The French experience of post mining management

Christophe Didier, Jacques Leloup

THE FRENCH EXPERIENCE OF POST MINING MANAGEMENT

DIDIER Christophe[1], LELOUP Jacques[2]

[1] *INERIS – Ground and Underground Division - Parc Technologique Alata BP n°2 – 60550 Verneuil en Halatte – France. Christophe.Didier@ineris.fr*

[2] *Ministry in charge of Economy, Finance and Idustry – 5 Place des Vins de France, Bâtiment ATRIUM – 75573 Paris Cedex 12 - France. Jacques.Leloup@industrie.gouv.fr*

ABSTRACT

During the period, which follows mining exploitation, traditionally called "post-mining", many disorders may develop, sometimes just after mine closure but sometimes quite long time later. In addition to potential instability development (subsidence, collapses), some abandoned mining sites can be affected by severe hydrogeological disturbances (floods), dangerous mine gas emissions on surface or environmental degradation.
The paper presents the French mining historical context that leads to the present situation, integrating a brief description of the major mining field having been exploited in France (coal, iron, salt, gypsum…). It identifies, describes and illustrates the major kinds of residual risks and harmful effects that affect the abandoned French mine sites.

The national systematic prevention policy adopted in France is then discussed. The objective is, as a matter of fact, to “invest” in research, diagnosis and land use management in order to prevent future accidents and social crisis our country had to face during the last 5 years. Thus, the “Mining Works Closure application” dedicated to the mining operators as well as the “Mining Prevention Plans procedure” and the “Mining Sites Screening process”, both dedicated to the State are presented. Some of the major tools used to assure the post mining risks management are also discussed: continuous real-time monitoring, damages compensation and preventive evacuation.

Finally, a short description of the national “post-mining risk management organisation” is presented in order to explain the co-ordination between public services or establishments involved in the risk management process.

1 INTRODUCTION

During several centuries, French mining activity contributed for a large part to the national industrial development. During the last few decades, under the combined effect of the resources exhaustion and international competition, the very large majority of French mining sites gradually closed down.

Formerly symbol of pride and solidarity, mining activity is now frequently associated with post-mining disorders and harmful effects. As a matter of fact, the mine closure do not result in cancelling completely and definitively the risks for people, activities and goods located in the influence of abandoned exploitations.

Thus, during the period which follows exploitation, traditionally called "post-mining", many disorders may develop, sometimes just after mine closure but sometimes quite long time later. In addition to potential instability development (subsidence, collapses), some abandoned mining sites can be affected by severe hydrogeological disturbances (floods), dangerous mine gas emissions on surface or environmental degradation (ground or water pollution).

The paper presents briefly the French mining historical context that leads to the present situation. It then identifies and describes the major kinds of residual risks and harmful effects that may affect the abandoned French mine sites. The national prevention policy is then discussed, explaining the French mining legal scope recent evolutions as well as the major prevention programs that are developed on the national territory. Finally, a short description of the post-mining risk management organisation is proposed to explain the coordination between public services or establishments involved in the risk management process.

2 FRENCH MINING HISTORICAL CONTEXT.

Like many other European countries, France has a long mining tradition. The extraction and valorization of raw materials located in its basement contributed, in a decisive way, to the French industrial power development.

On the French territory, the first signs of underground extraction of mineral resources (old flint mines, salt springs) may be roughly dated of the Neolithic era (5^{th} to 3^{rd} mill. B.C.). Before the Roman occupation, Celts and then Gallics regularly exploited gold and tin (1^{st} millennium B.C.). It is however during the Gallo-Roman period that the mining activity really develops with the beginning of silver, lead, copper and iron exploitation.

The mining activity then took the form of a multitude of local small-scale mining sites, distributed throughout the whole country (1^{st} and 2^{nd} centuries). After the fall of the Roman Empire, mining exploration and extraction strongly decreased during nearly one millennium. Under the influence of Central Europe developments and in order to satisfy the increasing economic needs resulting from demographic rise and political stabilization, prospecting and mining activities became again national priorities (XI^{th} – XII^{th} centuries). During this period, coal started to be exploited in the Hérault and Provence basins (SE of France) as well as in the Saar area (NE of France). It is however the industrial revolution (17^{th} – 18^{th} centuries) which has initiated the decisive impulse in the development of the French mining activity.

Technological progresses contributed to transform an activity, which up to that period was mainly small-scale, into an industrial production activity. In addition to the constitution of major mining fields (coal, iron, salt...), which contributed largely to the richness of the national economy, the beginning of the 19^{th} century was also characterized by an important diversification of exploited materials (oil, manganese, fluorite, zinc...). In spite of an overall unfavorable context (priority accorded to the colonial development, economic crisis of 1929), the mining activity continued to develop during first half of the 20^{th} century, mainly under the impact of the two World Wars.

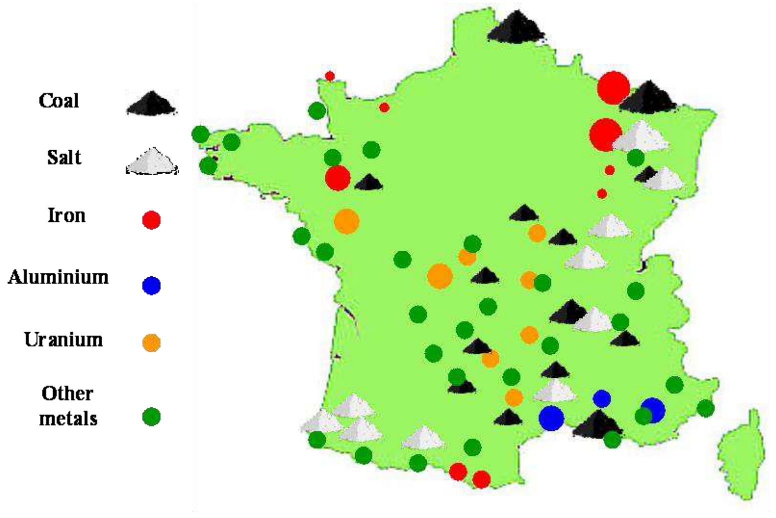

Figure 1. Major mining fields having been exploited in France.

After the Second World War, the national effort made for the rebuilding of the country and the reduction in the energy dependence of France facilitated the continuation of the rebuilding of the mining activity. The production of coal and lignite increased thus quickly to reach 60 million tons in 1958. During this period, important efforts of oil exploration were also made and the first uranium large fields began to be exploited. The development of the geochemical techniques and geophysics and the important progresses carried out in the field of prospecting enabled the discovery of several important sites exploited successfully by French mining companies.

The significant decrease of the rates in constant currency and/or the exhaustion of some major fields gradually generated the decline of the French mining activity. Initiated at the beginning of the years 1960 for coal and iron and at the beginning of the years 1980 for the exploitation of the other substances, this decline accelerated since the beginning of the years 1990. The closing of the last iron mine occurred in 1995 and the ultimate exploitation of uranium shut down in 2001. The exploitation of potash stopped in 2003 and the last extraction of coal panel closed down in 2004. From now on, the only active mining industry in Metropolitan France results from the extraction of salt, by underground or by solution mining.

France has thus now to face the "post-mining" management, much more than the management of the active mining. This new situation and the induced problems led the French State to take decisions and develop tools and competencies in order to manage properly the post-mining period. This heritage, even sometimes difficult to assume for the new generations confronted to serious harmful effects, results of a past period which strongly contributed to develop the French industrial power.

The priority of France is now to optimize the redevelopment of the areas directly affected by the progressive closure of mining activities, which were sources of employment and richness for local inhabitants. This step implies a very careful analysis in terms of surface occupation management and regional planning. It is important to identify and locate as precisely as possible the potential risks and/or harmful effects that may develop and affect people, goods and activities after the end of the mining extraction.

As soon as this diagnosis has been performed, it becomes possible to post the risk and take the technical measures adapted to each context, allowing the development of new activities in the safest and most adapted zones.

3 POTENTIAL RISKS AND HARMFUL EFFECTS DURING POST-MINING PERIOD

In spite of the mine closure, several kinds of risks and/or harmful effects may persist at long term. The closure of old mining sites does not automatically induce the definitive elimination of the risks resulting from extraction. Even no longer exploited, these abandoned sites may indeed generate consequences that may affect people and goods located under the influence of mining works and to disturb occupation or economic development on surface within the surroundings.

Taking into account the very large extent of the underground mining works that developed in large mining areas, it is usually impossible to get back to the initial state. For example, one estimates that, within the only Lorraine iron basin (NE of France), nearly 40 000 km of mine galleries have been drilled underground (either a length equivalent to the perimeter of the globe!). Under such conditions, mining extraction induces an irreversible disturbance of the rock mass behavior.

The persistence of long-term effects is thus generally impossible to avoid. This is partly due to the fact that old mining activities did not aim to avoid possible long-term harmful effects with respect to the environment. The first objective was to optimize the ore extraction with acceptable conditions of safety for minors underground. The question of long-term works behavior, which represents one of the major concerns today, did not constitute the priority of the former mining operators. This is also due to the lack of back-analysis available at that time concerning the long-term behavior of underground works.

The impacts induced by an abandoned mine can be of several kinds. They can result in potentially harmful surface or underground water flow modifications as well as surface instability developments capable of affecting, sometimes dangerously, people or good located in the surroundings. They can also consist in potentially dangerous or toxic gas emission or result from discharge of potentially dangerous chemical substances in the environment (rivers, soil, air…).

Below, it is given a short description of the main risks and harmful effects encountered in different French abandoned mine fields.

3.1 Floodings or disturbance of rivers' flow.

With mine closure, the dewatering system designed for extraction usually stops. This induces the submergence of abandoned mining works and the increase of the water table. At the end of the water table rising, a natural drainage of old mining works is established, generally by the topographically lowest adits emerging on surface. Abandoned works, even when they have been backfilled, generally constitute a much more permeable medium than the surrounding rock mass. They thus form a local hydraulic perturbation inducing that, in the surroundings of the abandoned mine, the water table never reaches perfectly its initial position (existing before mining extraction).

The sustainable disturbance of the underground characteristics of the perturbation due to the mining works impacts several factors:

- **Increase of the underground water stock** by creation of a mining tank. This tank can constitute a water resource if the quality is good enough but it can also constitute a harmful effect, or even a potential danger, in case the topographic situation can induce an overflow on surface, or, more dangerous, lets fear a violent draining.
- **Modification of underground water flow** by increase in the permeability and creation of preferential flow paths. This modification may sometimes affect areas located at large distance of mining works. It is thus not rare that pumping of supply drinking water is affected, up to several kilometers away from an abandoned mining site.
- **Modification of surface flow** due, partly, to the durable disturbance of the surface medium (subsidence due to mining works, deposit of waste materials on surface…). Some marshes or humid zones may therefore develop in sensitive areas. The river flow can also be affected by the new flow chart. The potential consequences of those surface flow modifications may be severe. Particularly when, taking benefit of the lowering of the water table during dewatering period, some significant zones have developed in previously "wet areas" during this artificial "dry period".

Figure 2. Discharge through an adit (left) and development of a wet zone close to an other adit (right).

All those possible effects justify easily the very careful attention that has to be paid to the possible consequences that the water table rising is able to induce on the goods and activities located on surface in the surroundings of the abandoned exploitation.

The main harmful phenomena having to be considered are very briefly described below:

- Modification of the outlet flow (modification of outlet flow, appearance of new artificial or natural outlet or reactivation of old ones).
- Appearance of humid zones or marshes (insufficient capacity of drainage of the surface).
- Flood of basements (equilibrium of the water table level close to the surface, possibility of impacting the underground structures like car parks or cellars…).
- Modification of the river flows (can generate an increase of the certain rivers' flow or a decrease of others rivers' flow, in particular during low water periods).
- Sudden and violent floods (sudden emission of very strong water or mud flows through, generally, an adit in connection with the mining tank).

3.2 Surface instabilities

Mining exploitation consisted usually in extracting a great amount of rocks in order to collect the ore, only valuable part of the excavated materials. The artificial excavations, dug underground or open pit, modified in an irreversible way the rock mass equilibrium.

Concerning **underground mining works**, which represent the majority of French mining activities, the mining method used depended mainly on the geological context and technologies available at the period of extraction. Considering post mining residual risks analysis, it is often suggested to classify mining methods in two great types: methods ensuring an integral treatment of the voids after extraction and those allowing the persistence of important residual voids after closure. For the first group (longwall, backfilling...), it is mainly the evolution of the overburden affected by caving which can be harmful. After abandonment, surface instabilities are thus generally restricted thanks to a low level of subsidence. For the exploitations allowing the persistence of important residual voids (room and abandonned pillar, dissolution cavities...), the stability of old mining works may be affected by a reduction in time of rock characteristics or potential environmental modifications (flooding of mining works for example). In addition to the possible occurrence of subsidence, this family of mining methods can also generate collapses on surface (sinkholes, massive collapses).

Figure 3. Effect of severe subsidence in Lorraine iron field (left) and major collapse of a chalk mine (right).

Concerning **open pit works**, the extraction consisted in creating pits within which the ore was located. The choice of the mining method resulted from an optimization between economical profit (to limit the volume of rock to remove) and the stability of the mining works (to avoid too sloping cliffs). The rock faces often generate, at long term, ground instabilities which can take the form of rockfalls of very different volumes. The combination of rock type and design of rock faces determines the volume of the potentially unstable rock masses.

The mining exploitation often generates the constitution of big **waste disposal** on surface in the vicinity of extraction sites. Some of them are set up in dry conditions and constitute waste dumps. Others, concerning ore treatment residues are stored within lagoons confined by retention dams. Failures of mine deposits generally result from unfavorable evolution of one or more factors controlling the mechanical behavior of the waste. The main risk is the occurrence of major surface instabilities.

The main harmful phenomena to be considered are briefly described below:

- Settlements (minor "recompaction" of a rock mass affected by the mining extraction process: goaf, waste disposal constitution).
- Progressive subsidence (smooth and progressive readjustment of surface. This phenomenon may affect houses integrity but is very rarely dangerous).
- Sinkholes (sudden appearance of a crater on surface. Potentially dangerous phenomenon)
- Rock slides or mud flows (disorders that may affect waste disposals).
- Rockfalls (in open pits dug in hard rock with strongly inclined rock faces).

3.3 Mine gas emission on surface

The extraction of large quantities of rock underground contributes to form a mining tank filled with mine gas. This gas consists of a mixture of several components with variable contents. Under the effect of various mechanisms (watertable rising, pressure differential...) mine gas may run out through natural openings (faults, cracks...) or artificial ones (shafts, adits...). If the mining atmosphere presents a dangerous constitution, safety on surface can be affected while mine gas is trapped in non-ventilated vacuums (cellars…).

The major hazards are : ignition or explosion (methane), intoxication (CO, CO_2, H_2S...), suffocation (lack of oxygen) or irradiation (radon).

3.4 Ground and water pollution, emission of ionizing radiations

Modifications and disturbances induced by mining works may induce, in a more or less significant way, deterioration of parameters governing the environmental quality within the mine surroundings. This degradation affects mainly underground or surface water as well as soil. They can also affect the atmosphere, particularly in case of ionizing radiation or toxic particles emission.

Environmental impacts result from complex physico-chemical phenomena related to the chemical composition of the extracted rocks as well as the mining method (underground or open pit, presence of waste dumps and/or treatment plant...). One of the major difficulties of mining environmental analysis consists in considering as objectively as possible the "share due part" that may be affected to the exploitation and the one that concerns the natural geochemical level prior to the exploitation.

To evaluate the importance of environmental risks and harmful effects, one generally analyses in terms of sources (nature, toxicity and capacity of pollution emission), vectors (water, grounds, air) and "targets" in contact with this pollution (human activities, ecosystem and their vulnerability with respect to a potential pollution...).

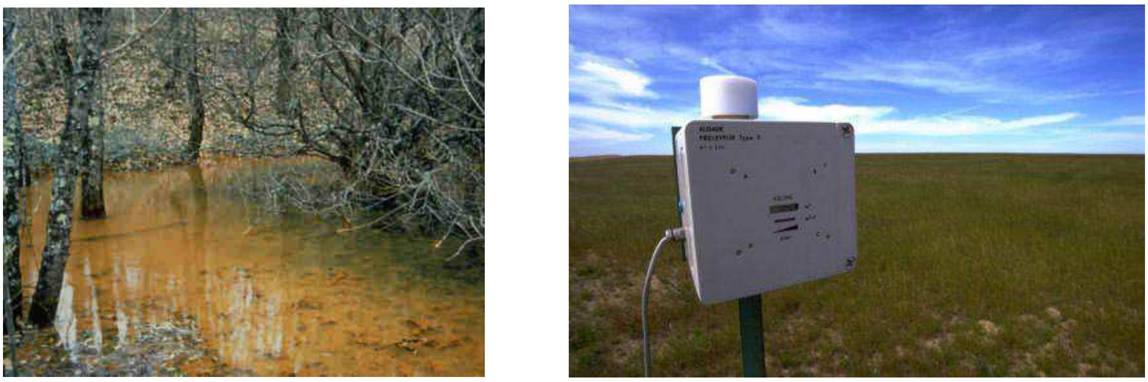

Figure 4. Effect on surface water of an abandoned coal mine discharge (left) and monitoring of ionizing emission above restored tailings (right).

4 POST MINING MANAGEMENT POLICY IN FRANCE

4.1 French mining legal scope and its recent evolution

In France, the difference between mines and “quarries” is made according to the type of extracted material. Under French Law, the exploitation of materials defined as "eligible for concession" is ruled by the regulations on mines, and the exploitation of materials defined as "non-eligible for concession" is ruled by the regulations on quarries. The materials "eligible for concession" include mineral substances which were considered, in 1810, as strategic and of prime importance for national sovereignty. These substances are mainly hydrocarbons (oil, gas, coal), salt, potash and metals. On the contrary, quarries are mainly used to extract building material (limestone, chalk, gypsum, slate, etc.).

In France, land owners have no right over the underground minerals or substances eligible for concession. Indeed, mines are subject to the "concession" rule. "Concession" refers to the contract, signed between the French State and a legal person or corporate body, authorising the exploitation of the substance subject to the contract against a fee. The word "concession" is also used to define the area granted to this person or body to perform his or its activity. Therefore, the concession is the administrative entity of reference in Mining Law.

The French mining legal scope stipulates that when the mining activity ceases (concession revocation or waiver), the exploited area returns to the “concessible” domain. If the former operator has disappeared or is failing, the State guarantees possible problems which could result from old works.

To face the post-mining problems, French State decided to apply a systematic prevention policy in order to identify potential harmful effects before they occur and thus to be able to prevent future accidents and social crisis. This policy represents a kind of “bet”, considering that the large amount of money invested in the prevention step will be cost-effective at the long term by reducing drastically victims and damages compensating costs.

To apply this ambitious policy, the French mining legal scope was considerably reinforced during the last decade. Several major acts have thus been voted by French Parliament related to the post-mining. Among them, one notes :

- a decree published in 1995 [1], precising the statutory and technical conditions within which an Concession-Holder may abandon a mining exploitation: the “Mining Works Closure Procedure”;
- the “post-mining law”, voted in 1999 [2] and accompanied with several decrees introducing, in particular, notions of
  - “Mining Risks prevention Plans”,
  - monitoring of post-mining risks,
  - damage compensation and preventive evacuation of people subjected to major risks.

These major elements are explained in the following paragraphs.

4.2 The “Mining Works Closure Procedure”

Over the last few years, the growing awareness of safety and environmental issues, as well as the knowledge gained thanks to the latest mine closures, led the French Government to strengthen the legal procedures pertaining to the closure of mining works. The French Government notably decided to integrate the notion of mine works rehabilitation in the mining laws and regulations in order to secure these sites and limit their impact on the environment.

In accordance with the French Mining Code, modified by an Act in 1994, the Concession-Holder must, from now on, notify the administration of the steps it plans to implement in order to prevent hazards associated with subsidence or collapse, ensure an efficient closure of the former works’ entries, and guarantee that the surface works and facilities do not jeopardise public safety and health or the main characteristics of the environmental surroundings.

The Concession-Holder must transmit a “mining works closure application” to the Préfet (French regional administrative authority) at least six months before the definitive closure of all or part of the mining works. The 1995 decree precisely defines the content of this application. The Concession-Holder, after a general presentation of the sites concerned by the closure application from the geological, hydrogeological and operational standpoints, must establish a list (in terms of quality and quantity) of the consequences that the underground works have already induced on the environment. It must then endeavour to assess the long-term consequences of the definitive closure of the works. Finally, he must define the possible counter-measures which he considers most appropriate and which could guarantee a hazard level in compliance with the surface occupation.

The application must be examined by the various involved administrative services and local councils. Therefore, the document must be sufficiently detailed and precise so that experts can give their opinion on the quality of the performed studies and relevance of the suggested counter-measures. However, it must also be understandable by non-specialists (mayors, members of associations, etc.).

Once he has acknowledged the application, the Préfet can either validate the technical proposals or prescribe further measures which were not planned by the Concession-Holder but which could prove to be necessary. If the Concession-Holder fails to complete the prescribed works, the Prefect designates somebody to perform measures required to secure the site at the Concession-Holder’s expenses. The Préfet notifies the final works closure by decree confirming that the measures implemented by the Concession-Holder are in compliance with the application or the additional securing measures.

Following the request of the French Ministry in charge of Industry and Mines, INERIS has developed a methodological guideline describing the recommended procedure to prepare and/or to evaluate this so-called “mining works closure application”. This document, established in 2001 is of great help for mining operators as well as Administrative services in order to optimise the technical content as well as the duration of the whole procedure [3].

4.3 The “Mining Risk Prevention Plans”

Parallel to the step of “Mining Works Closure Procedure” which has to be fulfilled by the Concession-Holder’s, it is the State responsibility to evaluate and post the residual risk and to integrate it in the management of the regional planning.

To standardise and optimise the various approaches already available in the field of natural hazards (floods, landslides…), the French State established, by a law drafted in 1995, the Risk Prevention Plans (PPR), that may nowadays concern Natural, Mining and Technological Risks since regulation extensions in 1999 and 2003 [4].

The major risks taken into account in Mining Risk Prevention Plans (PPRM for “*Plans de Prévention des Risques Miniers”* in French) are, in particular, ground collapse, severe subsidence, flooding, dangerous gas emission, dangerous ground or water pollution, ionizing radiation. PPRM presents two major objectives [5]:

- identification of the sectors which are the most sensitive at the long term, to risks or harmful effects related to mining,
- establishment of prevention, protection and safety measures adapted to the various identified post-mining constraints. These land use management principles are related to present and future surface infrastructures and activities.

The Préfet initiates a PPRM procedure by specifying, in particular, the investigation perimeter as well as the nature of the risks taken in account. In addition to the involved administrative services, local councils are also consulted and the PPRM project is subjected to a “public investigation” of the concerned population. At the end of the various consultations, the PPRM, possibly modified, is approved by a Préfet decree. The defined regulations become applicable and have authority on the Local Urbanism Documents established in each French city, by the municipal council.

A PPRM elaboration may be divided in 4 major stages described as follows.

The **informative stage** aims to collect available information (or, in case of absolute necessity, to undertake complementary investigations). It requires very careful sign research both on site and from archives. It leads to the elaboration of an informative map which constitutes an essential communication support because it contributes to justify the prevention step undertaken by analyzing the disorders and harmful effects having affected the site in the past.

The **hazard evaluation stage** aims to locate and hierarchise the exposed zones, according to the intensity of the foreseeable phenomena and their pre-disposition to occur in each zone. This evaluation stage does not integrate the nature of surface occupation. It leads to the establishment of hazard maps which locate the hazardous zones.

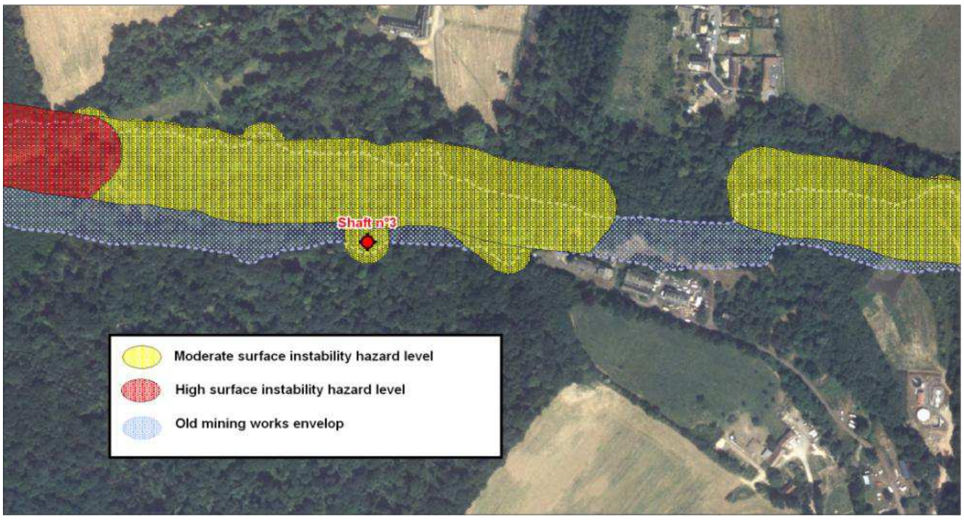

Figure 5. Example of a hazard map above abandoned iron mines (North-West of France) .

The **vulnerability appreciation stage** aims to characterize the existing vulnerability in the areas subjected to one or more phenomena and to identify the potential future projects which could develop within these areas. It enables to identify the amount of population subjected to different risk levels. One counts, in particular, the most sensitive equipments or buildings (hospitals, schools…). This stage leads to the elaboration of a vulnerability map.

The **regulation stage** aims to define homogeneous zones in term of land use management (prohibitions, regulations or recommendations) concerning existing equipments as well as new projects. The principles of this zoning are based on a “crossing” between hazard levels and nature of surface occupation (vulnerability levels). Directly connected to this zoning, regulation rules are established in order to manage, in a clear and operational way, the land use occupation for each zone subject to hazards.

As well as what has been done for the “Mining Works Closure Procedure”, the French Ministry in charge of Industry and Mines requested INERIS to adress a synthetic methodological guideline describing the recommended procedure for the elaboration of a PPRM whatever the nature of foreseeable phenomena (surface instabilities, floods, gas emission…). This document, accomplished in 2004, is now available for organisations and services involved in PPRM elaboration [6].

INERIS is also involved in performing operational PPRM realisation. During the last three years, the INERIS Ground and Underground Division thus realised about 40 PPRM throughout France. The PPRM elaboration program is going on and will be designed with the help of the “Mining Sites Screening Process”.

4.4 The “Mining Sites Screening Process”

About 3000 mining titles (concessions, exploration agreements…) have been granted throughout the whole metropolitan French territory. Taking into account the current rate of PPRM realization (about fifteen per year), one can easily estimate that the period needed to perform all the requested analysis may last several decades. It is thus essential to establish, as soon as possible, priorities so that the most sensitive sites can be treated prior to the others.

This is the main objective of the “Mining Sites Screening Process” that is to say:

- to hierarchise the order of the future PPRM realization
- to identify quickly the most alarming contexts requiring urgent safety measures.

The duration of this very ambitious step, carried out by INERIS in collaboration with BRGM, under the coordination of GEODERIS, has been estimated to about 3 years.

This innovating process will consist in reviewing all French mining sites in order to classify them according to their level of risk (mostly due to potential surface instabilities). It will also allow to recognize the 200 most sensitive mining sites in order to investigate them through a very simple and quick risk qualification step. Thus, this step is not based on a detailed and precise site expertise. Therefore, it will not substitute the PPRM elaboration program.

The sites selection methodology consists in hierarchising progressively, through various stages, the sites according to the available data. The first stage uses the information available in the French mining sites data base and associated GIS developed by GEODERIS. This information makes it possible to localise, roughly, mining works and to provide useful technical data for a simple risk evaluation. For the identification of equipments and infrastructures on surface, one has to work with recent topographic maps (scale 1/25 000). The crossing of the mining information available in the data base, with the kind of surface occupation enables to put in the lowest rank a first group of sites being either far away from any surface structure or without any risk of surface instability.

The sites that have not been “eliminated” through that first step are subject to complementary information on mining data and surface occupation (this step requires short archives research and site visit). With the new collected data, the remaining sites are then classified according to their more or less “risky” character using a decision-aid software based on multi-criteria analysis. The criteria list as well as their respective weights have been established by an expert college functioning as the steering committee of the process. This hierarchisation process makes it possible to recognise the 200 most alarming sites. For these specific sites, simplified risk evaluation and cartography are undertaken systematically.

To optimise the results reliability and the work effectiveness, the screening process is performed region by region, the task being delivered to INERIS and BRGM in their complementary areas of activities. Up to now, the process, initiated in January 2005, has already treated three regions, mainly in the south of France. The 19 last regions will go ahead, according to the progressive achievement of the mining data bases essential to the program.

4.5 The Monitoring of Post Mining Risks

The law of march 30th 1999 also called “post mining law” introduced a very important notion: the monitoring of post-mining risks. Prior to this date, mining operator was supposed to treat, by any adapted method, in every context and situation, the foreseeable risks in order to prevent or cancel them. This was not always possible at the long term and some important problems could occur after the Concession-Holder disappearance.

The 1999 “post-mining law” stipulates explicitly that if the geological and mining contexts do not allow, for some technical or financial reasons, identification of reasonable measures capable of canceling the risk, it is the Concession-Holder's responsibility to monitor the risk in order to assure public safety in preventing foreseeable accidents. Monitoring may also be undertaken during a transient period, when risk management measures are performed (backfilling, moving of people…). To transmit the monitoring management to the State before mine closure, the mining companies must deposit funds allowing monitoring of the hazardous areas during a period of ten years. In case of abandoned mines, the authorities take over the permanent monitoring.

INERIS is fully involved in this operational monitoring management as well as in the technological development of innovating equipment.

Microseimicity is widely used to monitor hazardous areas using concepts similar to earthquake monitoring. Rock mass fracturing produces acoustic emissions that induce small ground tremors recorded by sensors (geophones and accelerometers). Data processing of microseismic events is based on waveform and frequency analysis, seismic energy and magnitude calculations, location of the seismic source and determination of focal mechanism that finally give information on the source process.

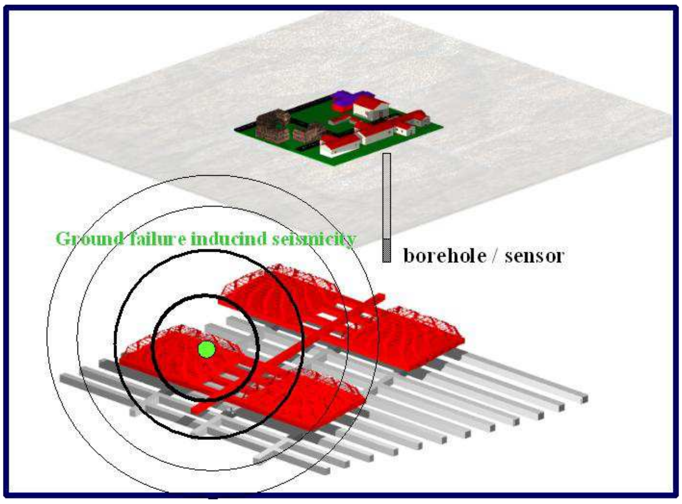

Figure 6. Example of a micro seismic monitoring station installed in the Lorraine iron ore basin.

Up till now, in Lorraine iron mining field (NE of France), about 15 towns are beeing monitored by microseismic networks constituted by several sensors. The seismic data are recorded and treated by the way of a specific software, SYTMIS, developed by INERIS [7]. Seismic events are immediately and automatically transferred to INERIS monitoring center in Nancy via phone transmission.

Among other parameters, two general and basic data are instantaneously processed : the number of events per hour and the cumulative seismic energy. If one of these parameters are beyond pre-defined thresholds, an alarm is triggered. Several monitoring teams have been constituted respectively for night and day duty and technical maintenance. They have in charge the permanent, 24 hours a day system supervision. The expert on duty receives a phone call on the dedicated mobile phone and has in charge the analysis of microseismic data and the follow up of the alarm up to its end. Specific internal procedures are followed, which ensures the best quality of the alarm management. This supervision is full part of the overall risk management process supervised by the civil protection administration and local authorities who are responsible for taking appropriate decisions and related operations.

Concerning technological improvement, the present major development axis is the implementation of a Global Geotechnical Monitoring System dealing with different coupled and complementary monitoring techniques from a unique centralized operational monitoring system. This system will integrate real-time seismic technology, automatic classical geotechnical monitoring as well as "real time GPS" surveying technology.

The objective is to develop, in the following years, an operational, cost effective monitoring GPS micro network technology able to give fundamental information on quasi static ground surface movement at a rather large scale. Such features will optimise considerably quality and amount of data to be analysed, costs related to data transfer, archiving, etc. while increasing significantly time life of some parts of equipment set up on site.

In order to enhance its capacities in operational monitoring as well as technological development, INERIS recently founded a National Center of Monitoring of Ground and Underground Risks Monitoring. The task of this expertise structure, taking benefit of several scientific partnerships, will be to answer to the concrete needs of the authorities and of the mining operators concerning monitoring of post mining risks.

4.6 Damage compensation and preventive evacuation

The mining operator is responsible for the damages that can result from its activity, without any time restriction (even long time after mine closure). So, it is his responsibility to compensate victims of mining damages. It has to be proven that the damages resulting from any another origin can not be attributed to another origin.

The major innovation of the "post mining law" results in the guarantee of the State. In order to avoid that victims may not be compensated in case of Concession-Holder disappearance or insolvency, the legislator expected the State to deal, in this specific context, with the victims compensation.

The post mining law also stipulated that, in case of a major mining hazard threatening seriously public safety, the goods exposed to this risk may be expropriated in case the protection and/or prevention measures appear to be more expensive than the expropriation cost.

This statutory process is restricted to the cases of major risks and extreme urgency. Due to very strong socio-political constraints, this step is the ultimate risk management solution, when any other possibility appears to be inadequate (for technical and economical reasons). During last years, about hundred houses have thus been expropriated throughout France. People have then be relocated in other residences.

5 NATIONAL POST MINING RISK MANAGEMENT ORGANISATION

The action of the French State concerning post-mining consists in identifying the risky abandoned mining sites and evaluating the corresponding risks in order to determine the suitable preventive measures able to secure, when necessary, the stakes located of surface.
As described before, these measures can take the form of reinforcement works or constraints applied to town planning (MRPP). Moreover, the French State has sometimes to assume exploitation and maintenance of water stations (pumping or physicochemical treatment), installations of firedamp management or devices of monitoring when concession holders no more exist and public safety is concerned.

To assume these missions, the State is based, at the national level, on some Services of the Ministry in charge of Industry (Department of the Regional Action, Quality and Industrial Safety and General Department of Energy and Raw Materials). At the regional level, 24 "Underground Divisions" of the Regional Departments of Industry, Research and

Environment (DRIRE) manage the technical and administrative supervision of mining and post-mining activities. Concerning the DRIRE organisation, some interregional “post-mining poles of competencies” were set up in Metz (NE of France), Alès (SE) and Caen (NW).

Moreover, the State initiated the creation of the public structure GEODERIS, pole of expertise and support to the administration for the study of the behaviour of the mining works, the characterisations of the possible risks and the determination of the measures to be taken to prevent the risks. This Public Structure gathers competencies of the National Institute of Industrial Environment and Risks (INERIS) and French Geological Survey (BRGM).

For the operational post-mining management, the State entrusted to BRGM missions of prevention, monitoring and safety concerning the disused mining concessions. This organisation assures, on behalf of the State, a control of the securing works initiated when necessary. It also manages the hydraulic installations (pumping and treatment) transmitted by the mining operators to the State when the local communities do not prefer to recover them, as envisaged by the French Mining Code.

Finally, in order to provide a scientific support needed for expertise and risk management, a Scientific structure, GISOS, has been created. This structure is common to public organisations (INERIS, BRGM, School of Mines of Paris, Polytechnical Institute of Lorraine…). GISOS has three major axis of research: comprehension, characterization and modeling of mechanisms and structures, role of fluids (water and gas), risk analysis principles and development. Every 3 years, GISOS organizes an international post-mining symposium, to share with foreign experts the knowledge and expertise improvements in the area of post-mining.

6 REFERENCES

[1] Edict n° 95-696 of 9th May 1995 modified by edicts n°2001-205 and 2001-209 and “arrêté” of 8th September 2004

[2] Law n°99-245 of 30th March 1999 relative to responsibility in terms of damages related to mining extraction and post-mining risk prevention.

[3] DIDIER C. (2001). Methodological guideline for mining works closure application. INERIS-DRS-01-25750/R01. April 2001. 130 p + illustrations and appendices. French language.

[4] Law n° 95-101 of 2 February 1995 applied by Edict n° 95-101 of 5 October 1995 for Natural Hazard PPR. The extension of PPR to mining risks is defined in law n°99-245 of 30th March 1999 and edict n°2000-547 of 16th June 2000.

[5] DIDIER C., LELOUP J. (2005). The MRPP : a powerful operational regulatory tool to prevent and manage post-mining risks. Proceedings of the 2nd post-mining symposium GISOS 2005. 16-18 November 2005. Nancy (France). 12 p.

[6] Elaboration of Mining Risk Prevention Plan. Methodological guideline established under the scientific co-ordination of INERIS. INERIS-DRS-04-51198/R01. 30 June 2004. French Language to be translated in English.

[7] COUFFIN S., BIGARRE P., BENNANI M., JOSIEN J.P., (2003).). Permanent real time microseismic monitoring of abandoned mines for public safety. Proceedings of the 6th International Symposium on Field Measurements in Geomechanics FMGM

2003, 15-18 septembre 2003, Oslo, Norvège, pp. 437-444.

Web sites :

INERIS: http://www.ineris.fr

Ministry of Industry: http://www.minefi.gouv.fr

GISOS: http://www.gisos.org