Environmental impact of mining activity in the Rudňany Ore Field, Slovak Ore Mountains

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Abstract: The Rudňany Ore Field is known by the long-run underground exploitation of Fe, Cu, $BaSO_4$ and Hg ore fixed on the ore veins. Mining activity caused a significant intervention on environmental conditions in this area. The worked-out spoils were stacked near the shafts, where make the expressive morphological elements - pit tips. Through blows the mined-out parts of ore veins reach the land surface and create an extensive depressed zones. In this zones the danger of dynamic breaks still exists, what threatens human and animal lifes and also the stability of buildings. Long-standing running of dressing plant have affected an imission loading of area (mainly by Hg) and originated the setting pit generation. Original groundwater circulation is modified, groundwater and surface water quality is locally negatively affected (including drinking water resources).

1 INTRODUCTION

The underground exploitation in the Rudňany Ore Field (RRP) reaches in the old past ages and continues, though after major restrictions, to date. Up to date were 25-30 million tons of siderite, baryte and copper ore exploitated. Generated exploitation products cover an area of approximatelly 8 km^2 and reach depth 400-680 m downwards from land surface.

The objective of this paper is to characterize the degree of a resulted mining impact on the environmental conditions of studied area on the base of archive data from ore exploitation, mineral, hydrological and environmental exploration.

2 MINING ACTIVITY PRODUCTS

An vein gossan was exploited on the Rudňany ore veins before the 17th century, either directly from the land surface or by diggings, shalow pits and short galleries. The extensive growth of exploitation began in the half of 17th century, when the Cu, Ag and Hg ore stopes by shafts reached to the depth of 200 m were made. The stope workings reached the depth of 300-400 m in the half of the 19th century, when fast decadence and termination of Cu exploitation began.

The new iron ore exploitation succeeded after 1895 and continued up to 1995, when restriction of ore exploitation began in Slovakia. Only residual resources of baryte ore are exploited in RRP at present.

The great drainage ditches were created as a result of ore exploitation. Their width varies from some metres to some tens of metres, depth to some hundreds of metres and directional length from some hundreds to 2500 metres.Through blows this ditches reach on the places of a near-surface stopes the land surface and create extensive depressed zones to some tens of metres deep. This stoping grounds situated on the parallel ore veins are jointed each other by the horizontal opening and exploration workings (galleries, cross cuts) and workings of particular mining levels are jointed each other by the vertical workings (shafts, pits, ore chutes, ventilation funnels).

The worked-out spoils were stacked near the shafts, where make the expressive morphological elements - pit tips. In the area between Svätý duch and 5RPII shafts on the Droždiak vein, spoil is stacked along the valley, creating a positive relief forms or fills a hidden blows after the stopes (Hudáček et al.,1998).

The setting pit situated near the dressing plant is used for deposition of the ore dressing sludge. The seepage water of setting pit is concentrated and flumed into the Rudniansky potok creek.

At the beginning of mining, the workings were drained by the gravitational outflow through the opening galleries. With the mining depth growing of the shafts were excavated and more difficult way of mine dewatering – pumping - was practised. The mine waters were pumped on the Rochus mining level (461 m above the sea level – local base level of erosion) from the lowest mining levels (to 45 m under sea level) by pumping stations. Gravitational outflow on the Rochus mining level goes through the Rochus gallery to the land surface – on the setting pit.

A long-standing running of dressing plant have effected not only the ore dressing sludge production, but also an imission loading of area.

3 MINING ACTIVITY EFFECTS

The mining activity products affected the environment of studied area by heterogenous ways (Figure 1). Figure 2 gives a review of determined effects and their relationship towards the mining activity products.

The actual assessments shows, that strongest environmental impact is due to near-surface stopes and the emission from the dressing plant. These are evident also by a lay visual observation.

Actual results of landscape stability investigation (Mašlár & Olekšák 1997) show different forms of undermining effects in following parts of RRP:

- western part of the Droždiak vein (west from the Mier shaft)
- central part of the Droždiak vein and the Hrubá vein (territory between the Mier shaft and the 5RPI shaft)
- eastern part of the Droždiak vein (east from the 5RPI shaft to the Poráč shaft)

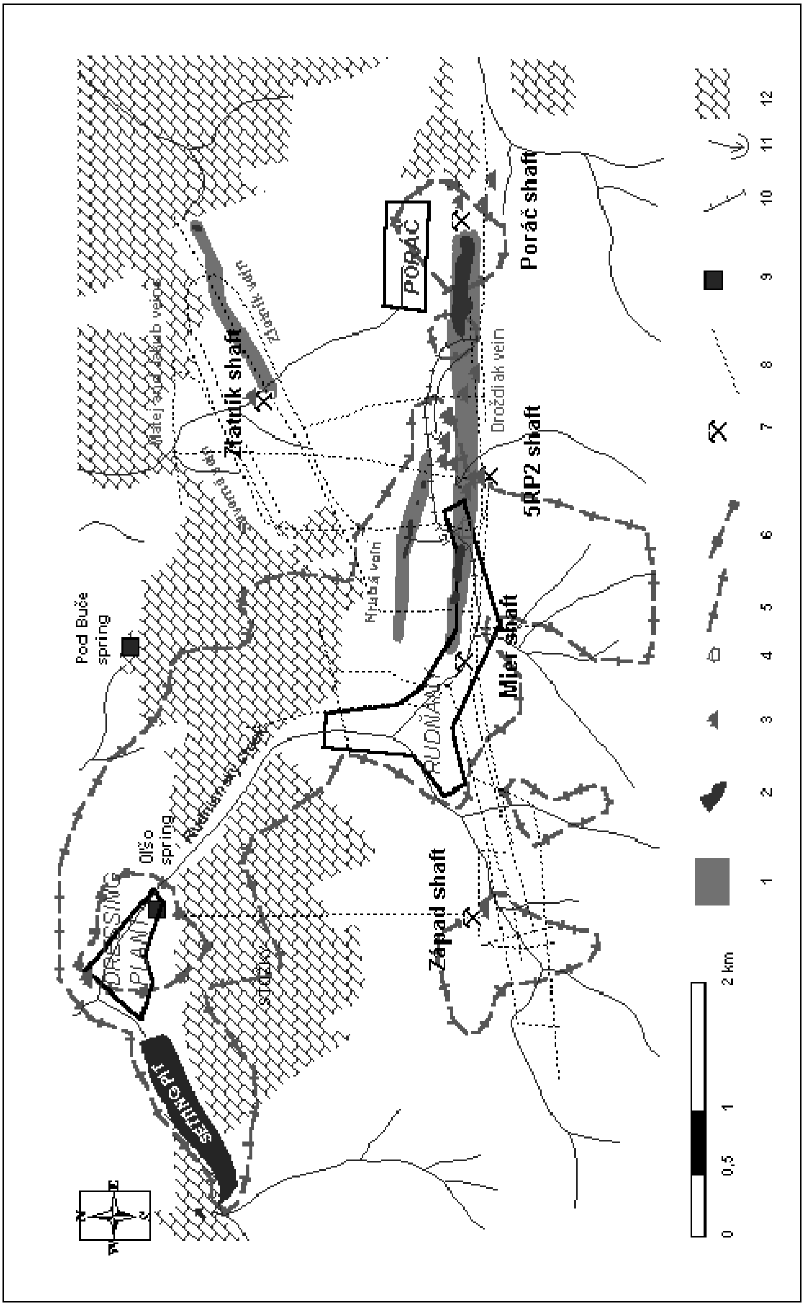

Figure 1 Schematic map of environmental impact in the Rudňany ore field
1 - areas of workings present in near-surface zone, 2 - open blows, 3 - spoils, 4 - communal waste, 5 - boundary of area with Hg content in soil from 20 to 50 mg.kg^{-1}*, 6 - boundary of area with Hg content in soil over 50 mg.kg*$^{-1}$*, 7 - shaft, 8 - main horizontal workings, 9 - exploited karst-fissure springs, 10 - streamflow regulation, 11 - stream loss, 12 - Middle Triasic carbonates, important aquifer*

There are no undermining effects on other veins which are situated in the north part of RRP (Severná, Matej, Jakub), because stopes are situated deeply in the underground. It is a geological setting consequence, as productive beds sink northerly. Only two less local blows have arisen on the Zlatník vein.
Productive parts whereupon the stopes begin in deep of 186 m on the western part of the Droždiak vein. In 21.4.1987 occured a local blow as single undermining phenomenon in this area. Generation of the planar surface blows is not liable, but there is not excluded possibility of the local horn blow generation (Hatala et al. 1989).

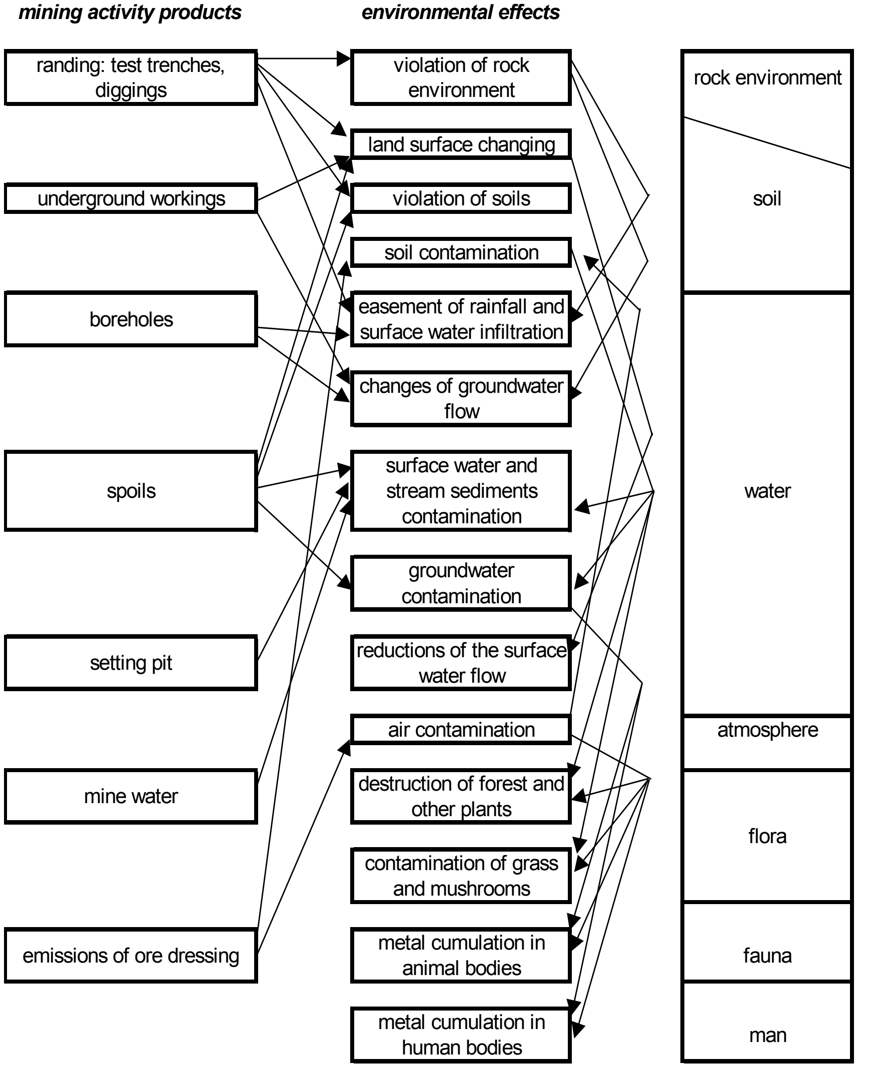

Figure 2 Generation scheme of environmental impacts in RRP

In central part of the Droždiak vein the exploitation was made by caving methods late. Relatively big planar subsidences originated here, which are stable nowadays. Most of them are filled by various sorts of waste. The slow falls of several building objects was documented here by geodetic measurements (to 255 mm during 1978-1980). Some of this objects are damaged by disruptions. Near this planar subsidences was locally documented the expressive faults of 20-30 cm wide, which are of lifted character and the southern inclination (Kunák 1982). Local blows on Hrubá vein arised in 1960, nowadays they are stable.

The most expressive effects of undermining are situated in the eastern part of the Droždiak vein. The vein was exploited downwards from the land surface. As the fall process result, the big blow zone named "Baniská" arisen creating the scenic phenomenon - strong longitudinal depression that is about 900 m long, to 100 m wide and some tens of metres deep. In cross section through blow zone are defined following undermining areas:

- blow area - the surface is crashed into steep depressions
- disruption area -disruptions generation of width to 0.5 m
- continuous movement area - continuous fall of unbroken surface.

Very slow falls of the Poráč shaft courtyard (15.2-43.6 mm since April 1990 to October 1997), the new highway segment (5-11 mm since April 1993 to April 1997) and the old highway segment (untill 1.7 m) were documented by geodetic measurements. The further expansion of all depressed area - mainly into back of ore, in places of stopes short deep - is possible to expect (Mašlár&Olekšák, 1997).

The dressing plant running caused the visible and significant environmental impact. The forest damage around the dressing plant is well recognizable from the great distance when the trees died in a relatively large area of the Stožky hill. Up to 70% of the mercury leaked into the atmosphere by dressing of the mercury ore, but a significant decline of emission production began in 1991 after the dressing technology modernization (Table 1). It was not strangeness to find the metallic mercury drops, often in the bark of trees. In 1991 there was emited 234 t of solid elements, 1197 t of SO_2, 105.4 t of NO_x, 8247.9 t of CO, 2.4 t of Hg, 3.772 t of As and 0.029 t of Pb (Furda 1992). The emissions of dressing plant caused the soil contamination. The results of soil sampling in Rudňany area (Geczy, 1993) showed high degree of Hg contamination of soil upper horizons in the area between Rudňany and Poráč villages (content of Hg > 10 mg/kg) and in the Rudňany creek valley (up to 20 mg/kg) with local maximum contents over 50 mg/kg (maximum 2614 mg/kg Hg). This contamination consequently rebounded in groundwater and surface water. An increment of Hg content caused the restriction of the karst-fissure spring "Oľšo" exploitation, whose infiltration area covers the limestone massif of the Stožky hill. Increased metal content was detected in mushrooms. There was detected mercury content values of 12 to 42 mg/kg in grass, 53-65 mg/kg in maple, 30-57 mg/kg in oak in the dell above dressing plant (Bobro et al. 1993). Metal transmission by food network into animal bodies was not examined, but we can suppose it in high likelihood.

Table 1 Emission amount of dressig plant in RRP

Year	Annual ejected amount (t/y)	Emission amount in cubature of technological gases (mg/m^3)
1988	2 054	701
1989	2 185	747
1990	2 879	1 085
1991	218	71

The violation of natural water circulation belongs to a lesser visible but significant environmental impacts of the near-surface stopes and their attendant blows. A surface blows enable the direct infiltration of precipitation and surface water into underground. Near-surface stopes make drainage of the near-surface zone groundwater in paleozoic rocks. Thus there was reduced the surface water discharge in some parts of the Rudniansky creek (Vránová 1966, Bajtoš 1999) or its inflows and locally the natural outflows were vanished. On the other side, the concentrated mine water efflux have arisen, which has an anomal yield and a typical chemism with the anomal level of some metal content. The average annual yield of mine water is 15-35 l/s. Final chemical composition of mine water is generated by metamorphism of waters infiltrated into workings (precipitation, surface water, groundwater) and by their mixing (Table 2). At the land surface pumped mine water after mixing has resulted into chemical type of $Mg(Ca)$-SO_4-HCO_3 with TDS content 1-2 g/l and pH = 8.0-8.5. According to miner's measurement, the pumped mine water is of high Hg content (maximum Hg = 0.12 mg/l, median Hg = 0.008 mg/l) and high As content (maximum As = 0.574 mg/l, median As = 0.187 mg/l).

Groundwater of massive zone (below near-surface zone) creates only nominal part of mine water yield and the original groundwater circulation is not significantly influenced in consequence of its low permeability.

The mine water is pumped from the Mier shaft and deflated on the setting pit. The increased metal levels in mine water results from ore minerals but also probably from the waste which is placed in blows. A permanently increased Hg and Mn contents (the worst - 5. class of quality by standard STN 75 7221 - Classification of surface water quality) was detected by the long-time monitoring in national network conducted by Slovak Institute of Hydrometeorology. Occasional increasing of Cu, As and Zn contents was also detected due to seasonal climatic changes.

Table 2 Chosen average values of groundwater and mine water chemism in RRP

Rock environment	pH	M	Na	K	Mg	Ca	Fe	Mn	Cl	SO4	HCO3	S1	S2	A2	Mg/Ca	Ca/Na	SO4/M	SO4/HCO3
		mg/l										mmol.z%						
Lower Triassic shales	7.8	345	6	2	17	59	0.07	0.07	6	89	130	8	36	56	0.6	18	0.17	0.87
Permian metamorphites	7.5	210	4	2	10	33	0.09	0.04	9	32	87	10	37	54	0.56	12	0.14	0.46
Carboniferous metamorphites	7.4	160	2	1	9	22	0.09	0.02	2	20	84	7	28	65	0.64	13	0.12	0.31
Early Paleozoic metamorphites	7.6	228	4	0	13	35	0.01	0	5	28	126	6	24	69	0.56	14	0.12	0.28
mine water	8.3	1406	28	6	131	156	0.35	0.04	11	506	509	7	46	47	3.47	12	0.26	1.35

Notes: M- TDS content, S_1, S_2, A_2 - Palmer - Gazda indexes

Effects of mining activity was observed also in stream sediments of area Rudňany - Poráč (Table 3). The maximal metal contents were registered in areas where streams flow through the stricken localities. The sample taken under setting pit exceeds 10-15 times environmental limit (by the Direction of Ministry of the Environment from 15.12.1997 No.1617/97) in As and Ba content and 33 times in Hg content. A contamination was detected also in the Hornad river, into which leaks the Rudňany creek in (compare metal contents above and under confluence in Table 3).

Table 3 Metal content in stream sediments of RRP

	Rudniansky creek in Rudňany area			Rudniansky creek under setting pit	Inflow of Rudniansky creek above setting pit	Hornád river above the Rudniansky creek outfall	Hornád river under the Rudniansky creek outfall
	Min	Max	Average				
As	6.7	214	49.9	1460	16.1	9	39.7
Ba	212	18000	3232	20690	1712	347	1908
Bi	0.2	31.4	4.13	183	1.3	0.3	1.23
Cd	0.05	1.4	0.27	2.7	0.35	0.43	0.57
Cr	40	160	107.1	110	77.5	57.5	103.3
Cu	25	1226	218	10530	82	55.75	100
Hg	0.5	127.3	20.08	338.1	4.35	0.19	15.32
Sb	1.5	350	41.97	3600	5.26	1.68	6.83
Zn	61	603	176	312	81.5	94.75	155.3

Notes: min, max, average - minimum, maximum and arithmetical average from the set of 21 data

Increased metal content in sediments of the Ružín dam (localized on the Hornád river about 40 km under the Rudniansky creek outfall) is combined also with mining activity performed in RRP. An anomalous contents manifest mainly As, Ba, Cr, Cu, Hg, P and Sb.

Numerous spoils are localized mainly beside exploitation shafts. They modify the previous surface designe by a positive form origin or fill the blows. The mineral content of spoil substance is relatively stable and an acid drainage doesn`t originate in such amount which could contaminate the environment significantly, although surface water seeps across some spoil bodies. Local groundwater contamination was determined only in the dressing plant area (presence of ore dumps and escorials) and near the Poráč shaft.

4 CONCLUSION

The long-run exploitation in RRP caused the significant environmental impacts. The near-surface stopes and the emissions of dressing plant caused the most expressive negative incidence. In extensive blow zone the danger of dynamic breaks still exist, what threatens human and animal lifes and also the stability of buildings. The further gradual expansion of the depressed area is assumed, when sanitation of damaged objects is uncertain - it will be probably necessary to rehouse some inhabitants.

The emissions from the dressing plant are accumulated in soil. It locally induced the forest devastation, groundwater and surface water contamination and contaminants were being got into animal and also human bodies through the nutritive chain. The contamination reaches from RRP as far as the Ružín dam (40 km distant) by streamflow transfer. The mining activity impacts is possible to sanitate only partially, they will influence the loading area permanently or during very long time.

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Wpływ działalności górniczej na środowisko na obszarze występowania złóż rud Rudňany, Słowacja

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Streszczenie: Obszar złóż rud Rudňany jest znany z wieloletniej eksploatacji rud Fe, Cu, $BaSO_4$ i Hg, występujących w żyłach rudnych. Eksploatacja górnicza spowodowała znaczne zmiany warunków naturalnych na tym terenie. Odpady poeksploatacyjne gromadzono w sąsiedztwie szybów, gdzie wytworzyły one wyraźne formy antropomorfologiczne. W efekcie wyeksploatowania żył rudnych na powierzchni występują obecnie rozległe strefy depresji. W strefach tych istnieje niebezpieczeństwo dynamicznych zaburzeń górotworu, co zagraża życiu ludzi i zwierząt a także stabilności budynków. Wieloletnia działalność zakładu uzdatniania wpłynęła na zanieczyszczenie terenu głównie związkami rtęci spowodowała powstanie stawów poflotacyjnych. Naturalny obieg wody uległ zmianie, lokalnie pogorszyła się jakość wód powierzchniowych i podziemnych, w tym również zasobów wody pitnej.