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PANORAMA OF THE POST-MINE RESIDUAL RISKS

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Abstract. The mining industry residual risks can be divided into 6 main chapters which are as follows: surface instability, waste mechanical instability, waste chemical instability, waste fire, tailing dam's instability, and residual contamination. Most of these risks are present in every old mine but their importance would depend mainly on the mining method, the depth, the type of ore or overburden materials, and the method of the dam building. They can be very different from one site to another. It seems to be important to analyse them site by site, and create a procedure to prevent all the buildings or infrastructures in the risky area from destruction. This procedure could be similar to the Seveso type industry building restrictions.

Key words: old mines, risk, collapse, slides, ARD, tailing dam.

Abstrakt. Zagrożenia występujące na terenach opuszczonych przez przemysł górniczy można podzielić na następujące kategorie: niestabilność powierzchni terenu, mechaniczna i chemiczna niestabilność składowisk odpadów górniczych, pożary hałd górniczych, niestabilność składowisk odpadów poflotacyjnych oraz ogólne zanieczyszczenie terenu. Większość tych zagrożeń występuje na wszystkich terenach starych kopalń, jednakże zależą przede wszystkim od stosowanych metod wydobywczych, głębokości kopalń, rodzaju rudy i nadkładu oraz metody konstrukcji składowiska poflotacyjnego. Rodzaj zagrożeń może bardzo różnić się w zależności od kopalni. Należy zatem zbadać je w każdym przypadku oddzielnie, a następnie dla każdego przypadku opracować niezależne procedury ochrony wszystkich budowli oraz infrastruktury znajdujących się na zagrożonym terenie. Taka procedura może być wzorowana na ograniczeniach wypracowanych dla budowli przemysłowych w przypadku Seveso.

Słowa kluczowe: stare kopalnie, zagrożenie, zapadanie, osuwiska, kwaśne wody, zbiornik osadów poflotacyjnych.

INTRODUCTION

Every year post mine problems occur in a part of the World. Some regions are completely in a very bad state, and European countries are specially exposed to those problems mainly because of the large number of the old mines, and also because of the demographic expansion which causes a global need for construction terrain. This fact connected with the lack of regulations cause a serious risk in many regions of our continent. Generally, Europe entered in a post mine century, and it is time to manage these residual risks that can remain for centuries and be as problematic as residual industrial pollution or Seveso type industrial risk. A complete investigation of those risks looks to be important and the results should be included in the land use plans. Only the European law seems to be able to solve this problem.

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RISKS CLASSIFICATION

Analysing the different risks associated with mining industry, it looks easy to classify them in the 6 main chapters. They are not present everywhere and their importance will mainly depend on:

- the exploitation method,
- the depth,
- the type of ore,
- the method of the waste material deposition,
- the construction's type of the tailing dam.

Looking for all these factors, they can be organised in the 6 chapters as follows:

- risks of surface instability and collapse,
- risks of wastes mechanical instability (slides),
- risks of waste chemical or physical instability (mainly ARD and Radon emission)
- risks of wastes fires,
- risks of tailing dams (mainly flows)
- risks of chemical residual contamination.

In the following text, this classification will be presented and the main risks illustrated with field examples, often non published yet.

RISKS OF SURFACE INSTABILITY

They are well known and very often they are of "convergence type". This is a slow movement of the surface which can descend the slope with the speed from some decimetres to meters. This is a well known process which does not affect modern buildings, built with para-seismic rules, but which mainly affects old buildings. This type of movement could continue for a long time, even if the main movement generally occurs during the 10 first years after completing the mining works.

The second type of movement is more problematic. It is a strong and rapid one, of the collapse type, which mostly tends to a sinkhole or crater which can be created suddenly (in one hour) and can swallow any surface construction.

Two types of mines are generally involved in that process:

- evaporite minerals mines (salt, potash, gypsum, boron),
- rooms and pillar mines.

The movements generally occur when mining works are not very deeply located under the surface (50 to 200 m), and when the width of these works is larger or equal to the thickness of overburden. In such case, the rocks mechanics calculation cannot be applied and we can have a sudden collapse of the cavity.

The main causes of those movements are:

- phreatic level variation which changes the mechanical characteristics of pillars rocks (especially when rocks contain a large amount of clay);
- pillars in chain rupture;
- quick dissolution of salt or other evaporites by fresh water which suddenly increases the size of the previous work.

Three types of sinkholes can be observed:

- small ones (up to 10 m diameter size) which are generally "fontis" type. They use to be developed in rooms and pillars mines, on the top of a rooms cross. They generally occur in shallows mines (10 to 50 m depth);
- large ones (up to 500 m diameter size), "crater type" which used to be characteristic of evaporite minerals mines. The depth of such sinkholes can be even 100 m, and they can occur very suddenly;
- general collapsed surface (Clamart type) where there is no obvious sinkhole but a surface totally perturbed on a very large perimeter (1 km or more).

What are the pre-collapse signs? They are very few and generally they may not be observed:

- noises and cracks with a quick periodicity;
- eruptions of generally dark and nauseous water;
- sometime stones blow away from the walls due to gas eruption.

The only way to prevent consequences of this accident type is a total and preventive evacuation of the risky site. The best way for it would be to prepare a surface occupation plan that, if it is followed in spite of the political pressure, could let the people leave the risky area for a sensible purpose.

RISKS OF WASTE MECHANICAL INSTABILITY

Wastes are generally deposited by simple dumping. This method is cheep and traditional in mining industry. The main problems which it causes are:

- the dipping of the deposit slopes is close to the stability limits,
- the deposit drainage is not secure and can be progressively tamped by fine particles carried down by the infiltration water,
- after some years, a phreatic level could rise in the deposit changing its mechanical properties and directing towards instability,
- very often the trees plantations grown on the waste could increase this risk factor.

Centuries ago, size of such deposit was very small, essentially because of human working capacity. With mechanisation, nowadays dumps can be raised up to 400 m high and in such cases dump slides are very probable and can affect surrounding population.

Most of accidents are caused by circular type slides. They are not very dangerous for population or infrastructures staying away from the event, at the distance of about 1.5 times the waste height. This is the recommended protection area around this type of slides, if they are deposited on a inclined surface dipping less than 5°. If the risky slope is dipping more than 5°, and especially more than 10°, a flow slide of Aberfan type can occur.

The slide phenomenon is created by collapse of a metastable structure mainly due to saturation of the deposit with water. It starts by a circular slide induced by the higher interstitial pressure which fluidise part of the slope sediments. This material which quickly takes a semi fluid property, flows along the slope at a speed between 3 to 11 m/s and with a noise which remembers a jet motor roar. In the Aberfan case history, the total displacement of the material was 450 m, and it has destroyed a part of the village swallowing houses and a school. In this accident 28 adults and 116 children died. This case shows the importance of defining larger safety area down the slope especially when the outcrop slope is dipping around 10°.

"Debris slide" is another risk when the slope is dipping more than 25°. It generally occurs slowly but it can go very far from the initial place (up to one km). In such case risky area is larger and can reach a lower part of the valley slope.

Another phenomenon can occur principally in sediments well covered by a waterproof material (compacted clay). In such a case, an "outburst failure" could occur which appears when an overpressure of water in the dump takes place. This is a very quick phenomena looking like a burst that leaves a hemispheric cicatrix in the dump. The risky area in such case is not greater than 1.5 to 2 dump heights.

For these phenomena, the following causes always appear:

- lack of efficient drainage system at the slope sediment base,
- the dip of the bed rock slope 5 to 30°,
- very often — existence of an artesian phreatic level beneath the slope sediments.

These accident-prone risks can remain for centuries, and it is important to consider every dump as a risky area for a very long time.

WASTE CHEMICAL INSTABILITY

It is caused mainly by the oxidisation of sulphides contained in the deposit. Frequently this reaction is due to pyritic ore, and generation of acidic water (AMD or ARD) is its result. Such water can dissolve every heavy metal contained in the waste or in the surrounding rocks. These waters are being polluted fast and can contaminate large regions downstream. This phenomenon can continue for a very long time (up to 400 years).

The oxidisation is mainly caused by:

- pH of water in contact with pyrite (x 100 for each pH unit),
- presence of "ferroxidans" type bacteria (x 10,000),
- typology of pyrite grains (x 1,000),
- granulometry and permeability of the deposit.

This is a big problem present in every countries and very difficult to stop if the reaction already begun. Risks area is very large but restricted to the water use (up to 100 km downstream). Other physico-chemical problems are caused by radon emanation and radium dissolution. They occur mainly in the uranium mines but can also be present in coal mines (Silesia) or in gold mines (Rand).

Radon is a strong radioactive gas which can produce an external irradiation, and which is naturally transformed in a soluble solid element named polonium after less than 4.5 days. Contamination area will depend on the rate of leaching a deposit by the wind. Polonium can enter into grass and contaminate milk, vegetables, and meat, existing in human food far away from the deposit.

The only way found to prevent this contamination is to cover the deposit with a semi proof compacted covering, inducing a duration time greater than 5 days. In that case the whole contamination remains in the waste deposit. If this preventive action is not carried out, the contaminant diffusion could go further than 100 km depending mainly on the wind action.

Radium which is an extremely radioactive soluble element can be dissolved by rain infiltration and travel downstream in rivers. It can be bio-accumulated in fish or contaminated drinkable water. It is clear that this element must be removed by water treatment far from the deposit, but the best way is to prevent its dissolution by a proof covering preventing any water inflow inside the dump.

Another contaminant, also involved in human health, is asbestos or any amphibole appearing in a dump. Contamination occurs mainly in dry areas where the wind can sweep fines particles (Australia, Brazil) but we do not still know if the water contamination by this element is not dangerous, too. In such case, contamination can also occur on very large area and the only way to prevent this is to cover the waste with a non contaminated soil. In all those cases risky areas are not easy to define, though.

COMBUSTION RISKS

They can occur in any coal mine or oil shale wastes, often a very long time after the reclamation (Champclauson, France — 130 years later). Most of these wastes contain up to 30% of organic carbon and can burn. The wastes fire can be caused by a forest fire or a spontaneous ignition, especially in bituminous or semi bituminous coals (Lorraine coal mines). It is quite impossible to stop such a fire, so the only way is to prevent it.

The main risks connected with the above events are:

- toxic gases emanations,
- destruction of all the construction built on the deposit,
- possible extension of the fire to any combustible area existing nearby the site.

Such fires can continue for many years, and a thorough monitoring is necessary for a long time, there. Therefore, it is important not to allow any constructions to be made on this type of waste, and it is also important to cover the wastes with an impermeable material in order to prevent the air access.

TAILING DAMS

These constructions are for over 200 years the most difficult problem. Their most frequent accidents were:

- circular rupture of the dam wall,
- a dam overflowed by heavy rain,
- liquefaction of the dam, due to an earthquake, mainly,
- collapse of the dam basement.

A result of such accident is creation of a heavy mud flow that destroys everything downstream up to 10 km, and a long time contamination of the whole downstream valley with heavy metals and chemical products. The most risky construction type is the upstream and spigotage one which is very common in central European mining industry, and also in Africa.

The most important recorded tailing dams accidents were:

- Chile (El Teniente) — about 2,000 killed people,
- Romania (Deva) — 87 victims and 74 injured,
- Romania (Baia Mare) — contamination with cyanide of the Tysa and Danube rivers,
- Spain (Asnalcollar) — heavy contamination of a natural reserve,

and many others (more than 200 officially recorded in the world).

The causes of accidents were always:

- either bad guidelines for a dam (granulometry of material deposited, design),
- or lack of an efficient drainage system under the dam's wall,
- or lack of properly dimensioned drainage of rain water inside a tailing pond.

A very large number of tailing ponds built with a very bad technology has been inherited. Some of them are known to be very dangerous but the amount of money necessary for their stabilisation exceeds the financial capacity of most of the countries involved. Unfortunately, there are still dams built with a bad technology, and some of them are even more than 225 m high.

There are no international regulations or accepted practices for reclamation of the old tailing dams. Therefore, a lot of crazy reclamation, which only increases the initial risks, can be observed in many countries. The lack of an efficient dam's wall drainage, which could induce positive changes in mechanical stability of the structure, is also observed very often. What is more, a long term monitoring is often run by unprepared people. This looks as being one of the greater post mining risks, and it is necessary to quickly organise a general inspection of all these endangered dams, and to prepare an European guideline for their reclamation.

RISKS OF RESIDUAL CONTAMINATION

Residual contamination of mining areas are often caused by heavy metals, arsenic, and radioactive materials, but also by salt, chemical products used for plants, and so on. Most of the heavy contamination appear in cases when a metallurgical plant is located inside the mining area. In such cases, heavy metals are in soluble concentrate forms that greatly increase the risks.

Radon and radium contamination is common in uranium mines but also in some coal mines (Poland). Mercury contamination is frequent in old gold mines but also in mercury mines (Spain), and in any sulphide ore deposit. Other main contaminants are: lead, nickel, chromium, cadmium, and arsenic, especially coming from the polymetallic ores mines.

These metals can be concentrated in grass, cereals (rice), and vegetables, but also in fish meat far away from the mine site. As the preventive actions, a general plan of soil use must be prepared in order to prevent residual pollution dissemination in aliments, after a monitoring and remediation of a mining area.

CONCLUSIONS

Mining and metallurgical areas contain a lot of problems that have to be clearly identified and, if possible, resolved. European countries have a lot of very often forgotten old mines, and the population growth induces an expansion of urbanised territories often entering into old mining or metallurgical areas or on nearby locations. The still remaining risks in these areas are not well recognised by the authorities in charge of infrastructure and urbanisation.

Therefore, it is important to prepare a global list of these risky areas and to map them to prevent any future problems. In such a global study, a particular attention must be given to salt or potash mines, and also to mines or underground quarries exploited with the "rooms and pillars" method.

Its looks also necessary to verify and treat every old tailing pond in Europe because they are remaining for centuries as a "Damocles sword" for the neighbouring population. A European directive has to be prepared for a uniform law for all the European countries to regulate the relationship between the mining residual risks areas and urban expansion or agricultural use of polluted soils or water.

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