

ENVIRONMENTAL REHABILITATION OF CLOSED MINES. A CASE STUDY ON ROMANIA

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Abstract

The present article attempts to analyze methods that can be used to restore a former coal mining site to a condition that is well integrated into its surroundings and that recovers the abandoned and contaminated land and renders its value to the community. The key concept that guides the present paper is that the coal mining is just a temporary land use and that the cost of cleaning the mining site should be an operating expense that has to be included in the budget of a coal mine company starting with the first year of operation. The coal mining industry in Romania is presented as a case study to emphasize the effects that closed coal mines have on communities where they are located and, based on the methods that are successfully used to solve similar problems, recommendations are formulated to improve the environmental rehabilitation of the mining sites.



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Introduction

The present paper analyzes several methods to rehabilitate areas where former coal mines are located. The main concern that the paper attempts to address is how to rehabilitate these areas in order to give them back an economic use. The environmental rehabilitation is viewed as part of the coal mining redevelopment strategy and it is one of the issues that needs to be addressed in order to sustainably redevelop an area.

Cleaning the mining sites is important for local economy especially for declining mono-structured cities for which coal industry was the major employer. Coal mining and its related activities creates a general perception of severe contamination throughout the area where the industry is located, which discourages private investment in developing the vacant sites. In many cases, mine industry had also a negative impact on the local agriculture, which represents an important source of revenues for many rural communities. The mining activity reduces the quality of the agricultural land due to the contaminants that are released in the water, soil and air. Also, the land that can be used for agricultural activities is significantly reduced. Therefore, cleaning the sites and creating the opportunity for revegetation is an important alternative to the industrial revitalization.

For many communities, economic arguments are the major drivers of the cleaning efforts of former coal mining sites. Even though there may be many investment opportunities in the area, the environmental contamination perception discourages any investment initiative. Therefore, the desire to remove the stigma of contaminated sites drives cities to rehabilitate and redevelop them.

The key concept that guides the present paper is that the coal mining is just a temporary use of land and that the cost of cleaning the mining site should be an operating expense that has to be included in the budget of a coal mine company starting with the first year of operation (Cobârzan 2007). Therefore, the present paper is concerned with cleaning these sites in order to create the opportunity for their future redevelopment.

Coal mining industry in Romania is used as a case study to illustrate the consequences of the industry on the areas where the mines were closed. Then the methods that are used by former Romanian mining companies to rehabilitate the mining sites are analyzed. The result of researching the literature regarding new methods to clean the coal mining sites will be presented. Based on these findings, some recommendations will be formulated regarding how to enhance the rehabilitation efforts of these sites in order to reintegrate them in the economic use.

Background on Romanian coal mining industry

Coal is a major resource that supports the economic development process worldwide. It provides electricity and it is also an essential fuel for different industrial activities (such as steel and cement production, to name a few). According to the World Coal Institute (2006), coal provides over 26% of global primary energy needs and generates 40% of the world's electricity. In the same time, coal mining and other related mining industrial activities impact the ecosystem. Coal mining has a negative impact on the surface and the ground water, soil, local land use, native vegetation,

wildlife population and human health. The nature of the environmental impact will be presented in a later section of the paper, when the methods that can be used to address some of the environmental problems are presented.

According to the Romanian National Institute of Statistics, in 2004, coal industry provided approximately 20% of the total energy needs. 15.3% was locally produced and 6.7% was imported. The national statistics show a steady decline of provision of energy by the coal industry (Hamlin and Cobârzan 2006). For example, the local coal production decreased with 2% from 2003 to 2004, indicating its decline as a source of energy.

The coal mining industry in Romania always raised economical, environmental and social issues. These issues became serious problems only after the fall of the communism regime in 1989. In 1997, as a response to the massive subsidies given to the coal industry, Romanian government decided to increase the efficiency of the sector by reducing government's direct intervention, to seek investment sources in the private sector and to adapt the mining industry to commercial operations.

The current situation of the coal industry is a legacy of the policies adopted by the communism regime, in order to subsidize the activity of this industrial sector. In the 1970s, as a response to the oil crisis, when Iran decided to stop the shipment of crude oil to Romania (among other countries), the former Romanian dictator decided to increase the coal production of energy in order to compensate for the reduced role of oil and natural gas in energy production (Hamlin and Cobârzan 2006). In this context, the former Romanian dictator launched a program to expand the production of coal by opening 35 new open-pits and underground mines. The coal from new mines turned out to be of poor quality and had a lower caloric content, and it was not enough to cover all the needs of all industrial activities. Therefore, large quantities of coking coal had to be imported from the Soviet Union.

The bottom line issue explaining the poor policies regarding coal industry during communism regime is, on our opinion, the fact that the quality of the coal deposits was not taken into consideration. Today, even though Romania has important reserves of coal that can ensure production for about 70 years (World Energy Council), coal deposits are of low quality. According to the World Energy Council these deposits are formed by hard coal, brown coal and lignite. The total coal reserves of Romania amount to approximately 1.0 Gt of hard coal and 3 Gt of brown coal and lignite. More than 80% of Romanian lignite reserves can be mined profitably in open casts, while the remaining 20% require underground mining. Lignite has only 1600-1800 kcal/kg, hard coal contains about 3000-4000 kcal/kg. The average humidity varies from 42% in lignite to 10% for pit coal.

Production of coal decreased after 1989, mainly due to the restructuring policy undertaken by the Romanian government (Fig. 1 - Data that are plotted come from the Ministry of Economy and Commerce, Proposal for restructuring strategy of the mining sector, 2006). The primary goal of this policy was to close down the inefficient mining sites. Fig. 1 shows the two major periods of decline in the coal production: 1990, first year after the fall of the communism regime, and 1997, the year when the decision to close the unprofitable mines was taken.

After 1997, the number of coal mines that were closed increased rapidly. In 1998, Romanian government received a grant from the World Bank to close 29 mines. Other 60 coal mines were closed with funds from the Romanian government. International Bank for Reconstruction and Development (IBRD) currently finances the closure of 40 mines. The outcome of this process is that large surfaces of land and many buildings are and will become abandoned. For example, the mines closed using funds from IBRD cover approximately 21,113 acres of abandoned land.

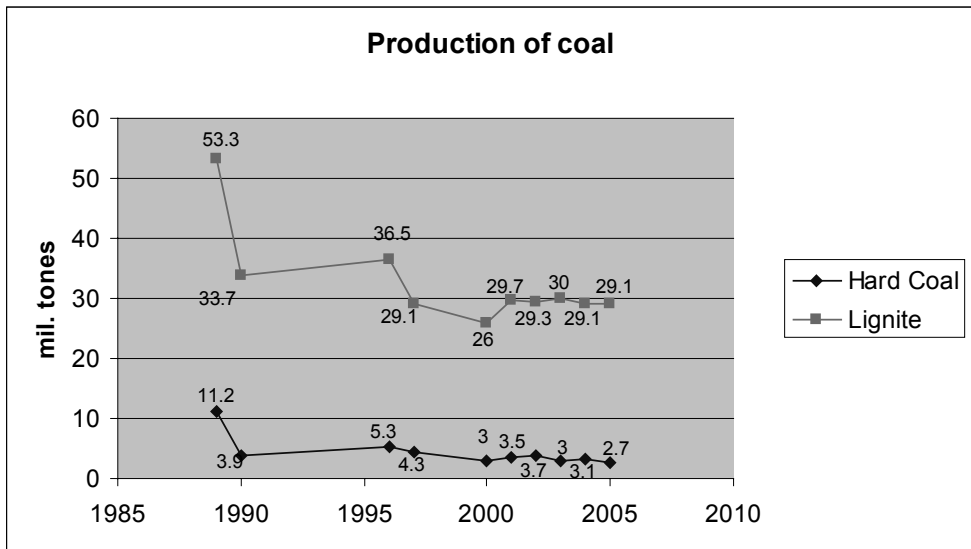


Fig. 1 Production of coal; Source: Ministry of Economy and Commerce

Closure of the coal mines had a negative impact on the areas where they are located. The socio-economic structures of these areas were severely affected and the degradation of the environment made these communities unattractive for future redevelopments. Even though some former mining sites were environmentally rehabilitated, contamination of many other areas still remained a major problem that contributed to the further decay of the communities where they are located.

The level of contamination of these areas was high because of the policies adopted by the mining companies, especially during the communist regime. Over time, Romanian mining companies reported a high level of compliance with the emission standards set by the governments at those times, but a comparative analysis of these standards indicates that the emission limits differed among companies. In many cases, the standards were set according to what a mine could achieve, rather than recognizing a more uniform standard to which mines should had endeavored to reach. Even more, the environmental protection was a low priority for mining companies because they were primarily concerned to minimizing their operating costs, and not to make investments in environment protection (Report on Institutional Requirements for Environmental Management and Environmental Enforcement in Romania 2002). Therefore, the level of contamination was high at the moment when mines were

closed and this is the reason they currently need a thorough rehabilitation before they can represent an asset for the communities. The following section of the paper will analyze what are the methods that are used by the Romanian coal companies to rehabilitate the closed and abandoned mining sites.

Methods used by the Romanian mining companies to rehabilitate the mining sites

A major environmental problem that was addressed when coal mines were closed was the pollution of ground and underground water. Most of the coal was extracted in the open cast pits and the precipitation water accumulated on the bottom of these sites. In many cases, the water was contaminated with particulates and posed the threat to get into the underground water. The approach to this problem was either to preserve the pond or to fill it with soil. If the pond did not pose a risk for people, animals or environment and the level of exposure was reduced, the accumulation ponds were preserved, but the access to them was restricted. In other cases, filling the pond was part of the strategy to level the terraces created through the coal extraction process. Other measures were taken to clean the contaminated underground water. The approach was to collect the underground water, treat it for metal particulates and then discharge it into local rivers.

Terraces created by the extraction of lignite had a high angle of slope, which made difficult the use of the land. Therefore, an important focus was paid to reduce the angle of the slope and to level the ground. The vegetation (trees, shrubs and grass) was planted to stabilize the surface ground.

Rehabilitation strategies also attempted to address the problem of contaminated soil and abandoned facilities. The solution was to excavate the contaminated soil and store it on a part of the site. The excavated ground was replaced with coarse cohesionless material. The highly contaminated sectors were covered with a drain and seal to prevent the access of the water and the migration of contaminants into the underground water.

Even though the coal companies had a complex approach in rehabilitating the mining sites, the lack of financial resources limited the number of sites that were cleaned and the level of rehabilitation that they could achieve. Pollution of water is still a problem, mainly because of the lack of a watershed approach of the water resources and the concentration on treating point sources of pollution. Environmental protection was not a concern for Romanian coal companies for many years and in some areas the level of contamination of soil and sediments is still high and needs a special attention and concentrated efforts to solve the problem. Another problem is the revitalization of soil, which is very slow and new methods need to be found to increase the rate of growth for planted vegetation.

Methods to rehabilitate coal mining sites

The following part of the paper presents the findings of the literature review conducted to identify methods that are successfully used around the world or that are under research to rehabilitate the mining sites. First, the environmental problems will be introduced and then the methods to address these problems will be presented.

We do acknowledge that the research that was conducted is not exhaustive and there are several topics that are under analysis of the specialists and are not addressed in the present paper. For example, two of these topics are the absorption method and the microbial community structure of the coal mines. More recently, the researchers focused their analysis on the microbial community structure of coal mines and their relation with the rehabilitation of coal mines (Claassens et al. 2006). Another direction of the researches is concentrated on analyzing the adsorption method (such as using chitosan micro spheres) to remove metal-ion from aquatic environments (Benassi et al. 2006).

Water pollution

a. The impact of mining on water

Open cast and underground mining affect water resources, by discharging huge amounts of mine water. When the mine water contains pyrite (FeS_2) in the range of 1–5% water becomes acidic. Even decades after the mines are closed, the acidic mine drainage frequently flows from open-pit mines, deep mines, and tailings piles. The acidic water mobilizes toxic heavy metals (including lead, copper, cadmium, and aluminum) and carries them downstream. Depending upon the concentration, the acidity and the metals are toxic to fish and other stream organisms. Another negative effect of acid mine drainage is that it degrades the water quality of the region in terms of lowering the pH of the surrounding water resources. High values of hardness of mine water reduce its utility for domestic purposes (such as drinking or bathing). Mine water makes surface water blackish and reduces aesthetic values of receiving water bodies.

b. Methods to clean contaminated water

One technique that is used for treating acid mine drainage is sulfate-reducing bioreactor (Tenenbaum 2004). In this bioreactor, specialized bacteria reduces sulfate ions (a typical component of many acidic mine drainages) into sulfide ions. Then, the sulfide ions combine with the dissolved heavy metals, forming metal sulfides, which precipitate and are retained in the wetland's organic mass.

This method consists in collecting acidic mine drainage in an artificial pond of up to an acre in size that is seeded with animal manure (which contains the necessary bacteria) and cellulose-rich waste materials such as wood chips and sawdust (for the bacteria to feed on). These bacteria need the sulfate in mine water as a nutrient. Compared to a conventional treatment system, the sulfate-reducing bioreactor has often a lower cost, more pleasant aesthetic, and a reduced need to monitor. Therefore, constructed wetlands are the dominant technology to clean the mine drainage or metal-contaminated waters.

Another method to remove TSS from mine water and workshop effluent is to allow the discharged water to move slowly through a series of settling tanks (Tenenbaum 2004). To check runoff water from over burned dumps, garland drainage should be constructed around the spoil heaps. Proper coagulant may be added to get settled the coarse materials in the garland drainage itself.

Soil pollution

a. The impact of coal mining on soil

Old spoil heaps represent the most notable form of abandonment associated with surface coal mining. They are difficult to rehabilitate and the coarse discard of which they are formed consists of various materials that contribute to the degradation of the quality of the soil. It is a combination of rocks that were extracted during mining operation and various amounts of coal that has not been separated by the preparation process. The shape, aspect and height of a spoil heap affect the intensity of exposure, the amount of surface erosion that occurs, the moisture content in its surface layers and its stability. Fresh spoils from the deeper coal mines sometimes contain sodium, calcium, magnesium, barium and strontium chlorides that hinder the growth of vegetation (Bell and Genske 2000).

b. Methods to support the restoration

Surface treatments of spoil heaps vary accordingly to the chemical and physical nature of the spoil and the chemical conditions. Usually, the restoration of spoil heaps involves the movement of large amounts of soil to create stable surface for vegetation to grow. The restoration also involves the treatment of spoil heaps that are burning and that do not allow leveling the soil. One approach (Bell and Genske 2000) to deal with this problem is, in the case the material had been lowered to its finished level, to cover it with clay and compact it on top of the hot spot and then to spray a layer of shale and spread and compact it over the clay. Boreholes should be sunk into these hot spots to determine whether they were cooling. If the temperature had not dropped within a year, then fuel ash is injected which extend down to original ground level. Drainage plays an important part in the restoration of spoil heaps, by collecting mine water and acid mine drainage in open ditch and cleaning the contaminated water.

If the soil is acidic, then it is important to neutralize it in order to limit the contaminant release from the dumping site. Several methods are used to neutralize the acidic spoil heaps. The most common is to mix the soil with lime by adding 7.5 tones of lime per hectare. More recently, some authors (Maree et al. 2004a, Maree et al. 2004b) recommended using limestone (CaCO_3) as an additive. The tests that they conducted showed that process control is simplified, the material waste through dosage is minimized, the limestone is non-hazardous, easy to store and readily available. Other additives that can reduce acid mine drainage are NaOH, fly ash and blast furnace slag rich in Al_2O_3 , SiO_2 , CaO and MgO (Tiwarky 2001).

After the spoil heaps are leveled and the acidity of the soil is reduced, a cover of soil is applied and fertilizers added. In some cases, the soil is obtained from another part of the land that was not contaminated. Different types of fertilizers are used to increase the growth rates of vegetation. Some authors (Mercuri, Duggin and Grant 2004) propose the use of saline mine water to increase the initial survival and maintain early growth. The same authors tested that the tree growth was significantly higher in green waste compost and biosolids. Also, the use of coarse coal washery reject

(chitter) as a top dressing material has resulted in successful establishment rates of trees and shrub (Charnock and Grant 2005).

The final stage of the rehabilitation process is the revegetation of the spoil heaps by planting a mixture of trees, shrubs and grasses to improve the site productivity. A series of researches were conducted to identify the most efficient plants that should be used to rehabilitate the soil and several species were proposed for different regions around the globe (Singh and Singh 2006, Banejee et al. 2004). Regardless of species that are selected, a series of criteria are recommended to be fulfilled. They should contribute to land stabilization, animal browsing and nitrogen fixation, while they are easily available.

Another method to rehabilitate the sites can involve excavation of contaminated areas. The ground that is excavated is replaced by soil, which would allow the construction of industrial and residential buildings. Usually the contaminated soil is stored within a sector of the site that was identified as highly contaminated, whereas the less contaminated material is distributed over the remaining sectors. The highly contaminated sector usually is covered with a drain and seal system, consisting of geosynthetics and clay cover to avoid the contact with the contaminated soil and to prevent the leaching of the water through the contaminated ground which would cause migration of contaminants into the saturated zone beneath the water table (Bell and Genske 2000). Monitoring the level of contamination of the water under the contaminated site is important. Therefore, a number of observation wells should be installed and the water should be continuously sampled. If an increase in value is detected, then some observation wells will be used to extract and clean the contaminated ground water (Bell and Genske 2000).

Recommendations

A sustainable redevelopment of the former coal mining sites in Romania requires to recycle degraded land and to recover it as a land resource. Many of these sites are contaminated and the ground is severely disturbed by massive old constructions, spoils heaps or terraces. Restoring the sites to a condition that is well integrated into its surroundings upgrades the character of the environment and creates the opportunity for economic redevelopment.

Based on the literature research, some recommendations can be formulated to improve the rehabilitation of the coal mines in Romania. One approach is to diversify the methods that are used to treat the acid mine drainage either by creating sulfate-reducing bioreactor ponds and wetlands, or by adding additives to reduce the pH of the mine wastes. Another focus should be on improving the quality of the land that covers the coal mining wastes, by diversifying the range of fertilizers. A symbiosis approach can develop by using the waste from other activities as a fertilizer of the soil. One example shows the relations that can be established with a water treatment power plant to use the municipal waste water as a fertilizer. This approach would meet the European Union requirements to recycle a major part of the waste locally.

One of the newest approaches to deal with coal mining waste reflects best the basic concept that coal mining is just a temporary land use. In India, the need to reduce

the time to recover the land of former coal mines led to the construction of a model that calculates the optimum quantity of coal waste that can be deposited on land and which does not pose an environmental and human health risk (Mukhopadhyay and Sinha 2006). This approach assumes a continue effort to rehabilitate small parcels of the mining area and to give it back to an economic use.

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