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# Assessment of mining activities with respect to the environmental protection

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*This paper deals with the impact of mining on the environment. Coal mining is still among the most widespread and most intense mining activity, which disturbs the landscape around us bringing regional environmental, economic and aesthetic problems. However, for many countries in the world, including the Czech Republic, deposits of raw materials play an important role, especially for purposes of producing electricity and thermal energy. At the same time, growing emphasis laid on the environmental protection can be observed worldwide. To meet the increasing ecological demands, it is reasonable to consider the most significant aspects of mining activities from the environmental point of view, as well as to consider the possibilities of the abandoned mines utilization as possible waste dumps. Parts of this problem consist in: the monitoring, environmental impacts assessment of exploration and mining activities and waste disposal mining, which may significantly contribute to the environmental protection in the future. Several parameters that can significantly affect the usability of the waste disposal mining, such as geological structure, hydro-geological conditions, material composition and physical and mechanical properties of rocks are discussed in detail in this work.*

*The article also includes a practical example of Environmental Impact Assessment process for the particular activity of OKD stock company, which is the only producer of hard coal (bituminous coal) in the Czech Republic. Its coal is mined in the southern part of the Upper Silesian Coal Basin – in the Ostrava-Karviná coal district.*

***Key words****: mining, environmental monitoring, environmental impact, landfill mining, waste disposal.*

## Introduction

Mining is a profession dealing with geological exploration, development work, mineral deposit mining, preparation of minerals, relevant construction as well as effacing of negative environmental impacts. Mining methods can be classified as:

- opencast (carried out in open pits or quarries),
- underground (carried out in underground mines),
- others (e.g. geotechnological mining methods – chemical, bacterial leaching, etc.).

In terms of mineral deposit mining, we distinguish coal, ore and industrial mineral (non-ore) mining.

The extraction of mineral resources is closely connected with negative environmental impacts. The manner and intensity of impact on the landscape depend on (Neset, 1984):

- the type of extracted raw material,
- mining method and its intensity,
- concentration of mining operations on a certain territory,
- geological conditions of deposit formation,
- morphology of the affected territories.

Coal mining is the most widespread and most intense mining activity that disturbs the landscape. In many countries, including the Czech Republic, deposits of energetic raw materials play an important role, as power and heat generation is largely dependent on them (Rybár, 2015; Blistan et al., 2012). In the Czech Republic, negative impacts of coal mining may be observed in North-Bohemian and the Ostrava Region. Fig.1 and 2 show coalfields of the Czech Republic.

All major components of the natural environment are usually affected, such as soil, water, and air. At the same time, especially in the localities with concentrated mining (e.g. Karviná part of the Ostrava-Karviná District - OKR), the landscape is affected as a whole, and the so-called mining landscape originates. There are noticeable changes in geomorphology, soil fund, greenery, atmosphere, hydrogeology and other biotic constituents of the landscape (Matouš, 1989).

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Soil is influenced in the most intense way, water is less affected and air comes last. Manifestations and impacts of opencast mining are completely different.

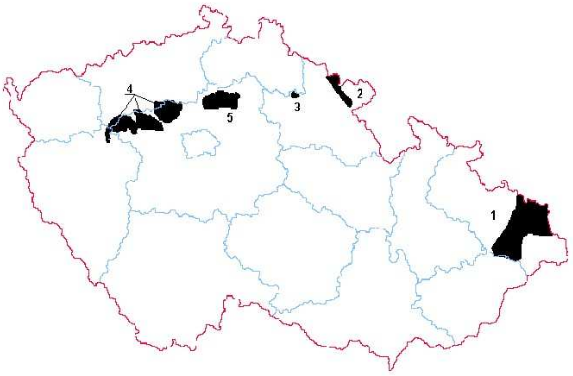

*Fig. 1. Black coal fields in the Czech Republic:1. Upper Silesian Coal Basin – 1600 km2 (predominantly in Poland), the only territory of current mining, 2. Vnitřní Sudety – mined out, no more economical, 3. Podkrkonoší – low-quality coal, nonperspective, 4. Střední Čechy – mined out, no more economical, 5. Mělník – no more economical, nonperspective.*

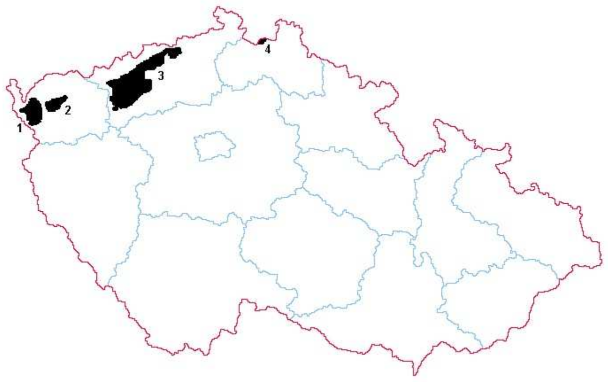

*Fig. 2. Brown coal fields in the Czech Republic:1. Cheb – it is not exploited with regard to the spa mineral water of Františkovy Lázně, 2. Sokolov – 25 % mining, 3. North-Bohemian – 3 parts (Chomutov, Most, Teplice), 75 % mining, opencast mining, 4. Žitavská – it is not exploited due to economic and technical reasons.*

## Underground Mining

Underground mining of mineral resources is manifested on the surface in the form of two characteristic elements, such as the occurrence of dumps (waste rock) and movements and deformations of the surface. Dumps influence the landscape and the environment in a negative way in many respects. They are atypical geomorphological formations in the landscape, especially when conical dumps are concerned (Vivanco, 2013). They are also the source of dustiness, both primary and secondary. In certain cases, when their ignition occurs, they are sources of waste products polluting the atmosphere further afield. Dumps also usually take up fertile land. Their decontamination and reclamation is difficult, and depends on the shape and dimensions of the dump (Sahu, 2015).

The second typical elements are movements and ground deformations caused by undermining. Movements of the undermined territory cause the following:

- substantial, long-term and spatially extensive destruction of the relief, landscape, residences, underground services, roads, in the sites of subsidence basins hazardous disposal sites of industrial and municipal waste are concentrated,
- irreversible changes in ground and surface water, the formation of drainless inundated subsidence basins, changes in the courses of rivers and streams and their falls of stream, changes in the catchment ratios in the sewage systems,
- damage and destruction to the soil profile.

### The impacts of undermining

The overall extent of undermining impacts depends on, in particular:

- intensity and character of mining impacts,
- ground morphology,
- structure, type and character of premises, facilities and soils found in the mining landscape.

Undermining shows in the long-term and, to some degree, cyclically. The cycle of the manifestations of undermining can be divided into three stages as for biotic action (Smolík, 1992), as shown in Table 1.

Undermining is manifested both by the movement of the rock mass in the surroundings of the worked out space and the rock mass in the main roof, as well as by the movement all the way to the ground, i.e. having an effect on the morphology of the landscape.

*Tab. 1. Stages of the effect of undermining on the environment.*

| **Stages** | **Type** | **Environmental components** | **Manifestations** |
|---|---|---|---|
| **1** | impacts of undermining | rock mass and landscape relief | subsidence, movements, deleveling, curvature, proportional horizontal deformations, discontinuous deformations, etc. |
| **2** | consequences of impacts of undermining | landscape and its constituents (anthropogenic sphere, pedosphere, and hydrosphere) | subsidence, lifting, shifting, expansion, compacting, tilting, change in the gradient, waterlogging, flooding, degradation, devastation, etc. |
| **3** | removal and effacement of the consequences of undermining | landscape and its constituents | repairs, decontamination, reclamation, regeneration, liquidation, demolition |

The manifestations of undermining on the landscape morphology can be diverse. Basically, they are divided into continuous and discontinuous deformations.

The character of earth ground deformation predominantly depends on a number of factors that can be classified as follows:

- geological factors (geological structure, the degree of tectonic ruptures, hydrogeological conditions),
- geomechanical factors (geomechanical properties of rocks),
- spatial factors (depth of mining, deposit dip, shape and dimensions of the worked out space, deposit thickness, landscape morphology),
- operating factors (technology of mining, filling method of the worked out space, failure of the roof due to earlier winning operations),
- time factors (formation rate of the area of extraction, the rate of overburden subsidence).

Continuous deformations are characterized by the gradual formation of a continuous subsidence basin, the shape of which is usually given by the dip of the worked deposit (inclined and steep dip) and the depth of extraction.

Discontinuous deformations of the ground are characterized by exceeding the soil or rock strength. Among the forms of discontinuous deformations, there are – ground degree, cracks, ground roll, earth fall and downthrows. Discontinuous deformations of the ground are accompanied by structural changes in the foundation soil the tensile, compression and shearing strength of which is exceeded. Discontinuous deformations of the ground are usually formed very fast, which on the other hand does not permit the use of rheological characteristics of building materials or foundation soils. For premises on undermined territories, discontinuous deformations are more dangerous than the continuous ones. Their influence of the landscape morphology is destructive (Hejmanowski, 2015).

Therefore, periodic measuring is carried out in undermined territories. Movements and deformations are measured in observations bases which are stabilized both in the terrain as well as in sensitive premises and facilities in the mining landscape.

The following can be found among the main environmental impacts of underground mining:

- dumps (dustiness, burning, washing away of sulphur),
- mining areas (gas bursts, ventilation outlets, etc.),
- concentration of industrial and municipal waste disposal sites,
- irreversible changes in water regime – formation of drainless areas,
- damage and destruction to the soil profile.

## Opencast Mining

Among the major consequences of opencast quarrying of mineral resources for the environment, there are:

- long-term and frequently irreversibly claimed land with high-quality agricultural and forestry soils that are locally accompanied by the devastation of rare wetland ecosystems with protected species of flora and fauna,
- changes in the landscape relief, including dumps, clearance, interfering neologisms are formed, exceptionally complete devices are removed – landscape dominants (Singh, 2016),
- the threat to the drinking water reserves bound onto the rock formations with all negative manifestations (contamination, reduction in the ground water level, interference with the natural circulation),
- formation of water areas that may locally cause irreversible microclimatic changes (Hüttl, 2001),
- the surroundings of mining operations are strained with increased noise levels and dustiness (e.g. the effects of blasting, transport of raw materials),
- development of related industry – power engineering, chemical industry.

## Environmental issues of deposit exploration, mining and its termination

Geological conditions and processes condition the character of the anthroposphere to a great extent, where effects of the mutual action of the geosphere, hydrosphere, atmosphere and biosphere with human activities are presented. Therefore, in a number of years, the so-called environmental geofactors have been monitored and evaluated in the form of special maps, among which there are mineral resource deposits, groundwater sources, including such for medical purposes, geotechnical and geochemical characteristics of the environment, soil conditions, geodynamic phenomena, etc., i.e. factors that are important in providing the needs for the human material and in the formation of the environment. In this respect, a geological exploration has a cognitive, appraising and informative function. Deposit exploration, and especially consecutive extraction and modification of the discovered deposits of mineral resources, may have a range of impacts on the natural, social and economic environment. In the sphere of the natural environment, it predominantly influences the rock environment as well as other constituents of the environment (hydrosphere, atmosphere, and biosphere). The movement of masses connected with the extraction is huge, and in its extent, it significantly exceeds the share of natural processes. Thus, much attention has been paid to monitoring and evaluation of environmental impacts of mineral resource industrial activities. However, it must be emphasized that the impact of mining plant activities has a local or maximally regional character only, as in the affected area of a region or state, for example, it is practically negligible. For instance, between 1930 and 1980, a mere 0.25 % of the overall area of the USA was used for opencast mining, dumps of opencast and underground mines and waste disposal sites from preparation plants. All mines for non-ferrous metals take up only 0.02 % of the area. Concurrently, approximately 47 % of the area affected by mining and waste dumps was reclaimed as per the end of the stated period. In Australia, the area affected by mining activities concerns an entirely negligible number of 0.001 %. With no doubt, there are other activities with much more extensive and serious impacts, such as power engineering, automobile transport, agriculture or timber cutting in tropical rain forests (Tab. 2). Nevertheless, e.g. deposit territories of opencast mining of coal, iron or porphyry copper ores deserve some attention (Hobday, 2014; Blistan et al, 2015).

*Tab. 2. Human activities and possible environmental impacts.*

| **Sphere of activities** | **Possible environmental impacts** | **Extent of impacts** |
|---|---|---|
| **power-engineering** | pollution of air, water, and soil, thermal effects, damage to the biosphere, agricultural and forestry land required | regional to global |
| **agriculture and forestry** | erosion, landslides, salting of soil, floods, pollution and changes in the water regime, influenced biosphere | regional to global |
| **transport and waterworks** | landslides, rock falls, earth flows, subsidence, floods, changes in the ground water levels, influenced biosphere, land required | regional |
| **industrial production** | pollution of air, water, and soil, noise, vibration, damage to the biosphere | local to regional |
| **mining** | changes in the landscape morphology, subsidence, landslides, reduction in the groundwater levels, pollution of air, water and soil, concussions, noise and vibrations, damage to the biosphere, land required | local to regional |
| **housing development** | changes in the landscape morphology, pollution of air, water and soil, thermal effects, noise, influenced biosphere, land required | local to regional |
| **tourism** | pollution of water and soil, soil erosion, damage to the biosphere | local to regional |
| **waste disposal** | pollution of air, water, and soil, the impact to the underlying rocks, thermal effects, land required | local |
| **transport** | pollution of air and water, noise, and vibrations, influenced biosphere | global |
| **waterworks engineering** | impacted water regime, changes in the landscape morphology, subsidence | local |
| **geological exploration** | possible impact on the water regime and polluted water sources | local |

It is apparent that the geological exploration does not represent a great danger for the environment. Both the impacts of the applied procedures are minimal as well as the valid regulations require disposal of the incurred interference with the environment immediately after work termination. The impacts of mining activities that must be analyzed already within the survey are more prominent. A part of the final report or the feasibility study of the mining plan must incorporate an assessment of expected impacts on all the environmental components and suggestions for their minimization and consequent disposal within termination work. During analyses, apart from the physical environment, the economic environment must also be respected, which has a comparable significance in assessing an exploratory and mining plan at least.

## Environmental impact assessment – EIA

The assessment process of the impacts of exploratory and mining activities plays a positive role in the plan preparation. It makes part of the system of preventive tools of environmental protection, and it appropriately complements the mining legislation. In its consequence, it leads to the minimization of the financial costs for the program implementation and related environmental measures (Antoci, 2012). The introduced system of the public hearing, which makes part of the assessment process, eliminates possible conflicts with the public. The screening process that is being introduced shall even improve the situation as the public will be involved in the assessment process already in the initial stage of the process.

The term of EIA - Environmental Impact Assessment - is grounded in National Environmental Policy Act of 1969 in the environmental domain, division 102.

This act brought a radical change as in the form of an Environmental Impact Statement (EIS), for the first time, a proposer of activity is obliged to prove that they will not significantly affect the environment.

The European Economic Commission stated in the Second Environmental Action Programme of 1977 that EIA is a necessary tool for environmental care. After many negotiations, European Community Council Directive 85/337 was negotiated on environmental impact assessment of certain private and public projects in 1985. The next important step was EEC Convention acceptance of environmental impact assessment exceeding the national borders in 1991 (the so-called Espoo). The individual countries applied EEC Directive 85/1985 in three forms. Some countries incorporated the issue of EIA into the existing legal norms (Wende, 2012), usually as amendments to land-use planning (Great Britain, Ireland, Denmark) or Acts on the conservation of nature (France). In other countries, EIA became part of Acts on the environment (Netherlands, Greece). At last, some countries adopted separate legal norms on EIA (Germany, Belgium, Spain, Czech Republic and further to the provisions of the environmental law).

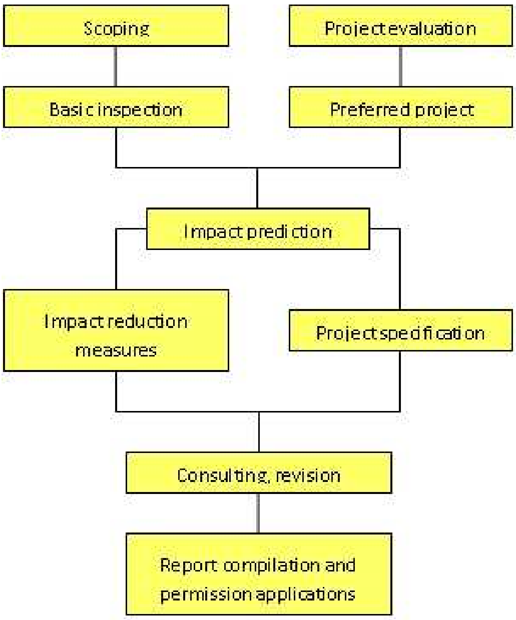

*Fig. 3. Chart of EIA process, according to SRK Ltd. (UK) (Schejbal, 2010).*

Currently, assessment of constructions, activities and technologies, assessment of development concepts and programs and assessment of products is underway. Procedures and required particulars differ in the individual groups. Projects are assessed in terms of ecological acceptability of the territory in question, consequences of the activities and possible accidents, cumulative and synergic phenomena, prevention and minimization of the project’s environmental impacts, disposal method of products after their expiration or utilization (possible recycling and disposal), applied assessment methods and comprehensiveness of information. At the same time, a comparison with the best available technologies is also required.

Along with the progress in the environmental legislation and requirements for ever stricter standards, environmental research is becoming a basic element of planning exploratory and mining programs. It is ideal to start such work already in the initial stages of the project preparation in order to prevent incorporation of such activities which would lead to complications or fatal events or unsolvable conflicts of interest. The first stage of the task, which is compulsory in certain countries, is scoping as a precondition of development acceptability for the approving agencies and investors (Schejbal, 2010). The following stage of study and assessment of impacts and proposals of possible solutions arise in the mutual cooperation of an engineering and environmental team (Fig. 3).

As stated above, the programs of deposit exploration do not have significant impacts on the environment. The majority of geological, geophysical and geochemical methods are non-destructive by their character. A certain impact is caused by the application of technical exploratory work connected with the construction of access roads and workplaces, which may lead to damage to forest plantations and farmland. The use of drilling and underground mining work may influence water conditions due to the discharge of mud and leaks of oil products. The circumstances are usually regulated by mining law that sets the duty of land reinstatement (if objectively and economically possible) and duty of surface exploratory work disposal and mine working securing. Exploratory programs are also bound to relevant permits that may include implementation conditions in terms of environmental protection. Within exploratory programs it is also necessary to follow another part of environmental protection, namely in terms of the final effect. It is not effective to implement the exploratory work, the results of which will not be applicable due to the environmental protection (e.g. deposits of building stone or gravel sand).

Environmental impact assessment is required for all activities connected with the exploitation of mineral resource deposits as they concern land, water sources, ecological systems, cultural and protected reserves and features as well as the whole public. Within the assessment, attention must be paid to the applied mining technologies as to their safety and degree of environmental impact (Popa, 2013). Highly effective technologies are preferred, minimizing the production of waste and improving the culture and sanity of miners' work. The main problem of opencast mining is the land required, impacted constructions of all types, surface watercourses and reservoirs, road connections, energy and product distribution systems, undesirable changes in ground morphology disturbing the original skyline, etc. In underground mining, apart from land required, what is greatly negative is the impacts of undermining that may manifest through ground subsidence, damage to surficial structures and facilities, changes in the ground and surface water regimes including the influence to their chemism, etc. Out of the above stated, monitoring system preparation and continuous remediation of waterlogged subsidence basins are required already in the preparation stage. Moreover, in both cases, attention must be paid to the volume of traffic in the territory which may, in some cases, show as limiting for mining activities. At last, the issue of air pollution caused by dust from traffic, preparation plants, dumps and settling basins as well as the issue of increased noise and concussions connected with blasting cannot be neglected (Hendryx, 2015). It is also vital to assess the possibility and probability of critical situation occurrences, such as fire or shock bumps. Another important aspect of the assessment is the requirement for continuous expert biological monitoring of the locality (assessment of species diversity of the locality, assessment of ecosystem resistance to increasing strain, etc.), operative elimination of mining activity impacts on the ground in order to protect the fauna and flora, and provide replacement plantation in the affected sites.

The procedural environmental impact assessment process may differ in details. Table 3 shows an example of detail arrangement of EIA process in the Czech Republic.

*Tab. 3. EIA Chart, according to CNR Act 244/1992 Coll.*

| Activity | Activity required | Arranged by | Recipient | Deadline |
|---|---|---|---|---|
| **PLAN** | plan prepared | investor | relevant authority | |
| **DOCUMENTATION** | documentation processed | authorized person | | |
| **HANDOVER** | sending of plan and documentation | investor | relevant authority | |
| | documentation sent to the relevant municipality and authorities in question | relevant authority | relevant municipality, authorities in question | 5 days |
| **PUBLIC CONSULTATION** | announcement on possible consultation | relevant municipality | citizens | 5 days |
| | public consultation | citizens | relevant municipality | 30 days |
| **STATEMENT** | written comments and statement | relevant municipality | relevant authority | 14 days |
| | statement to the documentation | authorities in question | relevant authority | 50 days |
| **EXPERT OPINION** | arrangement of expert opinion processing | relevant authority | authorized person | |
| | expert opinion processed | authorized person | relevant authority | 60 days |
| **PUBLIC HEARING** | public hearing | relevant authority | | 30 days |
| | report compiled | relevant authority | | |
| **OPINION** | opinion issued | relevant authority | investor | |

*Note: according to the plan character, the relevant authority is a local authority or the Ministry of the Environment of the CR, the authority in question is a state administration body of the concerned field of activity*

At present, worldwide attention is paid to *environmental impact assessment on the level of development concepts*. This trend is very meaningful as acceptance of a certain concept has direct consequences for the implementation of follow-up projects, in the majority of cases (Krzemeń, 2016).

For example, the concept of industrial policy of wording the basic development trends determines the types of vital raw material sources. The concept of raw material policy anticipates the focus of deposit exploration and extraction of mineral resources, or other methods of their acquisition (e.g. by means of import or through foreign cooperation). The concept of traffic policy may have an impact on the sphere of exploration and mining as the future development of roads requires the provision of necessary sources of building stone and gravel sand.

A part of the assessment of project construction and mining plant operation is also the evaluation of a project of their abandonment and follow-up reclamation of the territory in question (Tab. 4). This part of the assessment is very important as ill-conceived and objectively and financially unsecured projects may lead to consequent complications when the final arrangement of necessary work becomes the concern of public authorities. The existing mining laws or related environmental regulations fully control this sphere and impose the duty to create vital financial resources.

*Tab. 4. Typical plan of mine abandonment.*

| **Activities** | **Years before and after mining activity termination** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | planning of mine closure | | | | | closure | active care | | | | passive care | | termination |
| | -5 | -4 | -3 | -2 | -1 | +1 | +2 | +3 | +4 | +5 | +6 | +7 | +8 |
| **planned mine closure** | | | | | | | | | | | | | |
| plan revision and updating | ■ | ▨ | ▨ | ▨ | | | | | | | | | |
| plan approval by authorities | | | | ■ | | | | | | | | | |
| contract preparation | | | | | ■ | | | | | | | | |
| **underground facilities** | | | | | | | | | | | | | |
| dismantling of built-in equipment | | | | | | ■ | | | | | | | |
| waterworks closure | | | | | | ■ | | | | | | | |
| **superficial facilities** | | | | | | | | | | | | | |
| dismantling of built-in equipment | | | | | | ■ | | | | | | | |
| housebreaking | | | | | | ■ | | | | | | | |
| removal of infrastructure | | | | | | ■ | | | | | | | |
| utilization/dumping of all materials | | | | | | ■ | | | | | | | |
| **water management** | | | | | | | | | | | | | |
| drainage construction if necessary | | | | | | ■ | ■ | ■ | | | | | |
| monitoring of surface discharge | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| monitoring of mine inundation | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | |
| monitoring of mine water outflow | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| construction of settling pit drainage | | | | | | ■ | | | | | | | |
| monitoring of settling pit outflow | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| **remediation of the territory** | | | | | | | | | | | | | |
| ground development | | | | | | ■ | ■ | | | | | | |
| ground preparation for greenery | | | | | | ■ | ■ | | | | | | |
| seeding and planting trees | | | | | | | ■ | ■ | | | | | |
| research in settling pit reclamation | ■ | | | | | | | | | | | | |
| settling pit reclamation tests | | ■ | ■ | ■ | | | | | | | | | |
| settling pit greenery planting | | | | | | | ■ | ■ | ■ | ■ | | | |
| plant cover care | | | | | | | ■ | ■ | ■ | | | | |
| monitoring of plant growth | | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| **socio-economic issues** | | | | | | | | | | | | | |
| identification of alternative investments | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| consultancy for job winning | | | | | ■ | | | | | | | | |
| **termination** | | | | | | | | | | | | | |
| ▪ final report compilation | | | | | | | | | | | | | ■ |
| ▪ public release | | | | | | | | | | | | | ■ |
| ▪ territory vacated | | | | | | | | | | | | | ■ |

From the conceptual point of view, reclamation work can be divided into several successive phases:

- preparatory phase with its predominantly preventive and optimization function; it is grounded in the co-ordination of utilization of a raw material source and dealing with possible conflicts of interest,

- mining-technical phase when attention must be focused on minimization of mining impacts and controlled shaping of the devastated territory, especially through the suitable placement of dumps and disposal sites, the suitable shaping of the ground, etc.,
- biotechnical phase, which, through work of technical and biological character, modifies and improves ecological characteristics of a locality according to a chosen type of land reclamation (agricultural, forestry, orchard-park, water-management, recreational),
- post-reclamation phase initiated with handing over the reclaimed land for further use.

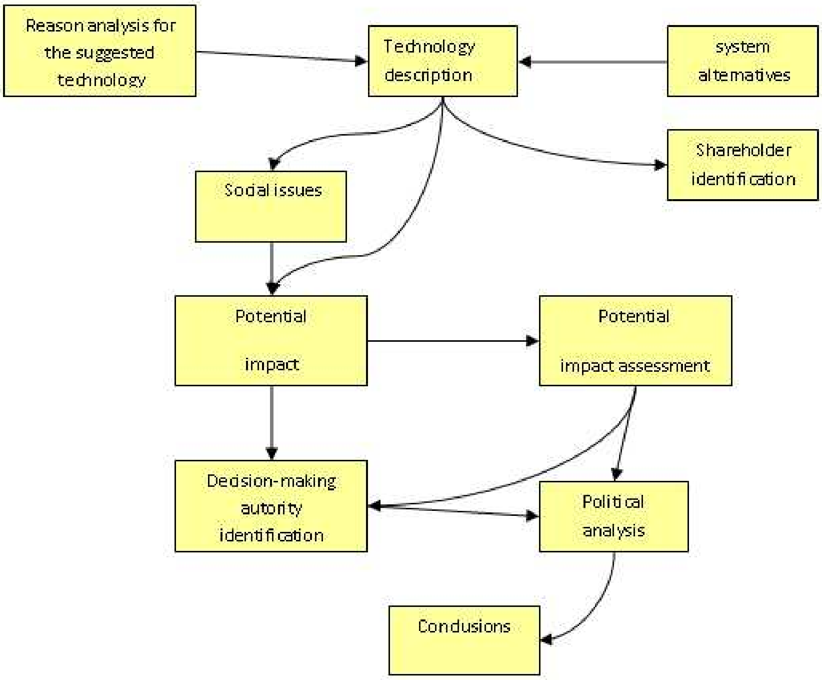

*Fig. 4. Chart of environmental assessment of mining technologies, according to UNEP IE (1997).*

The procedure of *EnTA - Environmental Technology Assessment* – designed by UNEP IE, is well applicable to the environmental assessment of mining technologies (Fig. 4).

### Refuse from mining and preparation

One of the main environmental impacts of mining and coal preparation, in particular, are settling pits for coal slurries. Settling pits cause extensive contamination of soils by toxic metals and organic pollutants, unfavorably influence the rock environment, including the quality of surface and ground water, and embody vast disposal sites of coal slurries (Rybár, 2016; Pavolová et al., 2016). Their combustion then causes air pollution. Air pollution is also brought about by burning of dumps.

## Disposal mining

In terms of possible reliable and relatively effective disposal of certain types of waste materials, underground mining gains another significant function, i.e. waste dumping. Thus, it is labeled as waste disposal mining (Younger, 2004).

### Characteristics of waste disposal mining

In the future, waste disposal mining may significantly contribute to the environmental protection. The beneficiation of waste both from mining as well as from other industrial branches for the mining purposes must be preferred. This is possible in the form of building and filling materials to be used in mining. With an ever increasing need of building materials underground, it is possible to make the use of the material advantages in the sphere of safety, rock mechanics and reinforcing technologies with the long-term safe disposal of industrial refuse underground by this way. In addition, in the long-term, waste disposal containing toxic and radioactive harmful substances may be realized in suitable rock formations below the ground (McEvoy, 2016). Long-term safety is guaranteed by a geological and technical system of multiple barriers. Disposal or dumping may also be carried out with the option of repeated use, or without it, namely inconveniently fitted cavities, chambers, cavern and deep wells.

In underground deposit mining, worked-out space is formed underground, which, for certain reasons, particularly safety ones, is filled spontaneously (surrounding rock caving) or backfilled with other material. In larger scales, the use of backfill is nowadays mainly required by safety and ecological causes. Mining and non-mining waste is used as backfill material. Backfilling the worked-out, or other free space in underground mining of mineral resources offers advantages independent of the economy, both in terms of safety (reaching more efficient ventilation and more favorable climatic conditions) as well as ecology (protection of surficial and landscape structures). Advantages even multiply if waste disposal is possible this way, which would otherwise cause problems in the environmental sphere. This again raises an idea of creating and using underground space for this purpose – to dispose of harmful substances. In mining, the issue of waste disposal is continuously growing in importance, namely in the way the classical backfilling of worked out space is completed with utilization and follow-up dumping of ecologically unsound waste in the existing underground space, or underground space specially established for the purposes. If a waste disposal through backfilling is the basic and only reason of mining, new aspects, tasks, and problems appear there.

### Reasons and preconditions for underground waste disposal

The current situation of waste production, of hazardous waste, in particular, is alarming in the production, social and consumers' spheres of the Czech Republic (Frantál, 2016). This unfavorable situation, mainly in respect to immediate possible changes in own production technologies that would lead to a radical turn in waste management (volume minimization, recycling, secondary utilization, etc.), demands an immediate search for ways how to limit or exclude contact of already generated and continuously formed waste.

The today's economic perspective and economic policies are unfavorable for dealing with waste issues, and the only hopeful process may be a very economical and financially undemanding one in the near future. This logically ensues a possible solution only for some, let's say, simpler and easier problems of waste management (Tausova et al., 2007).

There are sufficiently reliable and verified details, gained through long-term geological-exploratory and mining activities, on the fact that within the Czech Republic there are territories with suitable conditions. It may be an effective solution to a basic problem in the given space and time, i.e. construction of ecologically suitable disposal sites of regular and hazardous waste in appropriate geological, hydrogeological and geotechnical conditions making use of existing capacities or abandoned underground mines. Such operation of underground disposal sites shall be possible on the current worldwide level, as a prospective activity in the mining business. This procedure is characterized by current requirements and expected results in the future:

a) Favorable rock environment is the most effective safety barrier; underground object placement practically excludes an access of unauthorized personnel and action of surficial effects (changes in temperatures, solar radiation, high precipitation, etc.).
b) Conversion of selected mining capacities into long-term disposal site operation, prospectively long-term waste disposal underground sites, value up already expanded and largely written-off investments if main development mine workings, roads, and facilities, energetic, filling and ventilation systems are concerned.
c) Activities in the rock environment are specialized for a narrow circle of workers with formed habits for staying and working underground. Nowadays, mining and underground construction have available suitable technical means and technologies to create new space in the rock mass without excessive disruption of the rocks in the surrounding breaking.
d) Construction and operation of underground storage and disposal sites maintain jobs for specialized professions and skilled workers.
e) The transition from extraction to waste disposal mining is less time demanding than the construction of new premises on the ground. Construction and operation of disposal sites making use of existing capacities do not make demands on land required on the ground, does not require the construction of new power and media supplies, the building of new roads, does not strain the environment by other unfavorable impacts such as noise, dustiness, etc. (Hudeček, 2016).

One of the steps leading to the system, technically well-arranged and safe procedure in design, establishing and operation of underground disposal sites of various types of waste, is the processing of fundamental technical conditions for waste dumping underground, such as standards that must have the following targets:

1. to determine a uniform framework to deal with specific cases and ensure complexness of solutions,
2. to ensure system approach to set up and operate waste disposal sites underground,
3. to create the basis for processing normative documentation of a higher degree,
4. to provide professional and general public with proofs on reliability and safety of the suggested structures and facilities for waste dumping underground,
5. to elaborate and introduce effective tools for environmental protection (audits, assessment methodology, etc.).

### Conceptual approach to dealing with an underground waste disposal issue

Apart others, the approach for the utilization of underground space depends on the fact which space of the mine can be taken into account and what type of waste will be dumped there (Kerdsuwan, 2015). In principle, the extent of utilization includes areas from separate sections of active mines, via abandoned mining plants to new disposal site operations. Naturally, costs increase respectively. As the need for new underground spaces for waste disposal will be high, it is necessary to state several comments on the concept of new spatial formation and the waste disposal technology itself.

Above all, construction of underground waste disposal sites must be implemented by taking into account long-term safety and not the quantity of dumped material.

Therefore, the aspect of optimal geometric parameters of mine workings has a great significance in the disposal process. The solution depends on the considered type of waste disposal area, waste structure, and dumping method. The type of disposal area is determined by the fact whether the disposal site is established for repeated utilization of the waste or without it. Only solid or reinforceable loose materials and slurry waste should be used for dumping. The dumping technology depends on waste processing, namely by pumping, bulking or stacking for unprocessed, modified or packed waste. Currently, for example in Germany, they are at the stage of trial runs or operations of such underground disposal site types: chambers of salt mines, horizontal mine workings, and suitably modified wells.

## A practical example of EIA process for the particular activity of OKD, a.s.

The assessment of mining work with respect to environmental protection is one of the essential conditions for approval of development work and mining work on exclusive deposit by The State Mining Administration. Nowadays, the company OKD in Ostrava-Karvina region deals with the conclusions of documentation on environmental impact assessment (so-called EIA) processed with the intention to continue mining work of OKD, Karvina mine at ČSA plant for the period of 2015 – 2023 (Informační sytém EIA, 2016). This intention is cardinal for solving the present insolvency situation of the mining plant OKD as it concerns the possible extraction of more than 16 million tons of quality, mostly coking coal and almost 74 million cubic meters of methane. EIA conclusions should be properly interpreted based on wider knowledge of assessing mining work with respect to environmental protection, either for the professional and general public. The factual content of the presented article aims to support the theoretical education of both of these groups (professional and non-professional) and show the application of the given theory in the case of EIA done for the intention mentioned above to continue mining work of OKD.

### Forecasting methods and an initial assumption for assessing environmental impact

For processing documentation on environmental impact assessment (EIA) for the intention to continue mining work of OKD, Karvina mine at ČSA plant during 2015 – 2023, standard methods were used.

The methodology used for the hydrogeological survey is therefore based on a hydrogeological study processed using long-term time series of hydrogeological data of EIA processor from the area of interest and its broader surroundings. Moreover, the data from improved monitoring and hydraulic model processed in MOSFLOW program for the area of Stare Mesto near Karvina were used in the given study (Rapantova, 2013).

Recommended methodology was used to process the survey of personnel safety hazards. The correlation Dose – effect was assessed with the help of Authorization manual AN 15a – assessing health hazards of noise (SZÚ, 2007) and also based on recommended values for the noise environment by WHO (WHO: Guidelines for community noise) and the national legislature (NV No. 272/2011 Coll.). In the case of harmful chemical pollutants, assessing the correlation Dose – effect was based on national legislative limits for health protection and also on recommended values by WHO (WHO, 2005 and WHO, 2006) and toxicological values of IRIS database (US EPA, 2013) given for the reference concentration of the case in question. Within assessing the exposure, residential areas of the nearest surroundings of the intention in question were taken into account which resulted in the choice of specific reference points. The exposure was estimated with the help of conservative method as the maximum possible level of harmful pollutants effect. Exposure to physical pollutants is considered exclusively outdoor, exposure with regard to chemical pollutants is evaluated as the outdoor one and input of pollutants into the exposed organism is considered exclusively via inhalation. Health hazards were analyzed based on assessing the average annual concentration of harmful pollutants and maximum short-term modeled emitted concentration of pollutants. The coaction of ČSA plant operations has been taken into account already in the results of immission monitoring. Then, the modeling processed the estimation of the future immission share of pollutants produced as a result of the implementation of other mining works at ČSA plant. Exposure to inhalation was assessed based on maximum conservative estimation. The estimation assumed continuous 24-hour exposure per day, although current epidemiological studies assume a three-hour stay of a person outside in average. This fact overestimates conclusions on the possible environmental impact of the operation to a great extent and corresponds to the principle of precautionary provisions.

The diffusions of pollutants were calculated using SYMOA 97 software, the system of modeling sources of immission diffusion in the air, updated version from 2013 (Idea-Envi, Valašské Meziříčí, 2013). The software is accepted for similar operations as the obligatory methodology of assessing impacts on air quality by the guideline of Department of Environment in the CR. In accordance with the methodology, data of officially published immission factors for traffic impacts according to the Department of Environment CR were used for calculating immission concentrations (MEFA, 2013).

In the noise study, the presented results correspond to the levels of sound pressure of noise affecting a façade of the assessed building, according to the Guideline of Ministry of Health CR of 1.11.2010. The software HLUK (NOISE) + for stationary sources was calibrated on a model where the difference between calculated and measured value was within the interval of (-0,0 ; +1.0) dB compared to the measured value. The calibration of traffic noise was done in August 2013. The difference between the calculated value and the measured value was +0.6 dB towards the measured value. In the given assessment, there is the combination of stationary noise as well as traffic noise (traffic on tertiary roads). So the calculation deviation will probably be within the interval of <-2.0; +2.0> dB. The HLUK+ software, v. 9.19 contains computation algorithm resulting from the amendment to the guideline for calculation traffic noise. Spreading of noise from stationary sources is calculated by the program using a model relying on the sound performance of sources, their location and directionality.

Other uncertainties, used estimations and assumptions are presented in individual chapters. Generally spoken, this means that in professional estimations the least favorable possibility was always chosen. This means that the modeled or estimated environmental impacts in this documentation are more serious that they will actually be in reality, so the calculations are done with respect to safety.

Biological data are determined by general methods of biological surveys and assessment of biota impact.

In the given EIA, the presented work and technological procedures in mining work in OKD underground, Karvina mine, ČSA plant, result from actually operated and approved mining operations at the plant. An important fact in comparison to the past is the end of operations in the coal preparation plant at ČSA plant, and all the mined rock is transported via an underground cross tunnel to the coal preparation plant at Darkov plant. This fact has a positive influence on the noise and imission load which then affects assessing the impact of the intention on public health.

While applying the above-mentioned forecasting methods for processing EIA concerning the intention of continuing mining works of OKD, Karvina mine at ČSA plant during 2015 – 2023, shortcomings in information and uncertainties appeared, as it is usual and normal in every mining work planning, yet this article does not deal with them.

## Description of the measurement procedure, presented results

The assessment of the intention of continuing mining works of OKD, Karvina mine at ČSA plant during 2015 – 2023 by the methods mentioned above implies that the subsidence mainly in the area of Karvina ponds and industrial zone Nove Pole near Karvina will be at its minimum (Fig. 5).

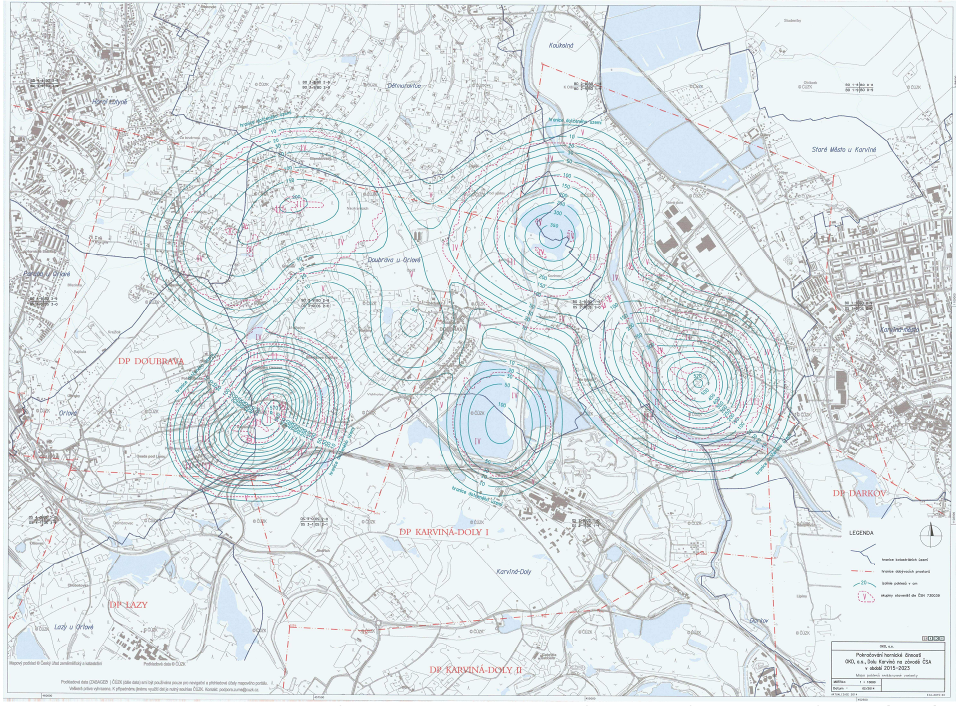

*Fig. 5. Floodable subsidence trough in the area of Stare Mesto in the broader floodplain of Olse river (Informační systém EIA, 2013).*

In coal mining and transportation, as well as in cleaning the environmental impacts of mining, no changes in technological processes related to such operations are expected. Neither are expected substitutions of the existing technology of mining on controlled caving for the filling method. This postulate is based on either technical-economical perspective and also safety perspective when filling the worked-out areas decreases the degree of the protective effect of worked-out seams as a means of vibration prevention. The incurred safety hazards of shock disturbances negatively affect also the surface of a built-up area by possible tremors. Therefore, the seismic monitoring system is being expanded.

The given intention of continuing the mining work does not invoke any key changes in producing sewage, and mine water, air pollution, noise load. Also, no negative effects on public health and employment will appear there. Newly developing mining works in the area of Stare Mesto will, however, cause subsidence which will result in the liquidation of a considerable part of the built-up area and the creation of a new lake supported by ground water. Mining in the area of Kozinec will deepen and expand the already existing lake as a result of the previous mining works.

Moreover, assessing the intention of continuing mining works of OKD, Karvina mine at ČSA plant during 2015 – 2023 implies that this intention of continuing mining works does not provoke any need to determine any special precautions concerning public health, either concerning the noise impact, air pollution resulting from mine ventilation or traffic. There is a positive element of underground transportation from ČSA plant to Darkov plant which decreased the noise and imission load in the surroundings of the former coal preparation plant at ČSA plant and along the surface transport line between the mentioned plants.

Imission concentrations and noise climate will actually not be changed as a result of implementing the given intention of continuing mining works. The number of citizens affected by the noise will reach 45 % in studied areas which roughly corresponds to the present situation.

Surface mining impacts might affect houses of approx. 1350 citizens who will be offered purchase of the houses and real estates.

In the area in question, affecting surface waters by ground waters continues with the quantity and quality approved by the competent water management authority. Sewage water discharge into receiving bodies is not expected.

The key aspect of the proposed mining works from the perspective of landscape changes is the creation of floodable subsidence trough the area of Stare Mesto in the broader floodplain of Olse river (Fig. 5). This basin will eliminate a part of a residential community of Stare Mesto and also a part of floodplain forests and subsidiary vegetation in this floodplain.

The important consequence of the mining intention in question is also the existence of an extensive system of setting tanks area of which exceeded the limit of possible load and will have to be reduced. The reduction means liquidation of recultivation of some tanks and reconstruction of remaining tanks to ensure functions of a sewage disposal plant.

As the intention of continuing mining works of OKD, Karvina mine, ČSA plant during 2015 – 2023 is only defined by general parameters, it will be necessary, in the future, to deal with conflict of interests, namely by more detailed assessment in the next steps of the intention preparation, in correlation with specification of individual aspects of the intention and the related incurred investments.

## Discussion

Natural conditions include geological structure and massif structure, hydrogeological conditions and geomechanical assessment of selected rock positions or the individual rock types with respect to primary massif stress-deformation state and the state brought about by mining activities. Other factors are also important: petrographic composition, stage of diagenesis and physical- mechanical properties of rocks (Dirner, 1998).

### Geological structure of the massif

In terms of geology, goal-directed and careful attention must be paid to the issue of waste dumping – it is the case of basic questions on the massif structure as a whole, structure, and position of specific rock positions (positions of water-bearing horizons and positions of stratification insulants) and tectonic conditions. As for the overall mode of deposition, an important factor is the depth of deposit placement or position where waste disposal site will be situated. The geological environment acts as an effective barrier against the spread of contaminants and isolates such substances from the biosphere.

The effectiveness of the geological environment is given by the ability to prevent the flow of groundwater in the disposal site vicinity and to reduce possible migration to a minimum by this way. The geological structure predetermines the geochemical conditions in the disposal site vicinity and conditions the hydrogeological regime, including the ground water quality. Ground water may contain certain elements, in dependence on the rock petrographic composition, stimulating corrosion of packing materials or support other processes (Švandová, 2016).

For assessment, tectonic conditions are very important as they significantly influence the hydrogeological regime of the rock mass and determine the initial character of primary massif stress-deformation state (Helms, 1988).

### Hydrogeological conditions

The study of hydrogeological conditions is one of the basic preconditions of the underground dumping solution. For example, in the Ostrava-Karviná District in the superincumbent and coal measures, several water-bearing horizons exist that may be within the gas zones ($CH_4$, $CO_2$). In principle, it is the case of a water-bearing subterranean horizon in the Quaternary, two or three water-bearing sandy horizons in the Tertiary containing mineralized confined water, water-bearing horizon of basal clastics on the boundary of the Tertiary and Carboniferous, called the Ostrava-Karviná detritus, manifesting various thicknesses and depths of occurrence, water-bearing zones and crevisse water in the Carboniferous contains mainly mineralized water of various composition and tension.

An operated mine shows water inflows which must constantly be drawn off. Apart from the mentioned sources, process water is also meaningful.

When a mine is in operation, the so-called steady water inflow is formed all the time. Due to permanent changes in workplaces in mine workings, water inflow into a mine may considerably vary especially transferring into other areas. The situation is different when a mine is going to be abandoned.

In the final stage of mine abandonment, with stopped pumping, gradual inundation of the worked space occurs. These are, in particular, cross drifts, roads, spatial mine workings (depot, engine halls, power transformation substations, engine depots, etc.) and old workings. The rate of inundation and water rise depend on the quantity of inflowing water, the volume of the free space in the mine and its horizontal and vertical distribution (Gomo, 2014). Water inflow into a mine can be quite reliably determined from operation documentation. It is more difficult with estimating the volume of inaccessible flooded space. Long mine workings, whose total length reaches several hundred kilometers, are more or less suppressed or caved, old workings in the worked out sections are filled with caved broken rock or backfill. The volume of free space going to be filled with water can be determined only roughly and thus also the estimated course of inundation, in particular a rise in water level, can fluctuate a lot.

### Petrographic composition, physical and mechanical properties of rocks

Both in the enclosing rock as well as coal mass compression strength, mass density and bulk density, porosity, modulus of elasticity, total elastic energy and speed of ultrasonic's spread are identified.

## Conclusion

Deformation and disruption of the rock mass in mining activities depend on the geological structure of the massif, including the structurally geological structure of the massif and petrographic composition of rocks, physical-mechanical properties of rocks, primary stress field given predominantly by a gravitational field and field of primary tectonic stress and finally, secondary induced stress field forming through rearrangement of primary stress due to mining activities. The individual factors form separate units within, but they are also mutually interrelated and influence one another. For instance, primary stress fields are affected by both the geological structure as well as by physical and mechanical properties of rocks.

Mechanical properties of rocks depend on their petrographic structure, age (consolidation), structure and other geological factors. In the end, induced stress fields are also the function of not only distribution of mine workings in time and space, but the geological structure and mechanical properties as well.

Dealing with the issues of deformation and disruption of the massif, it is necessary to build on a detailed geological cognition of the territory in question, physical and mechanical properties of rocks and assessment of primary and secondary stress fields and their changes within the part of the interest of the massif.

The locality must be assessed in terms of geochemistry. It is vital to take into account the issue of geochemical stability of water-air-rock phase interface, i.e. parameters affecting the rate of rock environment weathering, type of secondary transformations, adsorptive capacities, and functions of geochemical barriers. Interactions between the identified rock types, water types and expected waste material must also be considered. An analysis of dissolution of loose and crushed material in an enclosed system is carried out. Then, an identical process in the flow through the system is monitored. The surroundings of the prepared disposal site may be strained thermally. An idea of the reaction of the rock mass on the thermal changes can be obtained from the so-called thermal test. A very important value to assess the stability of the disposal site is a detail on the rock mass stress-deformation state and its changes in time.

The presented article describes, in its first part, the actual approach to assessing the mining work with respect to environmental protection. In the practical part, the text deals with the highly up-to-date problem of documentation on assessing environmental impacts (so-called EIA) related to the intention of continuing mining works of OKD, Karvina mine at ČSA plant during 2015 - 2023.

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