from 300 l/min to 1500 l/min or from $Q_{min}$ = 5 l/s to $Q_{max}$ = 25 l/s (measured during the time of active operations of the mine) while the water quality for the water supply, was controlled and approved by the authorized health institutions. From the aspect of hydrogeology in the wide area of the main mine and the surface dig "Suvo Rudište", conditions are such that there is no objective danger of any major water penetrations from the surface of the terrain that could endanger the stability of the underground facilities. The position and the height of the mine already enable the drainage of the groundwaters of the immediate perimeter in a natural way, and are gathered within the mine and flow out of the same due to gravity at 1740 m a.s.l.

The surface dig was opened as the depth-type with tiers and spiral transport routes at the dig, respectively between the tiers. The dig due to operations reached at its deepest section the height of 1870 m and considering the existence of activities in the part of the underground horizon underneath the dig itself at the height of 1865 m, there was a violation of stability in the disturbed section and a minor cave-in of the ceiling above the underground hallway at 1865 m. The depth of the dig has reached approximately 100 m, the length of the longer axis is 350 m, and of the smaller 220 m, and the entire dig is of an ellipsoid — amphitheatre shape. The condition of the rock mass within the dig is good, without any signs of subsidence and slides of larger proportions. The tier planes, the passages for communications, from the northern side of the dig have already began losing their original shape and the purpose of the traffic, while on the southern side they remain in good condition and could still be used for transport with minor improvements. Vegetation at the surface dig is practically non-existent. Considering the present configuration of the dig and the condition of the rock mass, the dig is not endangered with any potential peril and that can be confirmed by the fact that from the day of its closure till today the terrain has been stable.

**FLOW-OUT REGIME AND WATER QUALITY**

At the point of the flow out of mining waters from the main mine of "Suvo Rudište" mine, more precisely at about 50 m downstream where the flow is concentrated, the Thompson's weir for

the measurement of the flow, was constructed. The mining waters are gathered at the lowest point of flow-out at 1740 m a.s.l. and are via the existing (active mine) main hallway evacuated to the surface of the terrain. The catchment area starts from the height of the peak of Pančić at 2017 m, up to the level of the main mine at 1740 m — the point of the mining waters flow-out, or at about 250 m of the height difference of the border area of the basin of about 3 $km^2$. In the following tables the representation of several year of observations of the mining waters flow-out regime and mining water quality is given.

**Table 1.** The representation of the abundance of the mining waters from the main mine at 1740 m a.s.l. (2004–2007).

| Year/ Month | *"Water source of mining water"*, measurements Q (l/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| **2004** | 14.5 | 15.0 | 15.5 | 16.0 | 16.0 | 15.0 | 14.0 | 14.0 | 14.0 | 13.5 | 13.5 | 13.5 |
| **2005** | 14.0 | 15.0 | 15.0 | 16.0 | 18.0 | 18.0 | 18.0 | 22.0 | 22.0 | 18.0 | 16.0 | 15.0 |
| **2006** | 14.0 | 13.0 | 14.0 | 14.0 | 14.0 | 15.0 | 18.0 | 15.0 | 18.0 | 19.0 | 15.0 | 14.0 |
| **2007** | 13.0 | 12.0 | 13.0 | 14.0 | 15.0 | 18.0 | 19.0 | 20.0 | 21.0 | 19.0 | 16.0 | 15.0 |

The results gathered of the chemistry of the mining waters from the main mine at 1750 m a.s.l. indicate an increased concentration of certain elements — Fe, Mn, Cu, Ni and Zn (Table 2) while the microbiological indicators are within accepted limits.

**Table 2.** The results of the chemistry and microbiology of the mining waters testing.

| | mg/l | | mg/l | | mg/l | | mg/l | Pb (mg/l) | <0.001 |
|---|---|---|---|---|---|---|---|---|---|
| $HCO_3$ | 24.4 | Ca | 23.2–30.2 | P | <0.010 | Ni | 0.042 | Cd (mg/l) | <0.001 |
| $SO_4$ | 50.0 | Mg | 4.4–5.4 | $SiO_2$ | 12.2 | Li | 0.003 | T (°C) | 6.0 |
| Cl | 3.3 | Na | 2.2–3.3 | B | <0.1 | Rb | <0.01 | pH | 6.25–7.5 |
| $NO_3$ | 1.54 | K | 0.7 | Fe | 2.25–3.36 | Zn | 2.0 | M (mg/l) | 120–155 |
| $NO_2$ | <0.01 | $NH_4$ | <0.05 | Mn | 0.82–1.23 | Cu | 0.094 | $KMnO_4$ (mg/l) | 1.0–1.3 |

## THE DESIGN SOLUTION FOR THE SYSTEM OF WATER INTAKE STRUCTURE AND THE WATERCOLLECTOR

In accordance to all the discoveries and the existing infrastructural facilities on the location of the abandoned mine Suvo Rudište, the following conceptual solution for the provision of large enough quantities of accumulated water for different purposes is given as inevitable. The complete hydro-technical system "Suvo Rudište" on Kopaonik would consist of the following parts (Figures 1 and 2):

- The groundwater source – water intake structure,
- The facility for groundwaters treatment,
- Pumping stations 1 at the height of 1740 m a.s.l. and a high pressure transport pipeline up to the water collector,
- The water collector within the area of the surface dig "Suvo Rudište",
- Pumping station 2 within the future water collector.

The water intake – of groundwaters, will be conducted in the existing, main mine at the height of 1740 masl, in the regime of gravitational outflow. The total measured capacity is $Q_{min}$=12 l/s and $Q_{max}$=25 l/s, so that the water intake itself is designed as a combination of a vertical entry shaft (of a large diameter) and an underground water gate — water intake structure (laterally anchored within the main rock) for the stopping and accumulation of groundwaters, with pumping aggregates for further transport of the waters towards the treatment facility installed within it.

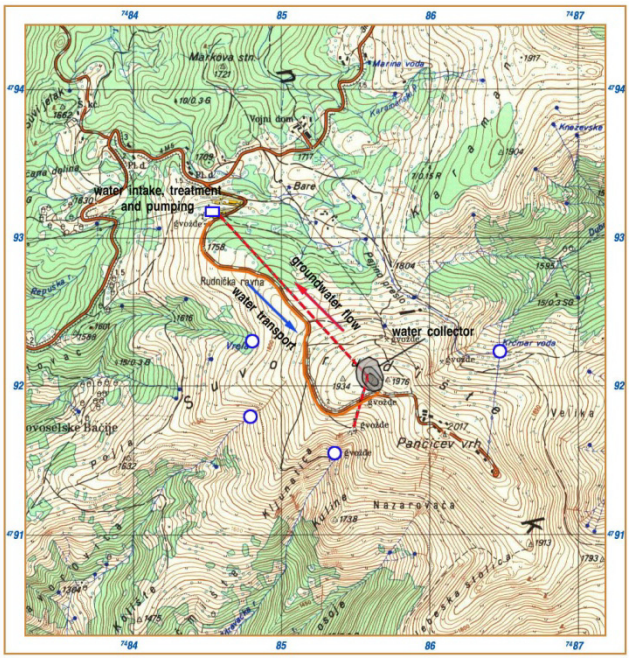


**Figure 1.** Objects disposition in the "Suvo rudiste" surroundings.

The mine groundwater is burdened with increased concentrations of iron, manganese and several oligo-elements and toxic heavy metals as: zinc, cadmium, nickel and copper. This is low mineralized water with a slightly lowered pH when compared to the drinking water, and is micro-biologically safe. Beneath the area of the water intake structure, the groundwater, mining water is further transported to the system for quality improvement — station treatment. It is designed that the process of deferrization and demanganization (with a minimal reduction of the copper, zinc, nickel and cadmium content) is conducted. During this treatment no external substances — chemicals are used outside of the facility, meaning, a true "green technology & green engineering" is in question.

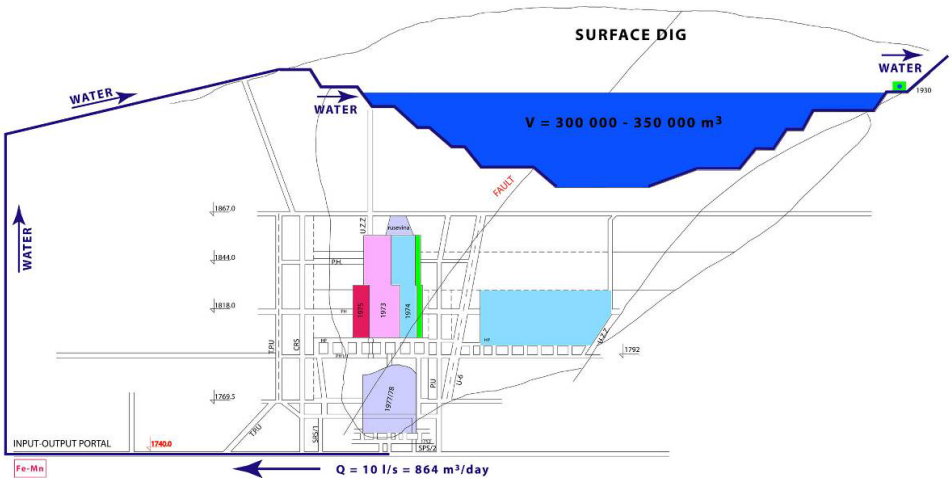


**Figure 2.** The design solution of water intake structure and watercollector.

The water that was collected and prepared would be, via an installed pumping station, further transported along the existing bypass route towards the peak of Pančić (the entire length of 2300 m) and would be enclosed within the existing ambience of the surrounding area without disturbing the said area. The transport itself of the groundwaters would be done by pump aggregates and via a high-pressure pipeline in the conditions present on Kopaonik.

During this same period, paralleled to the previous operations, the process of cleaning, preparing, concreting (Torkret method) and lining via a geo-membrane of the surface dig Suvo Rudište (preparing of the water collector) would be conducted, during which the accumulation of the intaken waters and the treatment of groundwaters is planned.

## ASPECTS OF BRINGING THE FACILITY AND THE ENVIRONMENT INTO ACCORD

A high assessment of the area eligibility is reached through the proposed solution of the land restructuring and the use of resources, due to the opening and return to its purpose of this part of Suvo Rudište for the programs of presentation and resource utilization, recreational — skiing – hiking, educational and other facilities. The possibilities of expansion of the borders of the protected area to the southern parts of Kopaonik are opened, in the direction of Leposavić municipality, i.e. the percentage of the entire protected area in Serbia is increased (that being one of the relevant conditions for the joining of Serbia to the European Union).

With planned construction of the water intake structure and with the treatment of the mining waters, the negative physico-chemical contents of the groundwaters (Fe, Mn, Zn, Ni and Cu) will be removed, which will create the conditions for the renewal of the eco-system in the mentioned watercourses that is now significantly in peril. It can be stated that this area has the elements of a “rock desert”. By building the suggested system, the restoration of the soil via biotechnical measures will be done — mass covering of the eroded areas, stabilization of loose slopes of the abandoned mine and prevention of further degradation; more precisely the improvement of the entire area and its increased closeness to other humane contents.

The biological diversity in the closer and wider area of "Suvo Rudište" — one of the highest zones of Kopaonik was destroyed by exploitation and opening of the mine surface and the slag deposit. The conditions for gradual revitalization of the biological diversity and the return of autochthonous sorts as well as the enrichment of the landscape are created by the construction of the facility and the implementation of the biotechnical measures.

**CONCLUSION**

Considering that on the territory of Kopaonik two significant elements of the development of Serbia can be found, and are interconnected (one protected — the National Park Kopaonik and the second, tourist – developmental, mountain resort of Kopaonik), it is of a national importance for the Republic of Serbia that the two segments mentioned mutually correspond and participate in the presentation and promotion of Serbia and its assets, with the adequate protection and securing of the area. The suggested Project is an adequate example where the mutual functions can be aimed towards the fulfilment of the national domain interests for Kopaonik and the Republic of Serbia.

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