Mining, Mining Waste and Related Environmental Issues in Slovakia

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Introduction

In Slovakia minerals and mineral-based products are the basis of production for metallurgical, electricity, chemical, brick, ceramics, tile, glass and other industries. Mining and quarrying of minerals (including extraction of crude oil and natural gas) contributed 7,523 million SKK, or 0,92% to Gross Domestic Product (GDP) at factor cost in 1999 (slow growth from 0,87% of GDP in 1998). Minerals and mineral-based products represent an important item of foreign trade of the Slovak Republic. Because of a large import volume of

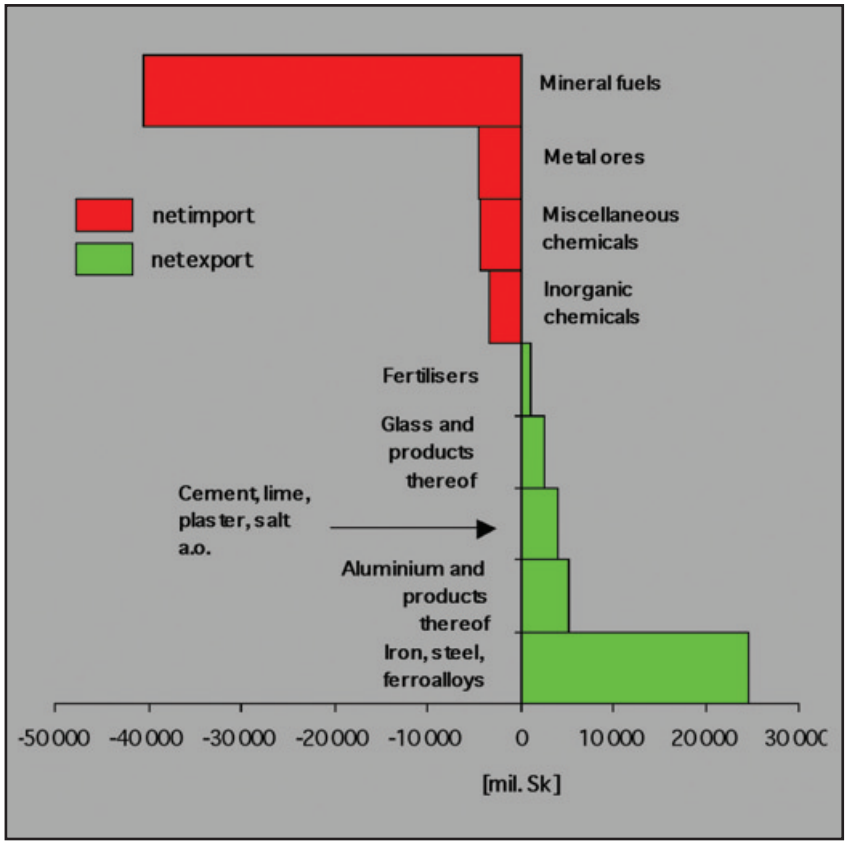


Figure 1. *Balance of trade in selected minerals and mineral-based products in 1999 (Source: Statistical Yearbook of the Slovak Republic 2000).*

mineral fuels (crude oil, natural gas, hard coal) and metals (iron ore, zinc, materials for aluminium metallurgy) foreign trade balance has been permanently passive (***Figure 1***). Domestic consumption of these minerals is covered mainly by import. The Slovak Republic is long-term dependent on import of mineral fuels, especially crude oil and natural gas, according to the amount of reserves and capacity of exploitation.

Exploitation of crude oil covered only approximately 1% of domestic consumption, exploitation of natural gas satisfied about 3% of consumption in 2000. In the matter of brown coal and lignite, mining output covers about 80% of domestic consumption. Slovakia has no economic deposit of hard coal or anthracite and dependence on import of this commodity is traditionally permanent. Majority of domestic consumption of **metals** is cov-

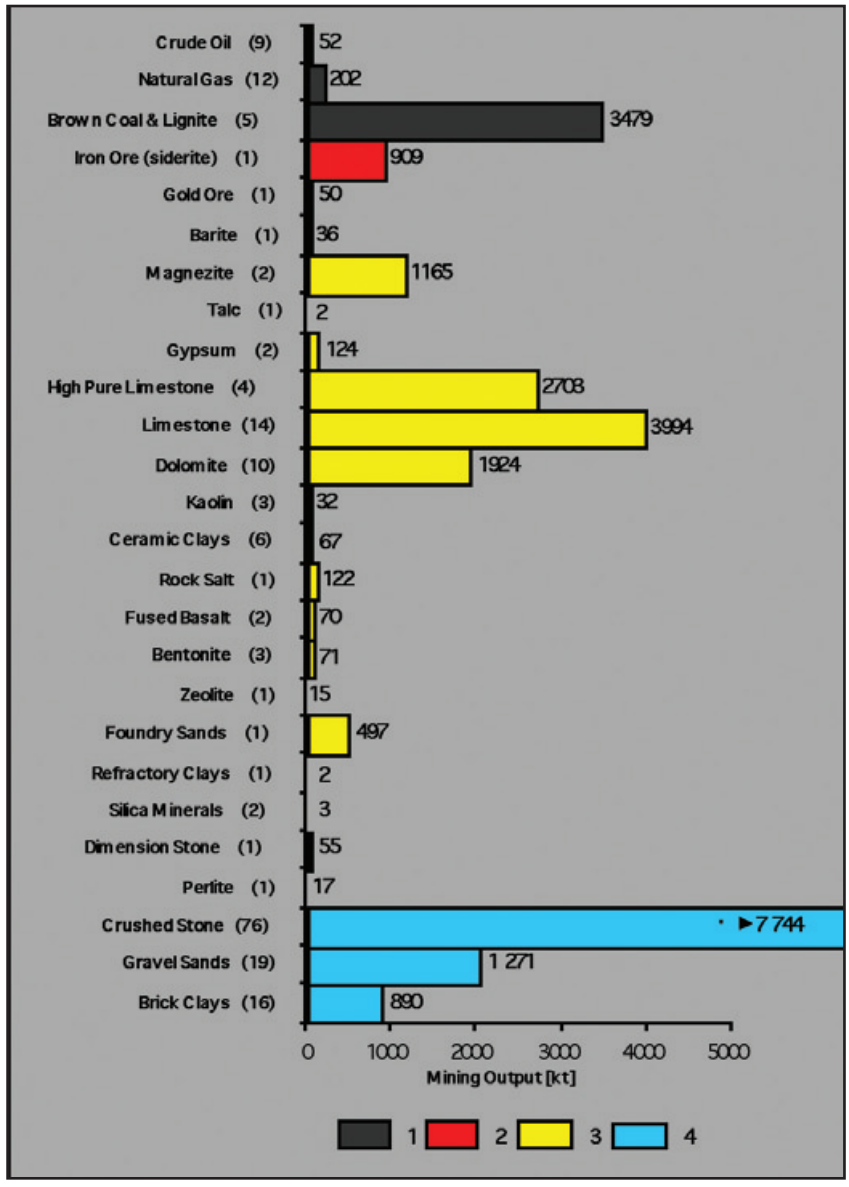


Figure 2. *Mining output of minerals in 2000. Figures in brackets represent number of mined mineral deposits. (1 - mineral fuels, 2 - metals, 3 - industrial minerals, 4 - construction materials).*

ered by import. Domestically produced iron ore covers only small portion (about 15%) of needs of the Slovakian iron and steel industry.

Industrial minerals mining share on total mine production reached 43% in 2000. The most important industrial minerals (in terms of export in 2000) were limestone and cement materials (cement and lime; 3,300 million SKK), magnesite and magnesia (2,100 million SKK), dolomite (216 million SKK), salt (111 million SKK), bentonite (73 million SKK) and barite (65–70 million SKK). A perspective group of industrial minerals is the so-called "ecological minerals", i.e. zeolites. An important export commodity could be talc from the Gemerska Poloma deposit. Production of industrial minerals covers in substantial volume domestic consumption.

Construction materials represent the majority of mineral deposits with significant share (more than 55%) of total exploitation of raw materials in the Slovak Republic. Resources of crushed stone, gravel sands and brick clays cover all domestic needs.

In 2000 the exploitation was accomplished in 282 active mines. Total amount of mined raw materials is presented in ***Figure 2***. The basic parameters of development in the mining sector are shown in ***Figure 3***.

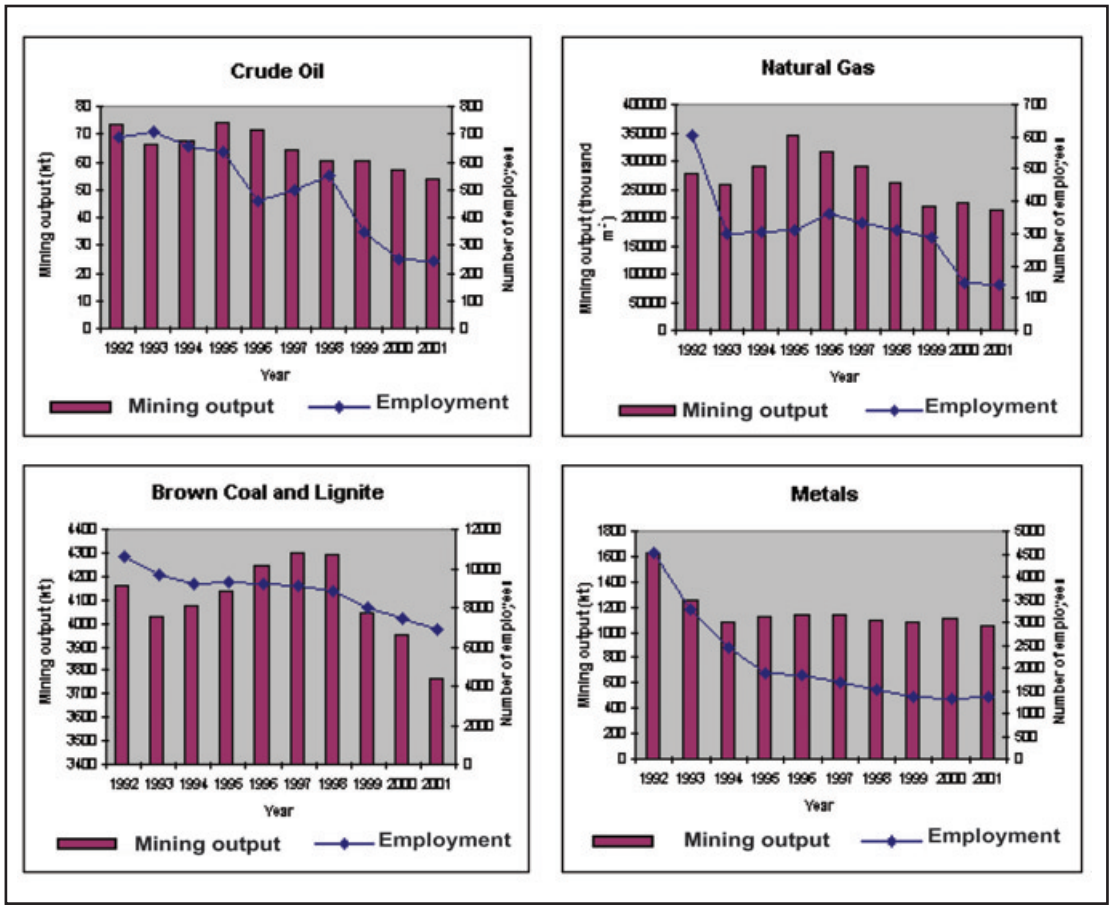


Figure 3. *Main indicators of mining output development in Slovakia between 1992 and 2001.*

Employment in the mining industry of the Slovak Republic has been continuously decreasing in the last decade, which continued in 2000 as a consequence of decline of mining industry, especially in the metal sector and in the last years in the energy sector, too. Slovakia belongs to the countries with extensive historical mining. This fact along with mining in the past few decades caused many environmental problems, with severe ecological consequences in some cases. At present, in relation to active mines, the following can be stated:

- in total (active and abandoned) 138 waste rocks stockpiles or tailings, of which 109 waste rocks stockpiles are in extraction areas and 29 out of them, covering an area of 2, 556 km^2 with a volume of 37,422,91 m^3. The number of active waste rock stockpiles is 87, abandoned waste rocks stockpiles reach number of 51;
- in total there are 114 tailings ponds (storing tailings from ore processing) of which 91 are in extraction areas and 23 out of them, covering area of 2,976 km^2, (69 active, 45 non-active).

Several waste rock piles are utilised for quarrying materials for construction industry, or as backfill material for mining pits and underground mines. Information on development in mining plants, tailings and tailings ponds in the 1999-2001 period is presented in ***Table 1***. Proportion of mining waste contribution to total waste production was 4,21% in 2000.

Table 1: Development in mining plants, tailings and tailings ponds in 1999-2001.

	1999		2000		2001	
	Number	Area (km^2)	Number	Area (km^2)	Number	Area (km^2)
Mining plant	443		282		266	
Tailings	139	2,473	132	2,132	138	2,556
Tailings ponds	152	2,916	107	2,945	114	2,976

Mining has a historic tradition in Slovakia. The oldest evidence of mining activities dates back to the Celtic era of 4th century B.C. An intensive development of mining activities started mainly in 12th century and continued up to the present. As a result of historical mining activities, there are many abandoned mining sites in Slovakia causing environmental problems in the present. Negative impacts on environment of historical and present day mining activities and ore processing can be summarised as follows:

- changes of land configuration as a result of replacement of huge volume of rock, stability disturbances, development of fractures and faults, depression of terrain, non-even consolidation of sediments, subsidence, activation of landslides, etc.,
- changes of hydrogeological regime in undermined areas and surroundings,
- changes of chemical composition of surface and ground waters, as well as soils in mining sites and broader surroundings,
- disturbance of tailings dams with possibility of contamination of surface and ground water and soil by leakage from tailing ponds, waste rock stockpiles, etc.,
- development of deep and sheet erosion related to deforestation and removement of vegetation cover.

Remediation of damages caused by mining activities is solved in Slovakia in several steps, conditioned on the character of the problem, ecological criteria, but mainly on economic factors. The process includes following stages:

1. **inventory** and evaluation of active mining sites of raw materials at 266 localities,
2. complex inventory of **abandoned** mining site; this stage was finished in 1997, in total 17,260 localities were registered,
3. inventory and evaluation of impacts of all mining sites on environment, on-going project since 1998,
4. preparation of state **monitoring** of the most risky localities **('hot spots')** of mining sector (on going project, 20 localities completed by the end of 2002),
5. proposal and realisation of **remediation** activities, on going project with goal to finish works in 2005.

Database

Summarising the above information, three databases concerning mining sites, mining wastes, and relevant environmental information exist at present in Slovakia:

(1) **Register of Exclusive Deposits** of raw materials governed by the Ministry of the Environment. This important source of information is up-dated yearly and published as "Slovak Republic – Minerals Yearbook" by the Slovak Geological Survey under the direction of the Ministry of the Environment.

(2) **Register of old Mining Sites** was created by the Ministry of the Environment between 1992 and 1997. It contains the following:

- inventory of old mining sites (galleries, shafts, tailings, mining waste deposits, etc.) with individual "inventory list" and localisation in topographic maps of different scales, e.g. 1:400,000, 1:50,000, and 1:10,000. As the "old mining site" was taken such mining site of which owner or managing subject is not known or does not exist;
- old mining workings with negative impact on environment and proposed for remediation from the point of view of safety of inhabitants were specifically denoted in this inventory;
- proposal for remediation was elaborated on general level – no co-ordinating (competence aspects), legislative, and financial aspects were solved in this inventory;
- altogether 17,260 sites were inventorised - 496 shafts, 4,913 adits or galleries, 10 tailing ponds, 4,566 pings a ping belts, 6,418 waste rock piles or tailings and 857 other objects related to old mining activities. This database is managed by the Ministry of the Environment through the Department of Informatics, State Geological Institue of Dionyz Stur.

Database of old mining sites includes following information: location (registration number, map sheet, co-ordinates, name of locality, name of object, administrative unit – district of mining administration), type of object, extension, surface (land) impacts, type of mined raw material and its specification, host rocks, data on groundwater, proposal for remediation, proposal for possible use of object, owner or management of object, remarks on environmental impacts, radon emanation, sources of information, date of registration, name of expert preparing registration data.

(3) **National Monitoring Database**
The goal of the on-going project is to create a database of mining impacts on environment, being accomplished in two steps:

- the first step (1998–2000) focused on inventory in electronic (including GIS) form of all mining activities in the Slovak Republic (old or historical, as well as actual mining activities) and their prioritisation from the point of view of remediation – altogether 489 localities with several thousands of objects were evaluated in this process,
- the second step (2001–2005) is an on-going process focusing on creation of state monitoring system predominantly taking into account first group of 20 most risky localities with negative influence on environment ('hot spots'), with possibility to extend the system in future.

Investigation methods

In past few decades in Slovakia several studies of mining sites have been accomplished with the goal to describe in details specific environmental aspects, like alkalisation of soils in the area of magnesite mining and treatment (e.g. localities Jelšava, Lubeník, Hnúšťa – Mútnik, Hačava), acidification of soils and natural waters (e.g. localities Smolník, Šobov), contamination of soils by heavy metals (localities Rudňany - Poráč, Banská Štiavnica - Hodruša, Magurka – Dúbrava, Jasenie, Pezinok). So far there exist only few regional studies, e.g. complex evaluation of environmental problems in the Stredný Spiš area (complex pollution by heavy metals, radioactive substances, etc.) or in the Malé Karpaty Mts. (pollution by heavy metals). The most complex evaluation is being done in terms of on-going project of the Ministry of the Environment "System of evaluation and monitoring of impacts on environment originating from mining activities". This is a very complex project and it is scope is the following:

- the territory of the whole Slovakia,
- all types of historical and actual mining activities (metals, magnesite, industrial minerals, coal, gas),
- all aspects of environment (basically divided on engineering-geological, hydrogeological and geochemical aspects),
- prioritisation of localities according to their impact on environment, based on established evaluation criteria.

As a result localities were classified into 3 categories:

I. Category. Localities and mining sites where remediation is required as very acute step to prevent damages on human health, environment (water, soil, biota) and estate. The impact is documented and damages are of large extent.

II. Category. Localities and mining sites with transitional characteristics with partial knowledge on the sites and extent of impacts, but due to specific factors (e.g. type of ore and natural conditions, changes in technology, ceasing of mining) threat of damages is either not so critical or requires supplementary investigation to clarify situation (with possibility to re-categorise the mining site).

III. Category. Localities and mining sites with apparently low or minor impact on human health, environment and estates due to different factors like historical mining, temporarily suspended mines, etc., for identification of impacts, satisfactory national monitoring systems exist or there are specific conditions for management

of accidents (e.g. gas deposits).

Environmental impact of mining activities is evaluated on the basis of the following criteria:

A Mining or ore processing is on-going, recently finished or historical
B Utilisation of chemicals (type, toxicity, amount or extent)
C Undermined territories (extensive and known, need of investigation, minor impacts, area and intensity of undermining is categorised)
D Geodynamic deformation (extensive and known, need of investigation, minor impacts, area and intensity of deformations is categorised)
E Other negative impacts on relief (regional and extensive character, local impacts, minor changes, impacts are classified according to agreed criteria)
F Hydrogeological and water economy conditions (extensive impact on drinking water sources of regional character, impact on local sources, minor influences, impacts on water courses is classified as well)
G Mine waters (classified according to amount and quality, as well as according to influence on surface water and hydrological conditions)
H Hydrogeochemical anomalies (geogenic or anthropogenic, regional, local or minor extent)
I Litogeochemical anomalies (geogenic or anthropogenic, regional, local or minor extent)
J Biogeochemical anomalies (geogenic or anthropogenic, regional, local or minor extent)
K Waste rock stockpiles (active, abandoned recently, historical)
L Tailings (active, abandoned recently or temporarily suspended, historical, fully or partially remediated or not remediated)
M Land use type (aspects of density of population, infrastructure, industry, agriculture, arable soil, forested areas)
N Monitoring (existence and need of monitoring, extent and frequency of monitored parameters, possibility of indication of impacts by more common state monitoring networks).

Ranking system of impact intensity allowed to differentiate among 489 localities in the scale from 44 (the lowest impact) to 231 (the highest impact) and on this base there were established 3 categories of localities (***Table 2***) as described above. Based on ranking system, Category I. (and another three localities of the Category II.) was denoted as "hot spots" for which monitoring system is being developed (***Figure 4***). The database for monitoring system will be open and according to economic possibilities other localities will be added to the system.

On the basis of the above described criteria and information a complex proposal of remediation measures will be compiled in 2005 to manage the problem of negative impacts of mining activities on the environment, including economic evaluation of the process.

Case studies – characterization of selected "hot spots"

Site 1: Horná Nitra – Brown Coal Mine

Hornonitrianske bane Prievidza Company represents the largest producer of coal in Slovakia. The yearly production in 2000-2001 was ca 2,847 kt. Brown coal is mined in "Hornonitrianska Coal Basin" from localities Bana Cígel, Bana Handlová and Bana Nováky (Bana Lehota, the only surface mine, was closed in 1993). Most of production (80%) satisfies the needs (more than 2,000 kt per year) of the main consumer, The Electric Power

Table 2: Localities of categories I. and II.

I. category		II. category	
Code: 150-		**Code: 100 - 149**	
Code	**Locality**	**Code**	**Locality**
231	Jelsava N1	148	Gelnica R12
231	Handlová P2D	142	Podrecany N3 Lovinobaòa
216	Banská _tiavnica R1	139	Spania Dolina R6
212	Cígel P2C	134	Dúbrava - Magurka R4
211	Rudnany - Porác R7 (inclusive: Zlatník N9)	129	Pezinok R5A
207	Hodrusa - Hámre R2	124	Hacava N6
198	Lubeník N2	112	Solivar N10
192	Slovinky R9	112	Sobov N25
192	Kremnica R3	111	Vceláre N27
187	Smolník R11	106	Lom.Lehota P2B
182	Nizná Slaná R8	106	Bana Záhorie P3
182	Roznava R10	102	Tisovec- Cremosné N30
179	Nováky P2A	102	Ladce - Budkov N33
179	Hnústa - Mútnik N5	102	Lietavská Lúcka N36
174	Bana Dolina P1	102	Kostiviarska N37
172	Novoveská Huta R16		
154	Kosice - Bankov N4		
altogether: 17 localities		**altogether: 15 localities**	

category: rest of localities

Code: 99 and less

Key: P – brown coal and lignite, R – ore deposits (mainly Pb, Zn, Cu, Hg, Sb, Fe, Au, Ag), N– industrial minerals (mainly magnesite, talk, asbestos, barite), P2C – identification code of locality in the particular mining area.

Station Novaky (Elektráren Nováky) and heating stations of some industrial factories (yearly more than 300 kt).

Mining history

The beginning of mining activities (surface mining) dates back 1825, intensive mining since 1912 (underground mining, at present most of mining works realised in depth of 250–400 m under surface).

Investigation methods

Past and present investigation efforts realised a brown coal deposit situated in the neogene basin related to tectonic-structural development of so-called Mid-Slovakian neovolcanics (Vtačnik Mts.). The coal bearing strata are of sarmatian age. From the geological point of view mines are documented mainly by archive of the Geological Survey of Slovakia ("Geofond") and individual mining archives. The most important data on geology and technology of mines are published in special issues of mines or in geological and mining periodicals. Monitoring efforts include all individual mines developed and the detailed moni-

toring system includes measuring and evaluation of amount and quality of mine waters, waste waters, and parameters for evaluation of geodynamic and undermining aspects.

Hazard source description

Main hazards on environment can be summarised as follows:

- the most important is activation of geodynamic processes on slopes and undermining of area (extent more than 30 km^2) with straight impact on settlements and estates,
- the second most important impact is represented by de-watering of mining fields and changes related to hydrological and hydrogeological conditions of the region. Mine waters are mixed with waste waters and total amount of waters is measured and inventory is publicly available,
- emission of contaminants (e.g. arsenic and sulphates) to environment due to effluent of mining and waste water is eliminated to acceptable extent by operation of water treatment plants,
- specific impact is represented by potential influence of mining on Spa Bojnice – clarification of this relation was solved by detailed investigation and monitoring.

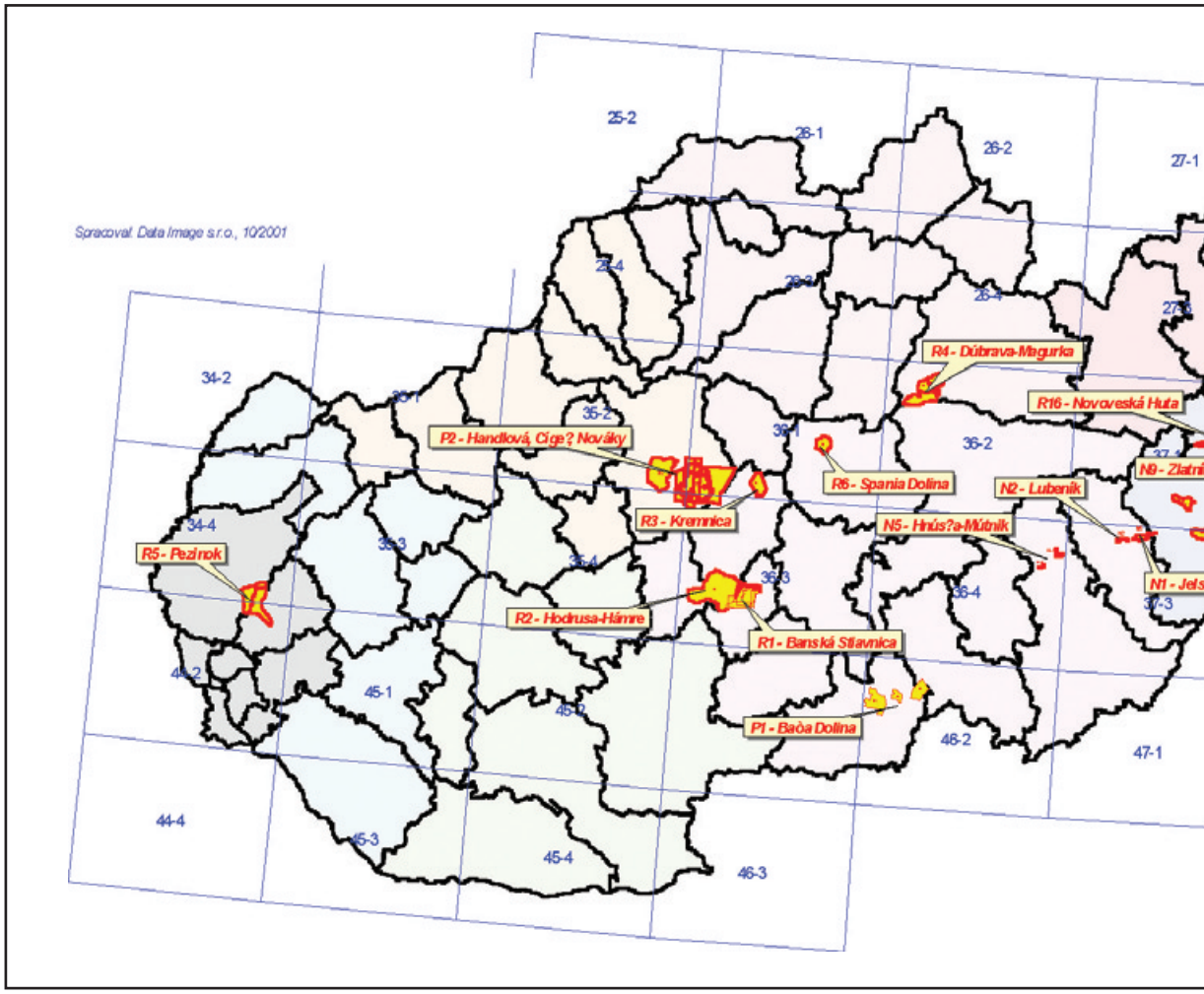
Environmental risks and impacts

- Hydrosphere: de-watering of water-bearing horizons, changes in hydrologic regime of surface and ground water,
- Soil: arable land is limited in usage during mining periods in individual fields, non-arable land and forests are impacted by activated geodynamic processes - damages are compensated as a part of current legislative process,
- Ecosystems: ecosystems are substantially influenced and changed. There is e discrepancy in evaluation of some changes in ecosystem because in several man-made depressions, which had developed as a result of underground mining, a new phenomenon occurred in relation to creation of wetlands with high quality biotop (from legislative point of view, according to Mining Act, depressions represent damages and have to be re-cultivated),
- Atmosphere: no substantial changes in air quality are caused directly by mining activities, on the other hand, ecological damages are caused by successive steps, i.e. burning of brown coal in Nováky Electric Power Station (arsenic, SO_2). However new technology rapidly eliminated ecological impacts hazards.

- Other:
  1. potential influence of mining on Spa Bojnice is a critical aspect of continuation of mining activities. Detailed investigation and on-going monitoring confirmed that springs and sources of healing mineral water can not be influenced by planned mining activities;
  2. damages on cultural heritage in the region are part of inventory of total damages cased by mining on society. Compromises are part of legislative solution of the problem. Technologically exceptional re-placement of historical church from the village Koš, can be mentioned as an example of compromise which enabled to extend mining activities.

Socio-economic impacts

Mining of brown coal in Hornonitrianska Coal Basin belongs to so called “social” mining, because state subventions are needed to keep mining acceptable. At this stage of economic devel-



opment questions of employment are taken into account as important socio-economic aspect.

Outlook

The agreed mining activities touch the horizon about 30 years ahead. The plan is to diminish step by step intensity of mining. Plan for remediation of the environment represents an organic part of overall development of mining activities and basically responds to legislative requirements of the Mining Act. Two specific activities were prepared to improve economic as well as environmental situation:

- utilisation of thermal waters for social (bathing, recreation) and technological (heating of air in the mine) goals. The second task was fulfilled;
- construction of "internal" Electric Power Station operated by the Hornonitrianske bane Prievidza.

Site 2: Smolnik – Cu, pyrite, siderite, and Au-Ag mine

Cu, pyrite, Fe, and Au-Ag mine is situated about 4 km ENE from the town Smolnik in the district Gelnica, Kosice Region in Eastern Slovakia. At present abandoned mine is managed by Rudne Bane, state enterprise, Banská Bystrica (State Administration of Mines).

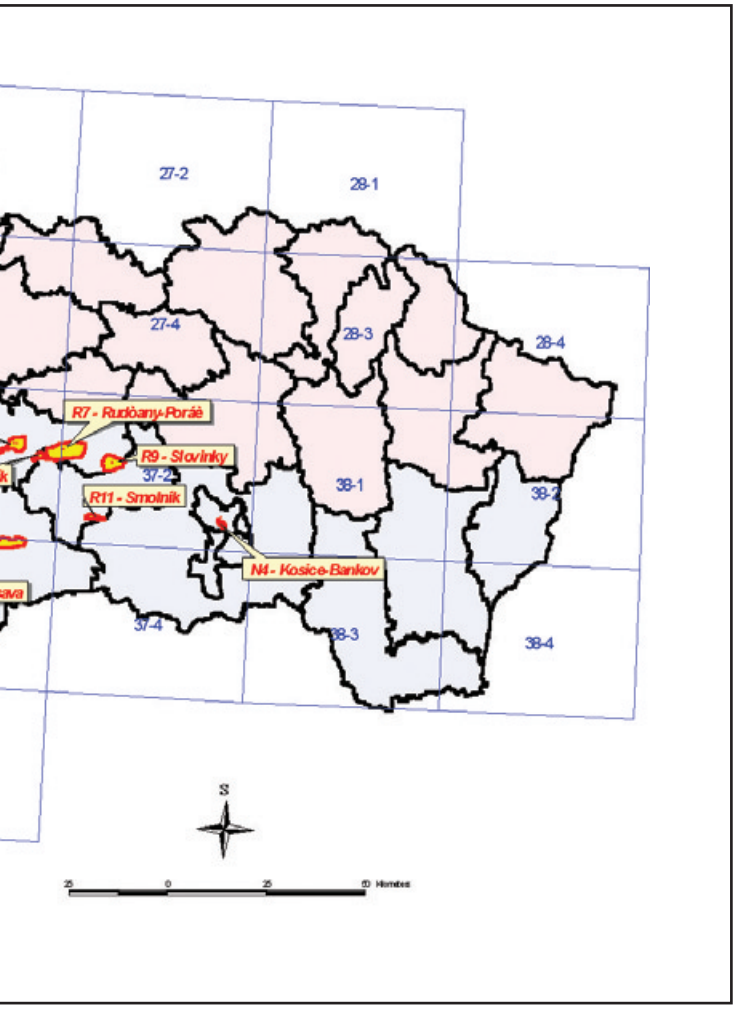


***Figure. 4**: Selected "hot spots" in the Slovak Republic.*

Mining history

This abandoned mine is famous for historical mining and extensive mining in past few decades. First evidences on gold mining are known since 1243 and since 1412 quantitative data on Cu mining have been available. Mining of Cu, Ag, Au, Fe is known since 1350. The most extensive mine adits were realised after 1853. With exception of short periods, mining of pyrite ore lasted from 1874 to 1956 (***Figures 5** and **6***). From 1964 interest was focused mainly on Cu ore mining (renewed Cu mining after about 100 year period). This activity continued till 1989, but directive to stop mining activities originated from 1987. Mining finished completely in 1990 and the mine was flooded with negative ecological consequences. In 1985 recultivation of mining area started, and a complex project for remediation of "hot spot" area was prepared in 1996.

Hazard source description

Main impacts on environment can be summarised as follows:

- the most important is acidification of environment and contamination of surface water, ground water and soil by mine waters and leakage from tailings ponds and waste rock piles (***Figure 7***),
- the second most important impact is represented by de-watering and changes in rock environment caused by surface and mainly underground mining, including undermining of terrain, with negative influence on the environment. The main risk is the failure of tailings dams.

Environmental risks and impacts

- Hydrosphere: de-watering of water-bearing horizons, changes in hydrologic regime of surface and ground water, extremely aggressive mine water with pH 1,5–3,0 and high content of Cu, Fe, Mn, Zn, Al, As, Pb, sulphates (hydrogeochemical anomalies and geochemical anomalies concerning stream sediments are known from detailed mapping), important river Hnilec is impacted by acidification caused by mine water through the Smolnik stream. In 1990, the mine started to be flooded with negative

Figure 5: *View of Smolnik old mining town.*

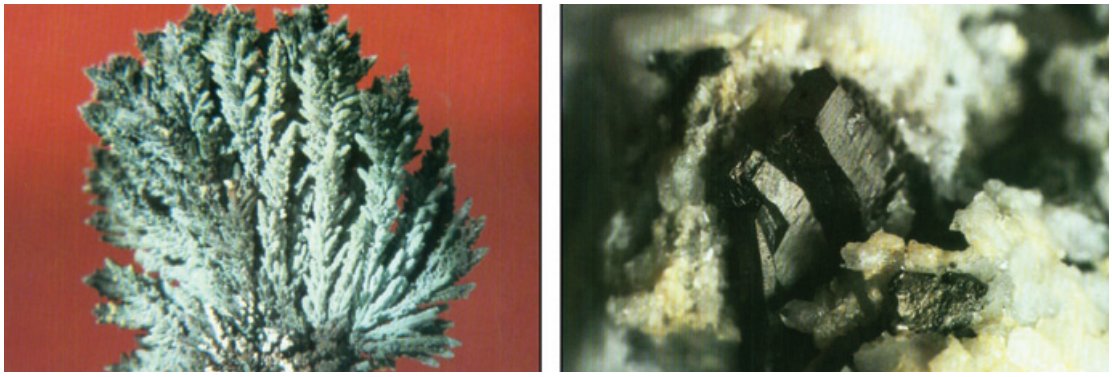


Figure 6: *Copper and pyrrhotine from Smolnik.*

ecological consequences. In 1994 there was an ecological accident when surface water of stream Smolnik and river Hnilec was acidified to such extent that huge number of fish died. Since this event new measures to prevent damages started to be prepared. Complex project for remediation of "hot spot" area was prepared in 1996.

- Soil: acidification and contamination by heavy metals, non-arable land and forests are impacted by extensive mining activities (shafts, galleries, open mine pits, tailings, tailing ponds, waste rock stockpiles, etc.

- Ecosystems: ecosystems are substantially influenced and changed mainly because of acidification of environment and damages on biotops. Surface water in surroundings of deposit exhibits pH 7,0–7,5 and acidified stream and river water below deposit reaches pH values 4–5 and very often below 4 with negative influence on biota. Damages on fishing in the region are solved by legislative way between mine management and local fishing administration.
- Atmosphere: ore processing caused contamination of air by ash (e.g. in 1985 about

2.2 t/yr) and emissions of SO_2 (4.4 t/yr in 1985).

Socio-economic impacts

Mining of sulphide Cu ores finished in 1990 because of changes in society (transition period to market economy) and stopping of state subventions to mine this type of ore. This decision lead to two consequences:

- firstly, questions of employment taken into account as important socio-economic aspect was less important than economic criteria and environmental damages;
- secondly, the state has to recover the territory (project of remediation in 1996) and pay for damages to some subjects in case of proved direct damages.

Outlook

According to project of remediation from 1996 two aspects have to be taken into account:

- to insure safety of inhabitants and estate (e.g. prevention to enter undermined area);
- to prevent environmental damages.

First aspect is related to the fact that some of the mine facilities are used by inhabitants to specific economic activities, in other words, people occupy the mine territory and the task is to prevent them against direct danger, e.g. by backfill of mining pits, shafts, etc. The second aspect requires measures which will mainly prevent acidification of the surrounding natural waters:

- to lower groundwater level to acceptable level and to remediate vertical mining workings (e.g. shafts). The goal is to prevent acid mine water to enter surface water,
- to prevent surface water to enter (infiltrate) mine area (drainage of surface waters out of mine area),
- to reconstruct hydraulic conditions in confluence of stream Smolnik with river Hnilec (the goal is to ensure conditions for effective mixing of waters),
- to monitor all systems (including tailings ponds) for the proper correction in remediation activities.

Figure 7: *Smolnik – outflow from sludge lagoon.*

Conclusions

Slovakia belongs to countries with extensive historical mining and this fact along with mining in the past few decades caused many problems in the environment, in some cases with severe ecological consequences. Elimination of damages caused by mining activities is solved in Slovakia in several steps. It is conditioned by character of problem, ecological criteria, but mainly by economic factors.

On-going efforts are concentrated at:

- evaluation of impacts of selected 489 mining sites (on-going project since 1998, inventory stage finished in 2000),
- prioritisation of localities according to risk and preparation of remediation activities,
- preparation of state monitoring of the most risky localities of the mining sector (on-going process 20 localities were prepared by the end of 2002).

Other on-going projects supported by the Ministry of the Environment of the Slovak Republic:

- evaluation of remediation activities efficiency after uranium mining in Slovakia,
- evaluation of potential impact of geochemical environment on health state of inhabitants in Spi_sko-gemerské Rudohorie Mts. (Spis-Gemer Ore Mountains) Region,
- evaluation of impacts of old mining activities on environment in Malé Karpaty Mts. Region,
- monitoring of environmental impacts in selected regions of Slovakia.

Future project concerning mitigation of mining waste environmental risk and impact:

- safety and elimination of old mining impacts in Malé Karpaty Mts. Region,
- L'ubietová – safety and elimination of old mining sites,
- Sb-As in waters in surroundings of Sb-deposits Dúbrava and Magurka (Nízke Tatry Mts.),
- sources of heavy metal contamination in the south part of Nízke Tatry Mts. Region,
- study of contamination mechanism from mining and processing of minerals,
- GIS of mine waters in Slovakia,
- application of remote sensing to the identification and monitoring of old environmental impacts,
- assessment of contamination risk of the Sb-Au-S deposit Pezinok and suggestion of remediation.

From the view point of State Environmental Policy mining activities represent only one of the activities with negative impact on the environment. To solve the problem in complex way the Slovak Republic will have to accept the Act on Contaminated Sites which will insure systematic solution of "old" environmental impacts, as well as present activities, including mining activities.

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