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POST-EXTRACTION MANAGEMENT OF MINE SITES

(Transmitted by the Government of France)[1] [2]

I. INTRODUCTION

1. Because of the growing pace of change, the world mining industry as a whole is increasingly subject to market rules. For many important, long-established mines, this fact, their reserves (as defined in the recently published United Nations International Framework Classification for Reserves/Resources, Solid Fuels and Mineral Commodities) and the recalculation of those reserves are leading to the halting of extraction, followed by rehabilitation of the site to place it at the disposal of the community (in the broad sense of the term).

2. Assuming that the mine is established on a greenfield site, the mining activity will comprise three phases: exploration, preparation and production. These first three phases are the most familiar. To them must be added - as was already the case in the past, but is particularly so today - a fourth phase, namely restoration of the site to a condition in which, even if not all the effects of mining (for example, the changes in the local relief) have been eliminated, it is suitable for communal use. It is this fourth and final phase of a mining site's life that we mean when we speak of “post-extraction management of a mine site”.

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3. In the modern world, the question of post-extraction management cannot be ignored. That is so not only because of the new economic climate, but also because the concepts of safety, security and environmental protection have acquired new importance and because solutions will only ultimately be deemed acceptable if they are reached in a climate of consensus.

A. The consequences of the definitive cessation of production at a mine site

4. The definitive closure of a mine has numerous consequences:

Human consequences (as a result of job losses, etc.);

Economic and social consequences (as a result of the disappearance of the direct or indirect economic benefits of the mining activity and the effects of that disappearance on society, the region and its development, etc.);

Technical consequences in terms of security and environmental protection as a result of the halting of mining and the abandonment of the underground and surface facilities: in place of active facilities, there will be lasting technical consequences that can only be remedied by means of specific studies and work aimed at returning to communities zones that are well-known, safe and environmentally acceptable.

B. The objective of post-extraction management of a mine site

5. The objective of this document and of post-extraction management of a mine site is to define the technical measures needed when mining ceases and to propose a methodology for applying them, given that the outcome should be:

The return of mining areas to the community under the best possible security, hygiene, health and environmental conditions;

The provision to future generations of (a) the means of verifying the continuing quality of the work done and (b) the technical information needed for any corrective action that may be required in the future.

6. It goes without saying that the above-mentioned measures must be compatible with the post-closure exploitation of residual resources, e.g.:

The recovery of pay material contained in inadequately washed tailings, settling ponds, etc.;

Use of completely barren waste in road-building, brick-making, etc.;

Recovery of methane.

C. The legislative and regulatory context of post-extraction management of a mine site

7. The return to the realm of ordinary law of mining areas the working of which has been, or is going to be halted for good and the conditions for that

return are usually dealt with in a country's Mining Code and the associated regulations. Technically speaking, it is a matter of summarizing those effects of mining that persist after production has ceased and then of defining the corrective and/or precautionary measures to be taken to ensure that the return takes place in acceptable and accepted conditions. In practice, however:

The texts available to serve as guidelines, having been drafted some while ago, basically concern the law of, and regulations for mining proper, i.e. production, whereas the issues that are the subject of the present paper are mostly only discussed from a general and administrative point of view;

Cases of the return of former mining sites to the realm of ordinary law have, as yet, been too few to provide representative examples.

To this must be added the fact that the growing, and relatively recent awareness of environmental hazards has led to the emergence in every country, alongside the bodies of law specific to particular types of industrial activity such as mining law or shipping law, of a body of environmental law that affects all sectors of industrial activity.

8. In many instances, therefore, redefining existing law and/or making it more precise is a prerequisite for developing a modern, comprehensive body of law on post-extraction management of mining sites that clearly expresses:

The underlying legal philosophy and principles;

The legislator's requirements as to the precautions to be taken for site rehabilitation and the limits on those demands;

The conditions of acceptability of the measures and precautions to be taken on and after the halting of mining;

The consultative machinery that must be set up if the measures and precautions referred to above are to be acceptable to, and accepted by all concerned;

The administrative arrangements appropriate to post-extraction management.

9. Nowadays, coverage of the above aspects is considered essential to the drafting of new codes of mining law (especially in projects involving the World Bank).

II. INVENTORY OF A MINE'S RESIDUAL TECHNICAL EFFECTS

A. Definitions

10. The effects in question, which are often, rightly or wrongly, termed the technical consequences of mining, are, in essence, of two kinds:

Measurable and easily identifiable direct technical consequences;

Less readily measurable and quantifiable indirect technical consequences.

The first kind of consequences will be discussed below. Of the second we shall merely give a few examples, leaving it to the communities concerned to decide how to overcome or mitigate them:

Impact on the potential for surface agriculture;

Impact on the archaeological or, more generally, the scientific potential of the affected areas;

Impact on the landscape;

Impact on the development of the mining zone itself and on its adaptation to the post-mining era.

B. The residual technical effects (technical consequences) of mining: inventory, definitions, classification

11. Paragraph 28 of this paper describes what must be done before the closure of deposit access points (vertical shafts or inclined galleries driven from the surface) in order to ensure that the workings - which, once the entries have been closed off, will no longer be accessible - are in a conclusively satisfactory condition from the points of view of physical safety and environmental hazard. Once this work has been carried out, risks and consequences will remain; they are, stricto sensu, the residual technical effects or technical consequences of mining.

(a) Inventory

12. Apart, perhaps, from a few real exceptions, the problems that remain to be resolved when the production phase is over are contained in the following list of risks and problems:

1. Problems and risks of soil stability and subsidence;

2. Risks associated with the residual atmosphere in underground workings;

3. Risks specifically related to the workings giving access to the deposit from the surface (shafts and drifts);

4. Specific safety problems relating to surface facilities (electrical hazards) and to networks or facilities associated with gases that may form explosive mixtures;

5. Risks inherent in the existence of subsurface galleries;

6. Risks and problems inherent to potentially contaminated sites;

7. Risks associated with the pollution of subsurface water;

8. Problems of mining-related surface water;

9. Problems of overground networks for gases other than those referred to in item 4;

10. Problems relating to spoil heaps;

11. Problems relating to the securing and future of surface buildings, rail infrastructure, settling ponds;

12. Problems of abandoned industrial land and site rehabilitation.

13. While the author has tried to make it as complete as possible, this list should not be considered exhaustive. It represents an inventory of the risks and problems that may affect a mining area once mining has ceased.

(b) <u>Definitions</u>

1. Problems and risks of soil stability and subsidence.

14. Underground mining creates voids that, as they have done in the past, can cause complex ground movements for some while after production ceases. If the mining is extensive enough (exceeding of a threshold depending on the depth of the workings), the movements will, after a few months, reach the surface. There will then be land subsidence, together with deformation, elongation and compression that can cause damage which must be either prevented or repaired - phenomena collectively known as MINING SUBSIDENCE. Similarly, in the case of opencast mines, prevention of instability problems requires measures to ensure the constant and lasting stability of the sides of the pit.

2. Risks associated with the atmosphere in underground workings.

15. In an underground mine, water will gradually penetrate the abandoned workings, moving upwards and driving the trapped air before it. This increases the pressure of the air in the enclosed workings and creates the risk of uncontrolled migration of atmospheres that constitute a pollution or explosion hazard.

3. Risks specifically related to the workings giving access to the deposit from the surface (shafts and drifts).

16. In most underground mines, the pay material does not outcrop and working it therefore entails the sinking of VERTICAL SHAFTS or the driving of HORIZONTAL or INCLINED GALLERIES (drifts). When the mine is closed, these must be secured against one or sometimes two potential dangers:

The collapse of the ground surface around the shafts or drifts;

In the case of coal mines in particular, the escape from the workings of dangerous atmospheres.

4. Specific safety problems relating to surface facilities (electrical hazards) and to networks or facilities associated with gases that may form explosive mixtures.

17. The risks to be dealt with here are those of electrocution from the electrical systems in surface facilities, which may be left as they are for a while when the mine closes, and those of explosion in overground gas piping circuits (e.g., CH_4 ducts in the case of firedamp or coke-oven gas, or hydrogen lines) or facilities such as methane drainage points or pressure-relief wells installed to provide a controllable outlet for underground atmospheres.

5. Risks inherent in the existence of subsurface galleries.

18. This category includes the risks as regards atmosphere and stability specific to galleries driven near the ground surface to facilitate the use of vertical shafts.

6. Risks and problems inherent to contaminated sites.

19. The activities of facilities downstream of mines, such as power stations, washeries, beneficiation plants or ore-processing facilities (e.g., coke ovens, coal-chemistry plants) may well have created soil and water pollution risks, and therefore health risks. Sites where such activities were practised need to be inventoried, studied and, if necessary, cleaned up and subjected to statutory monitoring. Also included in this category should be facilities where pollutants and harmful substances have either been simply stored, or have been created and accumulated in the course of the facility's use (as, for example, in the case of coke-oven gas ducts).

7. Risks of pollution of/by subsurface water.

20. This category includes, in the first instance, the risks associated with the pollution of groundwater in situ. It also includes the risks that may result from the rising of polluted groundwater to mingle with surface water.

8. Problems relating to surface water.

21. In this case the problems are those that may derive from:

The emergence of residual water at the bottom of a quarry or opencast mine, or, in the case of underground mines, the continued flow of such water along inclined galleries connecting with the surface;

The presence, since mining has always entailed heavy water consumption, of wells and water systems;

The possibility that mining will have altered the local relief and thereby disrupted the drainage system or even caused an elevation of the water table. In some cases, offsetting disturbances of this kind has necessitated the construction of pumping stations known as “water-lifting stations”; the future of such facilities has to be settled.

9. Problems of overground networks for gases (other than those referred to in paragraph 17 above).

22. Here the source of the problems is the survival of gas networks (e.g., compressed-air or nitrogen systems) entailing risks other than those referred to in paragraph 17.

10. The problems and risks associated with spoil heaps.

23. Mining generally results in the dumping in soil heaps of substantial quantities of waste material. Typically, these heaps originate in one of two ways, being composed either of the gangue left after concentration of the pay material or of waste rock from the driving of underground galleries or overburden from opencast mines. The risks associated with spoil heaps mainly concern instability and spontaneous heating. There is some concern about a risk of pollution of underlying groundwater through infiltration, but no evidence has yet been found of this phenomenon. To these basic problems may be added that of the ultimate fate of the spoil heaps.

11. Problems relating to the securing and future of surface buildings and facilities of various kinds (office buildings, workshops, store houses, bathhouses, washeries, power stations, rail infrastructure, settling ponds, etc.).

24. The problems here have to do with making the buildings and facilities safe and settling their future in the light of the relevant rules.

12. The problems of abandoned industrial land and site rehabilitation.

25. When mining and the related surface activities have ceased, the land concerned remains as industrial wasteland until it is restored to communal use. The problems in this category also include those of the rehabilitation of the sites of large quarries or opencast mines. In addition to the environmental aspects that concern us here, such problems also impinge upon physical planning when the areas concerned are extensive.

(c) <u>Classification of mining's technical consequences</u>

26. As with any classification, the one in question can be based on a variety of criteria, for example:

Risk as regards physical safety, the environment or both;

The definition of the affected area as extensive or confined;

The duration of the risk: short-, medium- or long-term or unlimited.

This author recommends a classification by risk, the advantage being that each consequence can then be linked to the applicable regulations, and hence to the requisite action.

27. Applying this principle, and given the inventory contained in paragraph 12 and the definitions contained in section II.B (b) above, we obtain a classification with three headings:

Safety: the problems and risks numbered 1-5;

Environmental protection: the problems and risks numbered 6-9 and 12;

Environmental protection and safety: the problems and risks numbered 10 and 11.

III. INVENTORY OF THE TECHNIQUES FOR USE IN REMEDYING THE RESIDUAL EFFECTS OF MINING

A. Introduction

28. For underground mines, the inventory proposed below naturally assumes the completion, prior to the closure of the surface access points, of all the preparations needed for the final abandonment of the workings, i.e.:

Verification of the stowing and performance of any additional work needed to protect against the consequences of possible excessive extraction or of future instability occasioned by the rise of water in the deposit;

The (generally partial) dismantling of workings;

The recovery of toxic or hazardous substances;

The removal or the insulation and earthing of electrical networks;

The readying of landings for the closure.

B. Inventory of the techniques that may be used

29. The techniques of whatever kind - definitive action, special studies or, in the case of risks of indefinite duration that cannot be eliminated, precautionary measures - that may be applied to eliminate, minimize, remedy or control the risks and problems enumerated in paragraph 12 are described below:

(a) Techniques for dealing with mining subsidence and ground instability (definition in paragraph 14)

30. In the case of underground workings, theoretical research and studies based on measurement campaigns have shown that, with few exceptions (mostly unstabilized fault zones), perceptible surface effects attributable to mining cease within five years of the halting of production. The following actions are advisable:

Drawing-up of surface maps showing the boundaries of the mine's zone of surface influence, together with the positions of the main faults in the deposit (it is noteworthy in this respect that methane extraction has no repercussions in terms of subsidence);

Making of subsidence forecasts and maps, and, perhaps, levelling and the installation of subsidence benchmarks.

This will make possible:

The definition of the precautionary measures, if any, to be applied in the event of fresh construction;

The determination of the corrective measures (e.g. jacking) to be applied to large structures (bridges, motorways, etc.);

The study and settling of claims for compensation in respect of structures of less importance than those referred to above.

31. In the case of opencast mines, all slopes should be subjected to a final survey and adjusted to angles such that they will remain stable.

(b) Techniques for dealing with the risks associated with the residual atmosphere in underground workings (definition in paragraph 15)

32. Here the risk comes mainly from methane, but the techniques proposed are also applicable to other mine gases. There are two principal techniques and they can be employed together or separately: installation of methane capture points and sinking of pressure-relief wells. In any event, arrangements must be made for monitoring of the mine atmosphere if there is any serious risk.

(c) Techniques for dealing with the risks inherent in shafts and drifts (definition in paragraph 16)

33. The work that must be performed in the case of shafts is as follows:

Purpose-designed treatment of aquifers or geologically sensitive zones;

Partial or total filling;

Laying over the shaft mouth of a reinforced concrete slab with orifices for checking the settling of the fill, the composition of the shaft-head atmosphere and, if appropriate, the rise of water in the deposit;

Establishment around the shaft mouth of a limited-access zone and a zone *non aedificandi* (which may or may not be of the same size as the limited-access zone), as well as of easements of access to the shaft head.

In the case of drifts, the following are necessary:

The installation, in the mouth of the drift, of a "seal" having orifices for checking the atmosphere and, if appropriate, the water level in the gallery.

(d) Techniques for dealing with the safety risks from surface electrical facilities and surface networks or facilities associated with gases that may form explosive mixtures (definition in paragraph 17)

34. In the case of the risks associated with electrical systems and facilities, there are three possible solutions (following the making of an inventory in the form of tables and drawings identifying the system components and their characteristics and purposes): dismantling; insulation and earthing; transfer to a new user.

35. The risks associated with surface networks or facilities for potentially explosive gases can be eliminated by: isolating facilities from the source of the hazardous gas; purging circuits by means of an inert gas; totally or partially dismantling the piping network (with, if appropriate, packing of the ducts left in place). These three types of action can be taken consecutively.

(e) Techniques for dealing with the risks inherent in the existence of subsurface galleries (definition in paragraph 18)

36. After inventorying of the workings concerned, the following action should be taken: the galleries should either be stowed from underground or uncovered and then filled in or, after they have been checked for long-term stability, they should be abandoned. At all events, they must be completely isolated from shafts or drifts.

(f) Techniques for dealing with the risks inherent to potentially contaminated sites (definition in paragraph 19)

37. The work involved here is among the most complex and time-consuming and is often very expensive. The only possibility is to proceed as follows:

Identify, from knowledge of the former mining activity, the sites where a potentially polluting activity was performed;

Audit each of these sites for those risks with a view to determining whether or not there was pollution and, if it is found that pollution may have occurred, study it:

Its origin(s);

Its extent;

Its intensity;

The possibility of further spread (in soil and water);

The cleanup options.

38. Once the method of dealing with the pollution has been chosen, it must be applied and the results compared with the objectives. After the treatment will come the assignment of the land concerned to a particular use and/or (if circumstances so require) periodic assessment of the residual pollution. Regarding the latter point, it should never be forgotten that soil pollution may be accompanied by, or give rise to groundwater pollution.

(g) Techniques for dealing with the risks inherent in pollution by/of subsurface water (definition in paragraph 20)

39. The first step in this respect is to study the pollution of the groundwater confined within the deposit. The research done on this subject shows that, if the work referred to in paragraph 28 has been properly carried out, that pollution can be considered negligible. There is, however, a risk that the water may become contaminated on migration.

40. The second step is to study, and perhaps to represent in diagrammatic form, the rise of the water in the deposit, and then to install devices to measure that rise, bearing in mind that, in the majority of cases, access to the aquifer will be via the shaft. It should not be forgotten that the rise of the water may extend over decades or even longer.

41. The third requirement is to consider in advance what measures should be taken if water does rise in the deposit with, ultimately, the risk of groundwater disturbance and to make the necessary preparations for those measures' timely application.

(h) Techniques for dealing with the problems resulting from mining-related surface water (definition in paragraph 21)

42. The remedies for the three problems mentioned can be summarized as follows:

Residual water (especially in the case of opencast mines): use in the landscaping of the site, and/or evacuation by pumping with, of course, quality-monitoring and, if necessary, treatment;

Boreholes and water systems: transfer to another user, or plugging of the holes and dismantling of the systems;

Pumping stations: as the first step, examination of their importance for the post-mining development of the site; as the second step, taking of the steps necessary for compliance with the law in the continued operation of those stations that are found to be essential.

(i) Techniques for dealing with gas networks (definition in paragraph 22)

43. After inventorying of the networks, three options are possible: transfer to a new user; dismantling; preservation in accordance with the relevant rules.

(j) Techniques for dealing with the problems of spoil heaps (definition in paragraph 23)

44. After inventorying, spoil heaps should be divided into: those from which material will be recovered in some way and that will be reclaimed when that has been done, and those that will not be put to any further use. All of the latter should be studied for:

Risks and areas of instability;

Risks of combustion;

Risks of pollution, should the heap comprise residue of a potentially polluting mineral.

Precautions should be taken to forestall those risks, namely:

Regrading of slopes;

Isolation from oxygen sources of the material prone to spontaneous heating, and/or application of any other of the well-known fire-prevention measures;

In the event of a pollution hazard, application of the methods enumerated in section III-2-6 above for contaminated soils.

(k) Techniques for dealing with the problems pertaining to the securing and future of surface buildings, rail infrastructure, etc. (definition in paragraph 24)

45. The first step is to inventory the facilities concerned and the second to investigate, item by item, whether they can be reused or not. It is worth noting that it may be feasible to leave some of the buildings or facilities as they are, as mementoes of the area's mining past.

46. If they are not to be reused, the facilities should be dismantled, due care being taken to ensure that they do not constitute a safety hazard before that is done. When a facility is to be reused, provision will have to be made for its transfer to the new user.

(l) Techniques for dealing with the problem of abandoned mining areas (definition in paragraph 25)

47. The techniques must be compatible with the intended future use of the area. The first requirement, therefore, is to define that use, which can only be done in the context of a physical planning project for the post-mining era.

IV. METHODOLOGY FOR SUCCESSFUL POST-EXTRACTION MANAGEMENT OF MINE SITES

48. Experience has demonstrated the value of the six-phase methodology described in the six paragraphs of this section. Ideally, the methodology should be applied to any mining area that constitutes a physical entity.

A. Inventory of mining activity - Constitution of technical archives

49. The technical consequences of mining are consequences of previous mining activity. The first step, therefore, is to identify all those activities and the sites where they were carried on. The second step is to compile for each activity and site a file containing all the items, such as plans, etc., concerning their industrial life and final status. The resultant set of files will comprise the technical archives.

B. Identification of residual risks on sites and of the applicable regulatory instruments

50. The first step is, using the inventory referred to in paragraph 49, to define, activity by activity and site by site, the nature of the residual risks according to the classification given in section II.B. The second is to group activities and/or sites by residual risk. The third is to note the regulations applicable to each risk.

C. Selection of the appropriate remedial techniques

51. The remedial technique(s) to be employed should be selected on the basis of the inventory of residual risks and in the light of the applicable regulations. It should also be determined how urgent the work is. Lastly, an inventory should be made of the work to be carried out and of its urgency.

D. Work scheduling

52. Knowing the resources available and the degree of urgency of each type of work, a work schedule can be established. That will also make it clear what interim measures should be taken in the period between the halting of production and the performance of the remedial work.

E. Execution of the work

53. The work should be executed according to the schedule. As each piece of work is completed, a report should be written and a copy added to the technical archives.

F. Monitoring of the consequences of mining after the above preparations for final closure of the mine have been completed

54. As was said earlier, the effects of mining are not confined to the short term. That entails the making of arrangements for the performance, once the work defined in paragraph 51 has been carried out, of the following tasks:

Preservation and management of the technical archives;

Answering of any requests for information;

Selection of any additional work that may be required to offset the degradation with time of the results of the preparations for closure;

Monitoring of the long-term risks and maintenance in good order of any structures or equipment that may have been installed in preparation for closure:

Monitoring of the water level in the workings;

Monitoring of operation of facilities for controlling the atmosphere in closed workings;

Monitoring of the condition of slabs sealing off shafts or drifts.

V. ESTIMATING THE COST OF POST-MINING MANAGEMENT OF A SITE

55. Estimating the cost of post-mining management of a site may seem difficult, but it is feasible (and, moreover, has already been done). It is, after all, possible to determine for each type of risk the number of sites concerned and the remedy applied. For example, 10 shafts may require solid stowing, 5 partial stowing, and 2 capping with a concrete slab.

56. Given this information, a calculation can be made of the number of units of work that each of these techniques entails. It will then be a matter of computing the cost of each unit of work. There are several possible ways of doing this: comparison with the cost of an earlier similar activity; consultation of firms specializing in the execution of, or engineering for the type of work in question; simulation studies (e.g., to determine the cost of mining subsidence); consultation of specialists with experience of this type of cost assessment.

57. The total estimated cost, or “provision for post-mining management”, can then be broken down by time on the basis of the work schedule, giving a provisional calendar for the drawdown of the provision. As the work proceeds, perhaps over several years, the provision should be reassessed to take account of:

The cost of work already done;

The actual unit costs incurred;

The changes, if any, in the regulations (which may alter the work to be done and the obligations to be fulfilled);

Work overlooked when the initial calculation was made;

Changes in financial indexes.

VI. CONCLUSIONS

58. Careful inventorying is an essential prerequisite for post-mining management. It can be started before production ceases.

59. Post-mining management always extends over a lengthy period (which can generally be taken as starting from the time at which production ceases). On the other hand, it can provide jobs for a while for some of the employees of the mine concerned.

60. The following points in particular should be borne in mind:

Mining memory tends to become lost quite quickly, especially where technical matters are concerned. Maintenance of the mining archives is therefore extremely important;

There is no universal solution, since every State has its own regulations and it is from those regulations that the operator's obligations derive;

The establishment when the preparations for closure are complete of permanent machinery for monitoring (and, should the need arise, action) is necessary, not to say essential.

This paper has not discussed hospitals, welfare facilities or staff housing, because, even though they are often owned by the mine operator, they are not "mining" facilities in the technical sense of the term. It is reasonable to assume that such facilities will continue to fulfil their original role.

61. No doubt an attempt should have been made, for the sake of completeness, to discuss the administrative problems that accompany work of the kind in question in this document. Since, however, both the administrative structures and the law and regulations involved vary widely from one State to another, the approach the author would recommend is simply to comply with each country's duly established procedures and to request their amendment when necessary.

62. The principal requirement for the smooth and swift performance of the activities described above is the maintenance throughout the entire period of an excellent climate of cooperation between all the parties to any project: central and local government and the natural and legal persons involved (including, of course, the former operator of the mine).

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