MINEO Alpine Environment Test Site
Siderite Mine Steirischer Erzberg, Styria, Austria

Socio-economic Impact & Environmental Hazards

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Title page illustration:
Steirischer Erzberg iron ore mine – 3-D view of an air photo draped over the digital elevation model (height 7x exaggerated)
1. Introduction

Ore mining industry can play a very important role in the national economy especially in Third World or newly industrialized countries. Mining for raw materials can form an important pillar of the industrial development of a country. Mining areas and places of raw material processing generate places of employment. The exploitation and consumption of natural resources is an important supplement to the national income. Earning and saving of foreign exchange adds to the federal economy by export revenue. In central Europe mining activities in general are declining during the last centuries due to economical and environmental reasons. The iron ore mine Steirischer Erzberg is one of the last big mines still active in this region.

The strength of the impact of mining activities on the local area depends on the legal position of the region and the state, the governmental supervision and control, the responsibility of the policymakers and the sensibility of the mining company itself. Inconsiderate exploitation regardless of the local situation and the population entails severe devastation. In an alpine environment with it’s sensitive ecosystem irresponsible mining can cause scars in the landscape that can be seen for many decades or even centuries. The soil often forms only a thin layer very susceptible to erosion. At the same time the soil formation rate is very low because of limited plant covering due to the short vegetation period.

In general the impact scenario for a whole mining project from the beginning to the end can be described in three stages:

1. A mining project starts with reconnaissance, prospection and exploration of the geological resources.
2. Then a time of extraction and processing follows.
3. The last stage is the closure of the mine with mine restoration and reclamation.

Phase 3 means returning the area on which the mine is situated back to as close to the original condition as possible.

At least before abandoning the mining area mining companies usually start reclamation projects. The objective of mine reclamation is to prevent or minimize adverse long-term environmental impacts and create a self-sustaining ecosystem as
near as practicable to what existed before the mining activity. Mine reclamation is an ongoing program designed to restore to an acceptable state the physical, chemical and biological quality or potential of air, land and water regimes disturbed by mining. Reclamation can be carried out at various stages of mining activity, after exploration, after surface or underground mining, or after treatment and processing facilities have been closed. Mine reclamation techniques consist of removing, relocating or demolishing buildings and physical infrastructure, closing pits and shafts, stabilizing underground workings, soils and slopes, treating tailings and waste water, and revegetating land.

The mine at the Steirischer Erzberg currently is in phase 2. An estimated 230 Mill. tons of ore - 200 Mill. tons in this century alone - have been mined. The economic reserves are calculated to 140 Mill. tons. The Steirischer Erzberg is the biggest iron ore open pit mine in central Europe. Mining of iron ore from the Erzberg dates back to Celtic-Roman times. More than 1000 years of ore-mining engrains the people living in this area and the landscape very strong.

Fig. 1: Ore production at Steirischer Erzberg (Voest-Alpine 2000)
2. History of the iron ore mine Steirischer Erzberg
(Illmaier 1992, Manfreda 1992)

- *In the 4th century* roman writers mention the famous Noric ore. Archeological documents indicate that the ancient Romans mined iron ore from the Erzberg and melted pig iron at a site called Feistawiese. However, it should be mentioned that some scientists are of the opinion that the genuine Noric ore was only mined in Hüttenberg, Carinthia, Austria.

- In *1171* there was the first documentary mention. Mining of the limonitic gossan was done until the middle of the 18th century.

- A new roasting technology in the process of ore-smelting was introduced. Since that time mining of the carbonate ore (siderite) was possible.

- Since *1250* new smelting methods („Radwerke“) were utilized. The increase of ore mining lead to increasing requirements of charcoal. The decimation of the local forest stand was the consequence.

- At the beginning of the 15th century the forests around the Erzberg were heavily decimated. Legal regulation were demanded to stop the exhaustive utilization of the forest. In 1495 the so called „Waldordnung“, a regulation to save the forest was passed by the Austrian Emperor Maximilian I.

- In 1570 the so called „Hammerwerke“ - small smithies - were booming. There was a great demand for ore.

- The beginning of the 17th century was characterized by shortage of wood, expanded devastation of the forest, riots and civil commotion and economic down-stroke of the mining industry.

- 1625 marked the end of the seigniorial time. It was the date of the foundation of a federal production union (Innerberger Hauptgewerkschaft).

- In 1839 a regulation called „Wäldervergleich zu Eisenerz“ was passed. This agreement was the basis for a regular and ordered forestry. Thus it was the basis for the well wooded landscape today. But the forest wasn’t saved yet, because the mining industry still had an increasing demand for wood. In 1857 the demand for charcoal of the whole mining industry of Styria was about 1,1 Mil m³. This was equivalent to a forest area of 300.000 ha and equivalent to the whole usable forest area in Styria at all.
By the end of the 19th century the time of using charcoal was over. Alternative combustibles like coke, lignite and hard coal, peat, gas etc. were used. This was the actual recovery of the forest in the surroundings of the Steirischer Erzberg.

1881 marked the foundation of the „ÖSTERREICHISCHE ALPINE MONTAN AG - ÖAMG“. Since the Middle Ages, many smaller companies known as „Innerberger Hauptgewerkschaft“ and „Vordernberger Radmeister-Communität“, operated small pits and adits producing iron ore. In 1881, these organisations were merged under the new company ÖMAG. With the foundation of the ÖMAG the enlargement of opencast mining began.

In 1891 the railway Eisenerz – Vordernberg was opened. This date marks the beginning of the well-regulated mining in levels as well. (Cede 1991)

In 1907 nearly the whole mining-area was subdivided in 60 levels which were about 12 meters high.

In 1943 modernizations like changing from hand working to mechanical mining increased the production rate.

Because of the increasing production rate much overburden material accumulated. As a solution in 1969 the filling of the Gerichtsgrabenbach valley with a total capacity of 480 Mil tons of overburden was decided after eight years of negotiations and studies.

In the seventies the world-wide recession of the steel industry caused a restriction of the output. In 1978 only 2,56 Mil tons of ore were produced.

In 1973 the mining company „ÖSTERREICHISCHE ALPINE MONTAN AG“ merged with the steel company VÖEST AG to form the VÖEST-ALPINE AG.

In 1986 the subsurface mine on the Steirischer Erzberg was closed.

In 2000 the open pit mine had a production of about 1.8 Mill. tons per year.
3. Socio-economic impact of ore mining

Dry surface mining has strong effects on human living conditions, generally spoken on the social environment. Frequent consequences include:

3.1. Resettling – relocation

Often it is inevitable to resettle the inhabitants of the area to be mined. Besides the relocation of settlements often traffic routes and the communication infrastructure have to be relocated, too. The consequences range from economic loss to social and cultural disruption. The latter will be all the more serious, where the local population feels strongly attached to a limited natural environment, cultural or religious localities, established social structures, territorial sovereignties, etc. .

At the Steirischer Erzberg because of the filling of the Gerichtsgraben valley the through road from Eisenerz to Präbichl had to be relocated. The new course was built on the north-slope of the Polster mountain. The people of three small villages (Wismath, Weingart, Leiten) were resettled in the course of the progressive mining activities. (Cede 1991)

Fig. 2: Mining area Steirischer Erzberg
3.2. Land-use conflicts

Another frequent consequence includes land-use conflicts when the area to be mined is being used for agricultural or forestry purposes or contains significant cultural monuments, recreation areas/facilities or the like that stand to be destroyed or are negatively affected by the mining operations. In the last century the mining industry at the Steirischer Erzberg needed more charcoal for the smelting process than ever. Therefore the demand for wood from the surrounding area increased, initiating land-use conflicts.

3.3. Work opportunities

Often mining projects require a large number of unskilled manpower. In some cases the local inhabitants can take advantage of the employment potential generated by the project. Since many centuries the mine at the Erzberg gave new jobs to the people living in the surrounding and in other regions. People were engaged at ore mining, at the ore smelting process, at smithies and other works in connection with the metal industry. Nowadays in the range of mining at the mining company VOEST ALPINE ERZBERG altogether about 190 workers are employed. 40 of them are working in ore preparation. 60 workers are engaged in new services sectors dealing with mining technology. (Hoffmann 1999) In 1980 the Erzberg works employ approximately 1900 persons (Asia Mining 1980). In 1984 the Erzberg mine had 1200 workers and 200 employees. (Skillings Mining Review 1984) Over the past years many people left the area because of unemployment. The village of Eisenerz presently has about 6500 inhabitants, which is only one third compared to 20 years ago.

3.4. Enlarged market facilities

Economic revival which improves the standard of living is always coupled with enlarged market and better communication and transport facilities. People from mining areas with a long mining history develop a pride of mining-tradition and mining culture.
Mining on the Steirischer Erzberg has a long tradition and took place since Roman time. More than 1000 years of ore mining engrains the people living in this area and the landscape very strong. In the township of Eisenerz there are many mining museums and historical interesting facilities. Since 1988 it is possible for tourists to visit the operating open pit mine. With two huge, discarded and adapted lorries (SLKW CAT 777C with 85 tons payload) 128 people can climb the Erzberg. Tourists can also visit the closed subsurface mine, which is adapted as a visitor mine. This tourist attractions decoy hundreds of tourists every day to the „Abenteuer Erzberg“. (“Adventure of the Erzberg”) and forms an additional attraction for summer tourism in the whole region especially on days of bad weather.

3.5. Scientific research, economic development, and education

Mining areas often form a nucleus for the development of new mining technologies and scientific developments. In the area of Eisenerz a research centre for mining is going to be established. Projects and collaborations with the Mining University of Leoben, Joanneum Research, the Geological Survey of Austria and other institutions are underway.

About 60 workers of the local mining company are engaged in new services sectors. The experiences in mining technologies forms a valuable capital of the mining company and is going to be offered to the domestic and international market. The new founded services sectors include mining consulting and performing works dealing with mining technologies.

*Mining consulting* includes drilling and blasting consulting, planning of new open pit mines or quarries, operating plans for mines, consulting in mine surveying and consulting in reclamation know how.

The *performing works dealing with mining technologies* include the performance of drilling and blast-works, exploration drilling, works in subsurface mines like cutting-through of galleries and headings, sanitation, etc., mine reclamation, machine services in the range of steel construction and repairs of diesel engines.

(MSE Maschinen-service Erzberg Ges. m. b H. (machine service company, founded in 1994, Voest Alpine Erzberg 2000)

[http://www.gt.de/uvp/publika/English/begin2.htm](http://www.gt.de/uvp/publika/English/begin2.htm) – Environmental Handbook,
Many studies were conducted to explore the natural resources and new economical possibilities for the township of Eisenerz. A change of the image from a mere mining area with mining and industrial traditions to a touristically attractive region should be initiated and the tourist potential should be assessed. (Pirkl 1996a)

The township of Eisenerz is a place of cultural and historical education as well. Many museums and old restored mining facilities give information about ancient mining technologies.

3.5.1. Selected projects

@mi - after mining

A 3 years EC project called @mi-after mining was started in 1996. @mi-after mining is a project within the European Community Initiative ADAPT and involves three municipalities in three different European countries: Arjeplog in Sweden, Eisenerz in Austria and Pyhäjärvi in Finland. The common problem was that the local labour market of each of the partners is dominated by mining industries which all are to close down in a few years.

The aims of the project were:

- New perspectives for a life "after mining"
- Secure existing jobs
- Create new job opportunities
- Qualification of employers and employees
- Decreasing the quota of migration

In each municipality mining may continue for a limited number of years. Even so, unemployment and migration will represent major problems in the future for each partner. The measures suggested by the local @mi-after mining projects will help to create a basis for improvement of the state of the local economies.

The members of the project recognised the importance to learn about the strategies of other regions in Europe – including the partner regions of the project - and about difficulties occurring when trying to realize the strategies. Those impressions are a
valuable input when development issues are discussed and decided "at home".

Fig. 3: Decade-old heap before (top) and 1 year after revegetation measures (bottom) (Photos by courtesy of H. Pirkl/Geoöko)

REKULT
A national research project on site specific and economic mining reclamation methods called „REKULT“ was started in 1997 and ended in 2000. Many test areas of this project were situated in the mining area of Erzberg. This research project had the aim to elaborate guidelines for promising procedures for modern mine planning and reclamation. Economical acceptable and environmental valuable reclamation methods are specified site specifically on the basis of geographical, topographical, geological, and climatic conditions. Of particular importance are strategic considerations in respect of optimal preparation of reclamation activities, which is regarded as integral part of the mining operation. In the project special emphasis was laid on safety aspects such as rock fall. Economically acceptable and
environmentally valuable solutions were expected to be found only by interdisciplinary co-operation of experts in the field of mining, geology, reclamation and forestry. Solution finding was assisted by a comprehensive database with practical examples realized until now. (Sanak-Oberndorfer et al. 1999)

Results of projects about the natural resources of the township of Eisenerz - new resources of the region (Pirkl 1996):

*Regeneration and health tourism:*

- The township of Eisenerz can offer a natural landscape for summer and winter tourism. Analysis of the natural resources have demonstrated that the land around the mine is unpolluted.
- A rare type of mineral water was found by hydrogeological and hydrochemical investigations in the mining area. The water shows a high magnesium mineralization (Mg-HCO₃-SO₄-water). This water is suitable for medicinal water and/or mineral water. (mineral water dispatch, medicinal bath, spa)
- The climate of the galleries of the subsurface mine was studied regarding air temperature, air humidity, and radon content. A radon content of 4000 Bq/m³, an air temperature of 7°C and an air humidity of 94 to 99% was found. (PIRKL 1996b). It could be possible to use the old galleries as medicinal galleries. This could be an economical valuable utilization of the discontinued subsurface mine.

(http://www.gasteinerheilstollen.com/healing.htm - radon)

*Education tourism:*

- In 1988 a visitor mine was established, so tourists can visit the discontinued subsurface mine. As mentioned above tourists can also visit the open pit mine by two huge lorries converted for transportation of passengers. In Eisenerz and Vordernberg there are museums of mining tradition, history, and mining technology. These tourist attractions decoy hundreds of tourists every day in the „Abenteuer Erzberg“. ("Adventure of the Erzberg")
- Policy and decision makers want to establish a research centre for mining in the area of Eisenerz. Projects and collaboration with the Mining University of Leoben, Joanneum research, the Geological Survey of Austria and other institutions are planned.

(Katter et al. 1998a, Katter et al. 1998b, Katter et al. 1999)
4. Legal framework

It is important that the government keeps the mining operations and incidents under surveillance. Mining is regulated under several federal and national laws. In Austria many laws have implications for mining and provide an adequate protection for people and environment:

- "Umweltinformationsgesetz" UIG: BGBl. Nr. 495/1993 (Environmental information law)
  This law codifies the obligation of the originator to inform the government about every environmental impact.
  Immission control is primarily concerned with the setting of concentration limits for a range of pollutants, including most prominently SO₂, NOₓ, ozone, and dust. Several regulations describe the measures to be taken if and when these limits are exceeded. The regulations also describe the country wide system of measurements of air quality and the organisation of the reporting.
- "Luftreinhaltengesetz für Kesselanlagen", BGBl. Nr. 380/1988 (Emission control law for boiler plants)
  This is the core legislation for larger combustion systems such as boiler plants for industrial and commercial use, describing their operation as well as data compilation and reporting.
- "Altlastensanierungsgesetz", BGBl. Nr. 299/1989 (Polluted area remediation law)
  Regulates the remediation of former waste deposits
- "Forstgesetz", BGBl. Nr. 440 (Forestry Law)
  This law regulates all processes which are in connection with the use and management of forested areas.
- "Abfallwirtschaftsgesetz" AWG, BGBl. Nr. 325/1990 (waste management law)
  The AWG regulates environmental friendly and economical avoidance, collection, utilization, and disposal of waste.
- "Umweltverträglichkeitsprüfungsgesetz" – UVP-G, BGBl. Nr. 697/1993 – (Environmental impact accessment law)
The UVP is a systematic check procedure to determine and describe the direct and indirect effects of a project on the environment already.

- “Wasserrechtsgesetz” - WRG, BGBI. Nr. 215 (Water law)
  Regulates the use and the protection of waters as well as the protection against the dangers of the water.

Sources of information:

2. "AIR-EIA: air pollution and environmental impact assessment: the multimedia information source." AIR-EIA is funded under the INFO2000 Programme of the European Commission under project number PUB-1221. [http://www.ess.co.at/AIR-EIA/austria.html]
5. Environmental hazards

5.1. Environmental impacts in connection with mining facilities (dumps of overburden, tailings heaps, tailings ponds)

Mining on the Steirischer Erzberg has a long tradition and took place since Roman time. In the 16th century underground mining started, which was closed down in 1986. Since the 18th century open pit mining activity increased, which are still underway. So the impact and interference on the landscape started 200 years ago. The mining affected area, which comprises the working itself, the dumps of overburden, the tailings heaps and the area of infrastructure facilities (administration buildings, transportation, workshops, processing equipment, etc.) is about 7.5 km² in size.

Dumps and heaps cover the landscape surrounding the working. The whole valleys of the Gerichtsgraben and the Hintererzberg are filled with dumps of overburden, tailings heaps and mud in several tailings ponds.

An estimated 230 Mill. tons - 200 Mill. tons of ore in this century alone – have been mined. From 1960 until 1987 there was the period of the highest production. The yearly extraction rate of ore was about 3.2 Mill tons. The top extraction, which was
reached in the year 1974 amounted 3.76 Mill. tons. Thereby 11.7 Mill. tons of overburden occurred and had to be deposited. (Reiter 1979)

In the year 1961 the plan of the filling of the Gerichtsgrabenbach valley with a total capacity of 480 Mil tons was submitted by the mining company. A long period of negotiations began.

In the preliminary stages of and during the negotiations major catastrophes in connection with dams or mining areas took place. There were the dam break of Frejus and the flood disaster in Vajont-Longarone. On the 16th of August 1965 a great mud stream penetrated till the downtown of Köflach/Styria because of a dam break in the nearby coal mine. Finally one of the most tragic disasters took place on the 21st of October 1966 as a waste tip slid down a mountainside into the mining village of Aberfan, near Merthyr Tydfil in South Wales. 144 people died in the Aberfan disaster, 116 of them were school children.

All these events had a great influence on the decision makers. After eight years of negotiations and several studies the filling of the Gerichtsgrabenbach valley was decided. Many opinions dealing with mining, soil mechanics, geology and hydraulics construction were taken. Numerous steps and measures were undertaken to avoid any nuisance and danger caused by the filling material.

To plan this huge filling project three key factors had to be considered: the underground, the material of overburden and the way of filling.

The following facts and potential risks had to be evaluated:

- Avoidance of erosion and slides from the slope of the heap and avoidance of a accumulation of water behind and inside the heap
- Measures to protect the settlement in front of the heap
- Studies about the flow rate through the heap at high water
- hillside stability of the north slope of the Polster mountain after filling
- Evaluation of the quality of the water after percolating the heap

Because of the filling of the valley the through road from Eisenerz to Präbichl was relocated. The new course was built on the north slope of the Polster mountain.
By implementing a wet dressing plant tailings ponds were needed. The area of the old heaps in the Hintererzberg valley was used for this purpose. The dams of these ponds are a further potential source of danger in the mining area and their stability has to be controlled thoroughly.

![Fig. 5: Tailings ponds at Hintererzberg (Photo by H. Pirkl/Geoöko)](image)

Accidents like in Baia Mare (Romania) on the 31st of January 2000 are making such decisions not easier for the future. Nearly 100,000 m³ of water contaminated with cyanide and heavy metals was released into Hungary's second largest river, the Tizsa, when a tailings dam broke. The dam was holding tailings produced by the Aurul goldmine. Mining in alpine sites is a tightrope walk between drawing profit, perceiving risk and being sensitive in solving environmental and social problems.

5.2. Emissions of geogenic and anthropogenic origin (air and water pollution)

During the last years strong efforts were made to explore the natural resources of the township of Eisenerz. A change of the image from a mere mining area with mining and industrial traditions to a touristical attractive region should be prepared and the tourist potential should be assessed. Therefore a number of studies about the environmental situation dealing with environmental impacts and risks of the whole region of Eisenerz were carried out.
In a project called "Naturraumressourcen und Umweltsituation der Gemeinde Eisenerz - naturwissenschaftliche Basis für einen Imagewandel der Region"- ("The natural resources and the environmental situation of the township of Eisenerz – scientific base of changing the image of the region"; Pirkl 1996) a spatial analysis of the emission sources in the whole region was carried out. The following sources of heavy metals were discovered:

- **Geo-lithogenic sources**
- **Redeposition and enrichment processes caused by mining and dressing**
- **Emissions, which are the result of modern infrastructure (waste disposal, sewage and traffic)**

**Geo-lithogenic sources:**
- specific types of rocks, e.g. black shales of the "Grauwackenzone"
- mineralizations
  - Fe-(Mn) mineralizations in Paleozoic carbonates
  - Fe-(Mn) mineralizations in lower Triassic sediments (sandstones and shists)
  - Complex sulfidic mineralizations in Paleozoic shists
  - Cu- and fahlore mineralizations caused by tectonic processes in different geological position

**Redeposition and enrichment processes caused by mining and dressing:**
- prehistoric copper mining and smelting on site
- historical copper mining and smelting on site
- historical and current iron ore mining
- historical iron ore dressing and smelting (many blast furnaces)
- huge heaps of the current iron ore mining
- huge slag-heaps from the smelting processes during the 20th century

The whole township of Eisenerz is drained by the river Erzbach. It is a closed drainage system, where the input and output of heavy metals can be studied perfectly. For this purpose geochemical and mineralogical analysis of active stream sediments, heavy-minerals, and soils were carried out.
The investigations gave the following results:

- The siderites contain no supplementary heavy metals or trace elements except mercury. However, Hg in soils is always below the limit of concentration.
- The black shales are the main source of heavy metals. Slightly increased values of e.g. antimony, arsenic, nickel, lead, zinc are nearly always caused by the occurrence of black shales, which are restricted to small confined areas.
- Ores and slags, which are often found in the watercourses in the township of Erzberg contain no contaminating elements.
- Slightly increased contents of nickel, chromium and zinc in the watercourses are caused by modern infrastructure facilities (asphalt abrasion caused by cars, residual suspended matter of the local purification plant)

Surface mining activities like the Steirischer Erzberg also lead to air pollution. Blasting in hard rock causes dust pollution. Air pollution in the form of gases results from the exhausts of vehicles and engines, as well as from the evaporation of blast smoke.

The extraction activities also impose a noise nuisance on the surroundings, with major noise sources including the machines and devices required for getting, loading, hauling, reloading, etc.. Various machinery is in operation at the Steirischer Erzberg. For loading the caterpillars CAT 992C and D and KOMATSU WA 800-3 are used, which can carry 10 - 12m³ of rock material. The top performance is about 1.000 tons per hour. Transport of ore and overburden is done by the heavy-duty lorries CAT 777C with 85 tons payload. Each heavy-duty lorry transports about 1 Mill. tons of rock material per year. (Voest Alpine Erzberg 2000)

Also nuisance in connection with blasting like vibrations have to be considered. As blasting agent pump slurries are used. The typical consumption of blasting agent is 125 g per ton of blasted rock. At one blast 40.000 – 60.000 tons of rock material is obtained.

Every day the ore is transported by train to the Voest-Alpine smelting plants in Linz and Donawitz. In the year 1984 a new loading installation in the Krumpental valley one kilometre south of Eisenerz was installed. This large loading installation meets
today’s requirements and offers a maximum of noise protection. Thus the mining industry tries to reduce the noise nuisance to a minimum. (Illmaier 1992)

5.3. Environmental impacts on the flora and fauna, micro-climatic effects

During the Middle Ages because of the increase of ore mining on the Steirischer Erzberg the requirements of charcoal increased. At the beginning of the 15th century the forests around the Erzberg was heavily decimated. Numerous legal regulations were enacted to stop the exhaustive utilization of the forest but the devastation of the forest increased. The end of the 19th century marked the rescue of the forest in the surroundings of the Steirischer Erzberg. It was the time when the use of charcoal was over. Alternative combustibles like coke, lignite and hard coal, peat, gas etc. were used. Now wood was only used by the mining industry in much smaller quantities for the timbering of adits in the subsurface mine. With the closing of the subsurface mine in the year 1986 also the last large demand for wood ceased. Nowadays huge areas of forest must give way for the heaps of the overburden material. (filling of the Gerichtsgraben valley, Illmaier 1992)

The large areas of the tailings heaps without any vegetation have strong influence on the micro-climate of the mining area. Particularly at the eastern slopes of the Erzberg desert-like climatic conditions can be observed. Many reclamation methods were tested by the mining company to counter such climatic extremes (Sanak-Oberndorfer et al. 1999; http://www.gtz.de/uvp/publika/English/begin2.htm - Environmental Handbook)

5.4. Measures to reduce hazards and nuisance

For the creation of effective measures against dangers and annoyances, which can result from the mining industry, a co-operation of all participants and local residents is necessary. For the solution of more complex problems experts of different fields of activity are to be consulted, whereby an interdisciplinary co-operation is most successfully. First of all the legal conditions have to be formulated so clearly and precise that no gaps enable possible sources of danger or other impairments.
In Austria the legal basis in the form of many laws and legal norms provide an adequate protection for people and the environment. (see chapter 4) The activities of the mining company is controlled by regulatory authorities and environmentally active NGOs. Interests of the mining company itself, the employees of the company, the people living in the surrounding area, people living on tourism and many other components must be co-ordinated. Conflicts can only be avoided by informative, reasonable and clear communication between each other.

Some measures that have to be realized in underground and open pit mines to prevent from possible hazards and nuisance:

- frequent measures in order to prevent subsidence, slides or rock falls. A maximum of mine stability must be ensured.
- the sealing of all adits, entryways, drifts, shafts, or other openings between the surface and underground mine working when no longer needed for the mining operations
- the filling or sealing of exploratory boreholes, which are no longer necessary for mining
- supervision and monitoring of the stability of tailings heaps and ponds
- revegetation programs to increase the stability of tailings heaps, establishing a diverse and permanent vegetation cover capable of self-regeneration and plant succession and at least equal in extent of cover to the natural vegetation of the area
- elimination of all mining-facilities after the mine is closed
- elimination of fire hazards and explosive materials
- elimination of contaminated materials, which can pollute surface or ground water, minimize the disturbances of the prevailing hydrologic balance at the mining site and in associated offsite areas and to the quality of water in surface and ground water systems both during and after mining operations and during reclamation

A corresponding example for solving conflicts and avoiding hazards is the filling of the Gerichtsgrabenbach valley already mentioned. (Reiter 1980; Stadlober 1980)

Scars on the landscape may last for hundreds of years even if mined areas stabilize and the vegetation recovers. Carefully planned reclamation can restore natural
conditions and greatly speed up site recovery. In the area of Erzberg tourism adds an increasing amount to the income for many of the inhabitants. A change of the image from a mere mining area with mining and industrial traditions to a touristically attractive region is going to be prepared. (Pirkl 1996a)

Therefore projects like „REKULT“ (Sanak-Oberndorfer et al. 1999) were started. The goal of this research project was the development of economical and site specific reclamation methods. The project was divided in two parts. In the first part information about legal regulations, aspects of security, reclamation technologies, the economical viewpoints and opinions of adjoining owners had been collected. In the second part reclamation methods for the typical alpine site “Steirischer Erzberg” were tested.

Fig. 6: Interrelating factors for site specific and economic reclamation measures (Sanak-Oberndorfer et al. 1999)

From 59 test areas important parameters like slope stability, lithology, jointing, grain size, grain distribution, soil activity, water balance, weathering and primary nutrient content were collected in a database. These information about the site status guided
specific reclamation strategies. Different reclamation methods were tested and the results were assessed.

Advanced remote sensing techniques can be utilized to detect many key parameters for site specific reclamation measures remotely. Main parameters to be identified in detail include lithology, soil, vegetation cover, slope and aspect. Therefore these methods are very promising as cost effective tools for monitoring large reclamation areas on a regular basis.
6. References

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