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# Establishment of guidelines for the inspection of mining waste facilities, inventory and rehabilitation of abandoned facilities and review of the BREF document

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## Annex 3

## Supporting document on closure methodologies for closed and abandoned mining waste facilities

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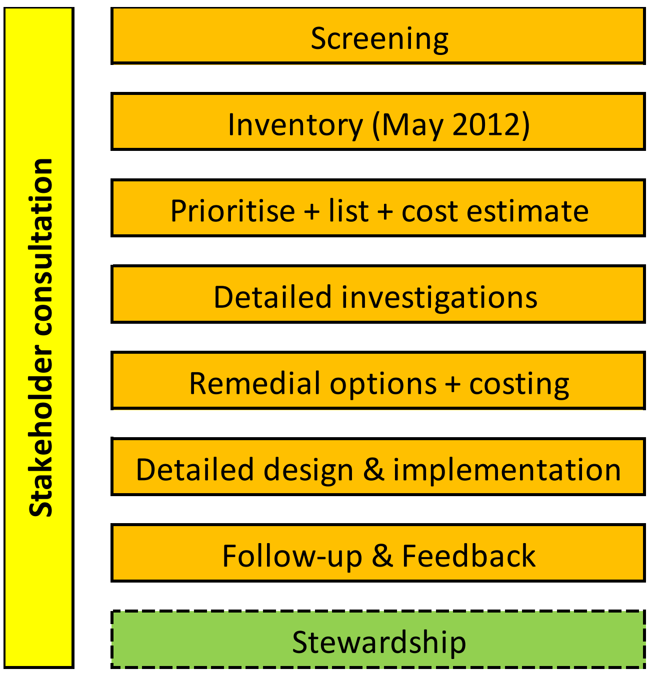
# Supporting document on closure methodologies for closed and abandoned mining waste facilities

## April 2012



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**Appendices:**


***AI*** Questionnaire questions on abandoned facilities

***AII*** Project Summary: Prioritisation of abandoned non-coal mine impacts on the environment (separate document)

**AIII** The Legacy of abandoned mines: The context and the action in Portugal (separate document)

# 1. Introduction

## 1.1This document

The main objective of this document is to support the EU Member States in developing closure and rehabilitation strategies and plans for closed and abandoned mining waste facilities and to support bodies in charge of closed and abandoned extractive waste facilities in their work in relation to Article 20 of the Mining Waste Directive, MWD (Directive 2006/21/EC on the management of waste from the extractive industries) in accordance with Article 21 of the same directive. This supporting document describes, summarises and reviews methodologies for the rehabilitation of closed and abandoned facilities in a risk based framework. The document has received several valuable inputs from main stakeholders..

The methodologies for the rehabilitation an operating and a closed or abandoned facility does not differ in principle. However, for a closed or abandoned facility closure planning cannot be part of the design of the facility and must therefore by definition become a result of the existing situation (often called a "retrofit") which in many cases is difficult as much of the background information on the facility may be missing (how to obtain this information should be addressed within the inspection methodology).

The economic constraints in relation to the rehabilitation of closed and abandoned facilities are well known. However, the necessary prioritisation of the rehabilitation of closed and abandoned sites should be made primarily on risk-based decisions rather than economic considerations as the environmental and economic consequences of not implementing required rehabilitation measures may become significantly more costly than the adequate rehabilitation. Actually, benefits assessments carried out at rehabilitated UK sites generally show benefits are greater than costs (Potter, 2011).

## 1.2Legal background and mandate

The need for a supporting document on closure and rehabilitation of closed and abandoned extractive waste facilities originates from requirements of the MWD, in particular those in Articles 20 and 21.

### 1.2.1 Article 20

Inventory of closed waste facilities

> *"Member States shall ensure that an inventory of closed waste facilities, including abandoned waste facilities, located on their territory which cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment is drawn up and periodically updated. Such an inventory, to be made available to the public, shall be carried out by 1 May 2012, taking into account the methodologies as referred to in Article 21, if available."*

Throughout this document, based on Article 20, the expression **closed (mine) waste facilities** includes abandoned waste facilities.

A Sub-Committee under the Technical Adaptation Committee for the MWD has already given some guidance on how to perform the inventory of closed and abandoned extractive waste facilities as required in Article 20 in the *"Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by article 20 of the directive 2006/21/EC"* (can be downloaded from the Commission's web-site).

### 1.2.2 Article 21

In addition, this supporting document has been developed to support the information exchange between member states as outlined in Article 21 (b) which states that information exchange should be organised to facilitate

> "*the rehabilitation of those closed waste facilities identified under Article 20 in order to satisfy the requirements of Article 4. Such methodologies shall allow for the establishment of the most appropriate risk assessment procedures and remedial actions having regard to the variation of geological, hydrogeological and climatological characteristics across Europe.*"

## 1.3 Definitions

This document uses the same definitions of waste, extractive waste, extractive waste facility, site and closed or abandoned site as the *Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by article 20 of the directive 2006/21/EC.*

**Waste:** According to Article 3 of the MWD - Definitions, "waste "means any substance or object which the holder discards or intends or is required to discard".[1]

The scope of the MWD, and therefore the inventory required by Article 20, is defined in Article 2 and detailed in Preamble points (6), (9) and (10) of the Directive. It is confined to "extractive waste" defined as "waste resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries".

This means that closed and abandoned waste facilities should be inventoried only if they contain waste directly resulting from the prospecting, extraction, treatment and storage at land-based mines.

As detailed in Preamble (10) of the MWD, extractive waste which may be radioactive shall be included in the inventory but not for the aspects directly related to radioactivity which are a matter dealt with under the Treaty establishing the European Atomic Energy Community (Euratom).

**Waste facility:** According to Article 3 (15) - Definitions of the MWD, waste facility is defined as follows:

> ***waste facility*** *means any area designated for the accumulation or deposit of extractive waste, whether in a solid or liquid state or in solution or suspension, for the following time-periods:*
> *− no time-period for Category A waste facilities and facilities for waste characterised as hazardous in the waste management plan;*
> *− a period of more than six months for facilities for hazardous waste generated unexpectedly;*
> *− a period of more than one year for facilities for non-hazardous non-inert waste;*
> *− a period of more than three years for facilities for unpolluted soil, non-hazardous prospecting waste, waste resulting from the extraction, treatment and storage of peat and inert waste.*

[1] In the MWD waste is defined in Article 3 which refers to Directive 75/442/EEC. Directive 75/442/EEC has been replaced by Directive 2008/96/EC on Waste.

*Such facilities are deemed to include any dam or other structure serving to contain, retain, confine or otherwise support such a facility, and also to include, but not be limited to, heaps and ponds, but excluding excavation voids into which waste is replaced, after extraction of the mineral, for rehabilitation and construction purposes;*

Closed waste facilities do not have any time element to their definition and can be divided into two generic categories:

1. Heaps or tips, and
2. Lagoons or ponds, including tailings impoundments.

**Closed or abandoned waste facility:** These terms are not defined in the MWD. For this work a closed waste facility is a facility where mining activity has ceased. Closed waste facilities are facilities with an identified former owner or licensee that have been closed in accordance with former licences or regulations. Abandoned waste facilities are facilities without an identified former owner/licensee and/or not having been closed in a regulated manner.

Often throughout this document, the word(s) **facility** or **waste facility** is used for brevity in place of **closed or abandoned extractive waste facility**.

**Site**: According to Article 3 (28) - Definitions of the MWD ***site*** *means all land at a distinct geographic location under the management control of an operator.*

**Rehabilitation:** According to Article 3 (20) - Definitions of the MWD ***rehabilitation*** *means the treatment of the land affected by a waste facility in such a way as to restore the land to a satisfactory state, with particular regard to soil quality, wild life, natural habitats, freshwater systems, landscape and appropriate beneficial uses.*

Some clarification may be in place for the often used terms **restoration/ rehabilitation/ remediation/ reclamation/ regeneration** which are often used interchangeably. However, there are many formal definitions of each which apply in different circumstances. The Post Mining Alliances (http://www.postmining.org/post-mining-regeneration-glossary.php) have tried to summarise these different meanings of these words in a mine closure perspective to provide an explanation for each term:

**Restoration**, in an ecological sense, seeks to artificially accelerate the processes of natural succession by putting back the original ecosystem's function and form. In an archaeological sense, the term implies the repair of old man-made structures to something approaching the original style, often using traditional materials and methods.

**Rehabilitation** (to some extent a different explanation than the definition according to the MWD). Some ecosystems may have been changed so dramatically that a return to the original landscape is no longer possible and rehabilitation - a partial return to a previous state - could be the only option.

**Remediation** generally applies to the environmental clean-up of land and water contaminated by organic, inorganic or biological substances.

**Reclamation** is the process of converting derelict land to usable land and may include engineering as well as ecological solutions. Restoration and rehabilitation (as explained above) are both aspects of reclamation.

**Regeneration**: Increasingly, society is demanding more from post-mining landscapes so that they can return economic as well as ecological benefits to offset negative closure impacts. Regeneration implies that a broad socio-economic (and environmental) perspective is being taken, including the mine site but also the environment and communities beyond the mine site itself.

# 2. Existing guidance on closure of extractive waste facilities

First it has to be mentioned that almost all experience, existing guidance and literature on the subject relates to the closure and rehabilitation of ***mine sites*** – not only to the ***extractive waste facilities*** which are the scope of the MWD. This should be held in mind when reading this chapter.

**Note:** It is recommended to assume an integrated approach to the closure and rehabilitation of mine sites and not only focus on the waste facilities.

## 2.1 Categories of closed and abandoned facilities

A list of the main categories of closed and abandoned facilities and associated main threats is given in Table 1. Flotation became commonly available in the beginning of the 20th century tailings production and tailings ponds started to be built. Previous to that time, most extractive waste facilities consisted of heaps.

**Table 1.** Main categories of closed and abandoned extractive waste facilities and associated main threats.

| Main categories of facilities | Subcategories (examples) | Main associated potential impacts/problems |
|---|---|---|
| | | |
| **Ponds/lagoons**<br>Constructed for the disposal of waste in slurry or paste form which normally involves some kind of confining structure on top or below surrounding ground level. Different variations exist depending on location (valley type, paddock type, etc.), different dam construction methods (centre line, up-stream or down-stream methods, etc.), dam construction material (clay, moraine, tailings, etc.), deposition method for the tailings (under water deposition, beach deposition, etc.). | Tailings management facilities (TMFs)<br><br>Silt lagoons<br><br>Sludge ponds from sedimentation and deposition of sludge from water treatment | See table 2 |
| **Heaps**<br>Constructed for disposal of solid waste. Containing structures are normally not necessary. | Spent ore heap - waste from heap leaching. Normal leaching chemicals are cyanide or acids.<br><br>Waste-rock heap - waste from accessing the mineral resource.<br><br>Spoil heap - waste from sorting of ore.<br><br>Fine waste-rock dump - waste rock from sorting of ore by mechanical (e.g., gravity), optical or magnetic means. | See table 2 |
| **Lake disposal facilities** | From disposal of extractive waste in lakes | Contaminated sediments, contaminated water, unstable bottoms and relocation by waves and currents, loss of land and restrictions on land use |
| **Sea disposal facilities** | From disposal of extractive waste in the sea | Contaminated sediments, contaminated water, unstable bottoms and relocation by waves and currents, loss of land and restrictions on land use |
| **Riverine disposal facilities** | From disposal of extractive waste in rivers | Contaminated sediments, contaminated water, unstable bottoms and relocation by waves and currents, loss of land and restrictions on land use, trans-border effects |

Disposal of extractive waste, especially tailings, was relatively commonly done to lakes, rivers and into the sea in the beginning of the 20th century often with limited control of the consequences.

Historically extractive waste facilities were often abandoned without any concerns regarding potential risks to humans and the environments, nor with regard to visual impacts, land-scape integration, land-use or similar concerns. Table 2 gives examples of the main risks associated with closed or abandoned extractive waste facilities (heaps and ponds) in a source, pathway, receptor related concept.

**Table 2.** Examples of potential risks in terms of possible sources, pathways and receptors related to extractive waste facilities

| Potential risk | Potential source | Potential pathway | Potential receptor |
|---|---|---|---|
| | | | |
| Loss of structural integrity | Physical movement of waste, water and confining structures | Movement over land, and transport by surface water bodies, groundwater and air (fugitive dust) | Humans and the downstream environment (terrestrial and aquatic environment, groundwater, surface water) |
| Incorrect closure | May lead to physical or chemical instability of the facility and the waste | Air, soil, groundwater, surface water, sediments | Humans, the environment and facility structures |
| Contains hazardous waste | The waste itself (direct exposure and fugitive dust), leachate from the waste | Air, soil, groundwater, surface water, sediments | Humans and the environment, in particular surface water, groundwater and sediments |
| Contains dangerous substances/preparations | The aqueous phase of the waste in a tailings pond | Soil, groundwater, surface water, sediments | Humans and the environment (in particular surface water, groundwater and sediments), |

Note that the definition of facility excludes excavation voids from the definition. This, however, does not exclude that extractive waste placed into excavation voids may constitute a risk to the environment. Abandoned mine sites may contain additional objects, such as in-situ leached mineralisations that are not waste facilities, but pose many of the same risks to the environment. In addition, at closed and abandoned mine sites there are often waste present that do not originate from the extractive activity but rather from historical metallurgical activities, such as slag and cinders, which may pose a significant risk to the environment. Finally, until recently, extractive waste was used as easily accessible construction material at the mine site and in the surroundings without any consideration of potential environmental risks, e.g. in filling out land, building roads and railway embankments, etc. Extractive waste may consequently be scattered around the mine sites which may constitute a significant source of contamination to the environment.

## 2.2The problem

Since the inception of mining approximately 3,000 years ago, mining activities have left their mark on the landscape - normally as the ancient areas of excavation or sites of metal working. Although ancient scars remain, it is the mining and associated activities since the industrial revolution that have left the largest scars. Prior to the industrial revolution most mining was for high-grade materials and therefore required comparatively modest excavation and generated relatively limited amounts of waste products. With the industrial revolution and improved enrichment techniques came large scale, often open pit, mining. Such mining not only removed large tonnages of ore but also of waste rock and produced large quantities of tailings as well - all of which require rehabilitation upon mine closure. Unfortunately, such rehabilitation on closure did not take place until recent years, and today the developed nations, as well as the developing and emerging economies, are faced with the need for closure and rehabilitation of mines and mining waste facilities that represent almost a century of mining activities.

The need to deal with the closure and rehabilitation issue is increasing all over the world, owing to public health and safety issues and to increased awareness of environmental contamination and the importance of environmental preservation. Inadequate, improper or neglected mine or facility closure results in abandoned mine site problems (UNEP, 2001). Specifically for Europe, new environmental policies and legal requirements, such as the Water Framework Directive (2000/60/EC), introduce environmental quality standards that have to be complied with within a specified time frame.

For the future, in order to prevent history from repeating itself, the majority of countries have put in place policies and legislation that provide directly (within the national Mining Law) or indirectly (normally within the national Environmental Law but also within many Foreign Investment Laws) for comprehensive mine closure. In Europe, the implementation of the MWD (2006/21/EC) includes requirements of provisions for proper closure of operating and future mines within the European Union. Already closed or abandoned mines, however, need to be addressed predominantly on a national basis.

The topic of abandoned mines is particularly difficult because of the associated financial and legal liability implications. UNEP (2001) stated that the causes of inaction and lack of real progress in addressing this issue relate to:

- the fact that mine closure practices have changed; that expectations related to proper mine closure have changed; the lack of clearly defined or assumed responsibility;
- the lack of definition of what is an abandoned mine site;
- the absence of criteria and standards of rehabilitation and
- the real and perceived cost of rehabilitation.

The physical impacts of abandoned extractive waste facilities and mine sites include, but is not limited to:

- altered landscape; unused pits and shafts;
- land no longer usable due to loss of soil, pH, or slope of land;
- abandoned tailings and waste rock management facilities;
- changes in groundwater regime;
- contaminated surface and groundwater, contaminated soils and aquatic sediments;
- subsidence and
- changes in vegetation.

These problems have environmental, social and economic impacts on countries and individual communities due to: loss of productive land, loss or degradation of groundwater, pollution of surface water by dissolved metals, sediments or salts, fish affected by contaminated sediments, changes in river regimes, air pollution from dust or toxic gases, risk of failing structures and risk of accidents where humans fall into ponds, shafts and pits.

## 2.3History of closure and rehabilitation of abandoned mines

Initiatives to close and rehabilitate abandoned mines (called abandoned, orphaned, derelict, abandoned mine lands, etc.) have been taken worldwide. More than 20 - 30 years of experience can be drawn from these projects and their methodologies. The most widely known initiatives are probably the US Superfund programme and the Canadian National orphaned/abandoned mines initiative (NOAMI) initiative. Other early initiatives were taken in Australia, e.g., in New South Wales (Issues in the decommissioning abandoned mines – a New South Wales Perspective, Johnson D.A., )

Many years of experience have resulted in the fact that most systematic attempts to address the abandoned mine problem (including the waste facilities) have ended up with more or less the same strategic approach, which in brief consists of:

- Inventory (divided into two steps screening and then proper site inspection with a preliminary assessment)
- Ranking and listing sites by priority
- Detailed site investigation and quantification of problems
- Investigation of remedial options
- Stakeholder consultation and decision to implement remedial actions
- Detailed remedial design and implementation
- Follow-up and feedback

In order to increase the understanding and acceptance of the remediation programmes, an information and educational campaign should preferably be linked to the programme.

Similar schemes have been implemented in large and small countries like the USA, Canada, Portugal, in states like Texas, California, British Columbia, New South Wales and at river basin scale like the Tisza river basin and the Dalälven river basin.

Common for all programmes are the limited economical resources and the long-term approach. There is no "quick fix" and the work has to be systematic and ongoing for a long time in order to address all the sites that need reclamation and to obtain the desired results. The financing of the work differs between the various initiatives.

Johnson (1998) summarises 20 years of experience in mine rehabilitation in NSW and concludes:

- Rehabilitation programmes need sufficient funds to ensure adequate and permanent environmental improvements.
- Rehabilitation works beyond those necessary to ensure safety and eliminate health hazards should not be attempted if funds are not sufficient to ensure lasting environmental improvements.
- The end result of any rehabilitation programme should be self-sustaining sites, compatible with the surroundings and requiring minimal on-going maintenance.

Implemented rehabilitation programmes have encountered many problems and obstacles in their way when trying to perform closure and rehabilitation measures at abandoned sites. Problems encountered in various rehabilitation programmes include, but are not limited to (Tremblay G., 2005):

- Funding - various funding models have been explored including e.g., public funding, shared funding with industry, partnerships, The Canadian Noami project explored the following possibilities/combination of possibilities Federal/Provincial/Territorial cost-sharing arrangement, levies on mining industry production, government-industry partnerships, redirection of a portion of existing mining tax revenue, use of fund interest, fines, administrative penalties, donations etc. Trusts may also be an opportunity (http://www.ausimm.com.au/content/docs/abandoned_mine_management_in_australia.pdf).
- Defining responsibilities - e.g., multiple jurisdictions, international waters, reserves, and matters affecting fishery
- Legislative and institutional barriers to voluntary remediation – legislation does not encourage voluntary reclamation which e.g., could be performed by mining companies, authorities, communities and landowners. A need to exempt volunteers from being "Responsible Persons" or limit/eliminate liability under various laws when willing to carry out "Good Samaritan" remediation.

An additional complication which can be regarded both as an opportunity and a problem, is that closed and abandoned mines are often highly prioritised explorations objects for the mining industry. Furthermore, closed mines are commonly re-opened and old extractive waste is in several cases re-processed. The reprocessing may be due to increased commodity prices, improved processing technologies or to extract additional elements from the waste.

**Superfund and AML – USA**

Initial Abandoned Mine Land (AML) Strategies (USA) is the approach that the Bureau of Land Management (BLM) has adopted to remediate the AML problem in the USA (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands.html).

BLM estimates that some 500,000 sites exist in the USA, making the problem seem so big that there is a risk no action is taken. AML runs in parallel with the Superfund which is the US federal government's programme to clean up the nation's uncontrolled hazardous waste sites (including selected mine sites) (http://www.epa.gov/aml/).

The programme is committed to ensuring that National Priorities List hazardous waste sites are cleaned up to protect the environment and the health of all Americans.

The Superfund clean-up process is relatively complex. It involves steps taken to assess sites, place them on the National Priorities List, and establish & implement appropriate clean-up plans. This is a long-term clean-up process. In addition, the programme has the authority to conduct removal actions where immediate action needs to be taken; to enforce against potentially responsible parties; to ensure community involvement; involve states; and to ensure long-term protectiveness.

Over the past 20+ years, the project has located and analysed tens of thousands of hazardous waste sites, protected people and the environment from contamination at the worst sites, and involved others in clean-up.

The Superfund clean-up process begins with site discovery or notification to the EPA of possible releases of hazardous substances. Sites are discovered and reported by various parties, including citizens, state agencies, and the EPA Regional offices. Once discovered, sites are entered into the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), EPA's computerised inventory of potentially hazardous substance release sites. Some sites may be cleaned up under other authorities. EPA then evaluates the potential for a release of hazardous substances from the site through these steps in the Superfund clean-up process. Community involvement, enforcement, and emergency response can occur at any time in the process. A wide variety of characterisation, monitoring, and remediation technologies are used through the clean-up process. The steps followed within the programme are:

- Preliminary Assessment/Site Inspection: Investigations of site conditions. If the release of hazardous substances requires immediate or short-term response actions, these are addressed under the Emergency Response program of Superfund.
- National Priorities List (NPL) Site Listing Process: A list of the most serious sites identified for possible long-term clean-up.
- Remedial Investigation/Feasibility Study: Determines the nature and extent of contamination. Assesses the treatability of site contamination and evaluates the potential performance and cost of treatment technologies.
- Records of Decision: Explains which clean-up alternatives will be used at NPL sites. When remedies exceed 25 million dollars, they are reviewed by the National Remedy Review Board.
- Remedial Design/Remedial Action: Preparation and implementation of plans and specifications for applying site remedies. The bulk of the clean-up usually occurs during this phase. All new fund-financed remedies are reviewed by the National Priorities Panel.
- Construction Completion: Identifies completion of physical clean-up construction, although this does not necessarily indicate whether final clean-up levels have been achieved.
- Post Construction Completion: Ensures that Superfund response actions provide for the long-term protection of human health and the environment. Included here are Long-Term Response Actions (LTRA), Operation and Maintenance, Institutional Controls, Five-Year Reviews, Remedy Optimization.
- National Priorities List Deletion: Removes a site from the NPL once all response actions are complete and all clean-up goals have been achieved.
- Site Reuse/Redevelopment: Information on how the Superfund programme is working with communities and other partners to return hazardous waste sites to safe and productive use without adversely affecting the remedy.

**NOAMI – National orphaned/abandoned mines initiative**

In 1999 and 2000, a number of stakeholders put forth requests to Mines Ministers in Canada to establish a joint industry-government working group, assisted by other stakeholders, to review the issue of abandoned mines. The Ministers supported this initiative and requested that a multi-stakeholder workshop be organised to identify key issues and priorities.

At the Mines Ministers' Conference, September 2001, the Ministers agreed on the importance of a large-scale programme for the rehabilitation of orphaned/abandoned mines sites. The National Orphaned/Abandoned Mines Advisory Committee was established upon their request that a multi-stakeholder Advisory Committee be set up to study various issues and initiatives relating to the development of partnerships in the implementation of remediation programmes across Canada. The Advisory Committee takes direction from the Mines Ministers and reports back annually at the Mines Ministers' Conference via the Intergovernmental Workshop Group (IGWG) Secretariat.

Various Task Groups have been established to undertake in-depth analysis of a variety of issues and to provide recommendations and advice. These include Task Groups on:

- Information Gathering/Inventory
- Community Involvement
- Legislative and Institutional Barriers to Collaboration
- Funding Approaches
- Jurisdictional Legislative Review

Responsibilities of the Task Groups include:

- To undertake specific activities, analyses and reviews;
- To synthesise documents, studies and activities into a series of status reports and recommendations for review and approval;
- To ensure publications, documents and information generated undergo a peer review process by members and identified experts (as appropriate), and is acceptable to members prior to release into the public domain;
- To manage projects, with proper financial accountability, and to report;
- To oversee project completion;
- To request, evaluate and accept proposals for work and manage contracts.

Detailed information related to the NOAMI project together with reports and publications released by the project can be found at: http://www.abandoned-mines.org/home-e.htm.

## 2.4 Recent guidelines on mine closure

Numerous guidelines on mine closure and mine closure planning exist at a global scale (World Bank, IAEA, ICMM, UNDP, etc), national scale (e.g., the Finish Mine Closure Handbook, Swedish Guidelines, US, Canadian, etc) and industry sector guidelines. In addition, larger mining companies have developed their own company-specific guidelines for mine closure planning, implementation and follow-up.

Most existing guidance on mine closure is devoted to planned or operating mines. Furthermore, the guidance aim at the entire mine site and not only the waste facilities. Over the last years, mine closure has developed from being primarily a safety and environmental issue to also cover socio/economic aspects. Industry and governments have realised that they have the most direct responsibility for defining and ensuring comprehensive mine closure within the broader context of the issues of “social/economic equality” and “sustainable development”. This recognition of a broader context of mine closure has greatly expanded the scope of government responsibilities and needed actions. This can be clearly seen in recent guidance on mine closure planning issued by e.g., ICMM (2008) Integrated Mine Closure Planning Toolkit or the Namibian mine closure framework from the Chamber of Mines of Namibia (2010).

Some of the guidance given in the above mentioned guidance documents does not apply, or only applies in parts, to already abandoned mines (waste facilities). Actually, some guidance documents explicitly state that they are not intended for closed and abandoned mines (e.g., the 2004 European BAT document on management of tailings and waste-rock and the 2000 Strategic framework for mine closure by the Australian and New Zealand Minerals and Energy Council and the Minerals Council of Australia).

Nevertheless, much of the methodology described in the guidance on closure planning for future or operating mines may also be used on the abandoned mines (waste facilities) when it comes to planning the closure, rehabilitation and follow-up of a specific mine (waste facility).

Specific guidance closure and rehabilitation of abandoned sites (waste facilities) can be found in, e.g., 2010 Abandoned Mine Land Programme Policy Handbook by United States Department of the Interior Bureau of Land Management, Abandoned mine site characterisation and clean-up handbook by the US Environmental Protection Agency, Abandoned mine lands site discovery process by US Environmental Protection Agency (1998).

In addition, experience from working with abandoned mines problems, closure and rehabilitation has fed back into recommendations for policy making regarding mining, e.g., The policy framework in Canada for mine closure and management of long-term liabilities: A guidance document by NOAMI (Cowan et al., 2010).

# 3. Questionnaire to Member States regarding closed and abandoned facilities

A questionnaire regarding closed and abandoned waste facilities was sent out to Member States as part of the information gathering process when preparing this document in order to address the following issues (where possible the information was requested to be divided into types of facilities and type of commodity extracted):

- Type of extractive activity that generated the waste (commodity and mining technique such as open pit, under-ground, in-situ leaching, sub-aqueous, other).
- Type and number of extractive waste facilities as a function of commodity and mining technique (if possible).
- Legislative framework regarding closed and abandoned mines (extractive waste facilities).
- Classification (Class A facilities or not class A facilities and if there are any facilities that are SEVESO facilities)
- Main environmental risks/problems related to the closed or abandoned extractive waste facilities (physical stability, ARD, contaminant leaching, dusting, erosion, land-use, toxicological risks, etc.)
- Risks of any trans-boundary effects
- Main closure options for the closed or abandoned facilities

The Questionnaire is included in Appendix 1.

No further efforts have been spent on evaluating the results from the questionnaire as the number of replies addressing closed and abandoned facilities was very limited. The reason for these poor results related to the questionnaire may be that member states are to report to the Commission the inventories of closed and abandoned sites in May 2012.

# 4. Safety

The safety, health, and welfare of all involved personnel that access an abandoned mine site is of paramount importance. Any closure and rehabilitation project should strive to eliminate or minimize physical or environmental conditions that may cause, or have the potential to cause harm, to persons, property, or the environment. Accordingly, safety and health risk assessments and management procedures should be an integral part of every project related to closed and abandoned mine sites. Guidance on health and safety practices can be found in, e.g., 2010 Abandoned Mine Land Programme Policy Handbook by United States Department of the Interior Bureau of Land Management

Note that abandoned mine sites constitute a large number of health and safety risks related to, e.g., unstable ground and slope conditions, unprotected steep slopes, falling or moving rocks, toxic gases, explosive gases, risk of drowning in shafts, pits, ponds etc., contaminated water, etc.

# 5. General framework for closure and remediation of closed and abandoned facilities

Based on the experience from completed and on-going remedial programmes for closed and abandoned mines it can be concluded that:

- There is a need for proper closure and remediation of closed and abandoned mine sites (waste facilities)
- A systematic long-term approach is necessary to address the issues
- Remedial programmes can be performed on many scales (national, regional, river basin, etc.)
- Financing the remedial programme is always an issue and resources are always limited
- Limited resources make it necessary to prioritise between sites (facilities) and to rank the sites in order of priority
- Rehabilitation works beyond those necessary to ensure safety and eliminate health hazards should not be attempted if funds are not sufficient to ensure lasting environmental improvements (this does not exclude implementing measures aimed at ensuring or preparing for such work)
- Any decision to perform remediation at a site should be based on solid information and go through a stakeholder consultation process
- The end result of any rehabilitation programme should be self-sustaining sites, compatible with the surroundings and requiring minimal on-going maintenance
- Follow-up and feedback is important in order to improve the remedial programme, the implemented remedial measures, to develop the regulatory framework for operating and future mining operations, promote stakeholder involvement, etc.

Each remediation programme will have to define its particular objectives and will have its particular possibilities and constraints. Nevertheless, a proposal for an overall programme strategy for rehabilitating closed and abandoned extractive waste facilities has been developed and adapted based on the experience from existing programmes. The proposed overall strategy, which should be seen as a possible starting point and as inspiration when developing the strategy, is outlined below and further discussed in the following sections, may contain:

- Screening and identifying facilities which <u>may</u> constitute a significant risk
- Establishing a site inventory of the facility and performing a first risk assessment to determine if the facility constitute a significant risk (and included in the list of facilities made public by 1 May 2012 fulfilling the criteria set out in article 20 of the MWD)
- Prioritising facilities based on risk and listing the facilities within the project area based on the priority (the definition of significant risk implies remedial measures are necessary, however, must be made due to limited resources).
- Detailed investigation of the facility and quantification of problems

- Investigation of remedial options and risk evaluation
- Stakeholder consultation and decision to implement remedial actions
- Detailed remedial design and implementation
- Follow-up and feedback
- Conducting education and outreach activities

Naturally, the objectives and constraints of the programme should be clearly defined before starting the programme. The proposed strategy is illustrated in figure 1.

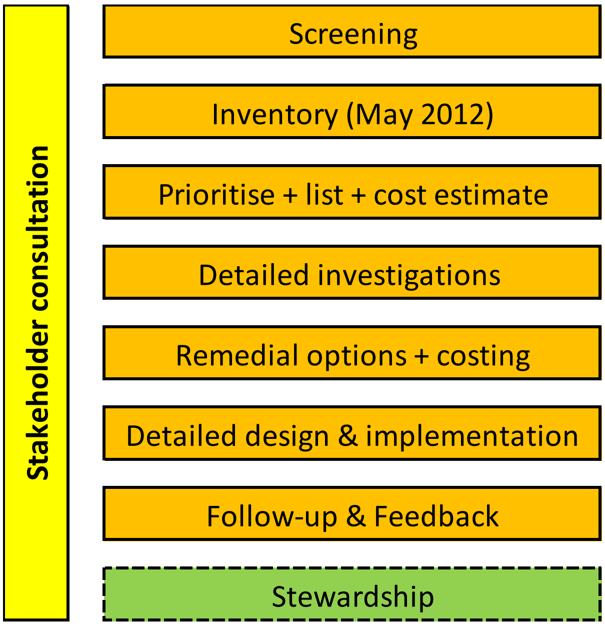


**Figure 1.** Schematic representation of proposed overall strategy for rehabilitating closed and abandoned extractive waste facilities.

The benefits of rehabilitation – environmental, socio-economic, human health etc may be significant. The UK Environmental Authority (Potter, 2011) have carried out several benefits assessments to support remediation of abandoned coal and metal mines with the results showing that the benefits are generally significantly greater than the costs.

Somewhat conflicting interests may exist as many abandoned mine sites (including waste facilities). In England and Wales, e.g., many old sites are protected as Sites of Special Scientific Interest (e.g. rare plants, geology) and Scheduled Ancient Monuments, and the Cornish mining area is now a UNESCO World Heritage Site (Potter, 2011).

## 5.1 Screening and identifying facilities which may constitute a significant risk

In the context of this document a facility which may constitute a significant risk is understood to be equivalent to the expression used in article 20 of the MWD implying a closed or abandoned facility that can *"cause serious negative environmental impacts or have the* *potential of becoming in the medium or short term a serious threat to human health or the environment".*

The European Commission has already given guidance on this in the Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by article 20 of the directive 2006/21/EC+ insert references . Therefore, screening and identifying facilities which may constitute a significant risk is not further discussed in this document. However, it is worth mentioning that considerable work related to screening and identifying closed and abandoned facilities was done within the PECOMINES project developed by the JRC in ISPRA. Further information and results from the PECOMINES project can be found at: http://viso.jrc.ec.europa.eu/pecomines_ext/main.html

## 5.2Establishing a site inventory and performing a first risk assessment

This site investigation is proposed to follow normal inspection routines based on:

- Planning of which facilities to inspect and the objectives of the inspections (overall inspection plan)
- Preparation of the inspection (desk work based on compiling and assessing available information, including but not limited to historical information, older investigations, environmental monitoring information)
- Site visit
- Evaluation and first risk assessment
- Reporting

For closed and abandoned sites much of the information necessary to perform an initial risk assessment is likely to be missing. This means that field investigations including some degree of sampling of deposited waste, water, sediments etc. may have to be carried out. Geotechnical and hydrogeological studies/assessments may also be required. Nevertheless, at this stage of the process the studies are at a very basic level and the precautionary principle should be the guiding principle when assessments are made based on limited information and on the experience of the team working with the initial site inventory and risk assessment. More detailed studies are performed, if necessary, at a later stage, see Section 5.4.

The objective of the data gathering at the initial site inventory could include, but is not limited to:

- Assessing if the previously gathered information about the facility is correct regarding volumes, type of waste, location, reclamation status, etc.
- Assessing the physical stability of the facility and its confining structures (if any)
- Assessing any unsafe areas and determining if physical hazards are present;
- Assessing the chemical stability of the deposited waste and assessing the risk of impacts on surface and groundwater as well as contamination of sediments
- Assessing if exposed waste may constitute a human or ecological health risk
- Assessing risk of erosion (by wind and water)
- Assessing the water balance

- Assessing land use or restrictions of land use;
- Determining if environmental degradation has occurred or is occurring; and
- Determining if a quick response is necessary to reduce an existing or potential threat to public health or the environment.

The level of assessment should be relatively basic, however, detailed enough to establish if the facility constitute a significant risk or not, i.e., whether the facility *cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment*.

In addition, general objectives of any necessary remediation actions of the facility should be set at this stage.

Some valuable guidance and tips on performing the initial site investigation can be found in Abandoned Mine Lands Preliminary Assessment Handbook, USEPA, 1998. Various checklists have been developed elsewhere, e.g., within the US ICPDR M2 methodology.

Within the European context the UK abandoned non-coal mines project (NoCAM – see Annex II and http://publications.environment-agency.gov.uk/) is a recent example of how to carry out a large-scale strategic prioritisation exercise. By focusing on catchments (WFD water bodies), NoCAM were able to identify the highest priority sites (for water receptors) with historic data rather than having to collect new data. It turned out to be an effective way to focus scarce resources on the most polluting sites, particularly when there may be thousands of potential sites and assessment may be resource demanding.

## 5.3Prioritising sites based on risk and listing the sites based on the priority

Once it has been determined that remedial measures are necessary at a facility it is necessary to prioritise the facility (or the necessary remedial actions) together with the other facilities (remedial actions) within the programme area.

Prioritisation can be made in various ways and based on different criteria. Normally, any risks related to rehabilitation works necessary to ensure safety and eliminate health hazards would be of highest priority. Other risks, such as environmental impacts outside the mine site, impacts within the mine area, and visual impacts would be of lower priority at a specific site.

The site that contaminates the most might not be the first priority to be remediated due to strategic considerations related to, river basin management, location, proximity to housing, value/sensitivity/ of impacted environment/waters, access, cost benefit analysis, etc. For this reason, it is complicated to develop a scoring system that will rank and prioritise between facilities. However, a scoring system can be used as a tool to group facilities according to risk and then the final ranking will have to be made evaluating the different options at hand taking into account the available resources.

Different ranking/scoring systems are available in the literature for guidance, e.g., the Portuguese preliminary ranking system (Da Silva, 2003)[2]. However, if such a scoring system

[2] The US Bureau of Land Management (BLM) has within the AML project found the use of complex point-ranking schemes to be of dubious value, as time is then spent explaining why the sites with the most points are

is to be used, it is recommended to develop a system that adjusts to the priorities of the specific remedial programme. Within the Pecomines project (Puura and D'Alessandro, 2005) a classification system for pressures related to hazardous water emissions from mine sites - comparison of pressures in ten EU Accession Countries was developed.

Other issues that do not affect the evaluation of the need for remedial measures, but might influence how the facility is prioritised include, but are not limited to (Johnsson, 1998):

- Land ownership
- Nature of pollution
- Nature of public risk
- The likelihood of further mining or exploration that may affect the facility
- Requirements for continuing maintenance
- The likelihood of reaching good final results within budget constraints.

General objectives of the remedial measures can be expressed as, e.g., risk-reduction, reduction of contaminant load or volume, reduction of emission of contaminates to the surrounding, reduced exposure, reduced erosion, protection of natural resources, protection of the land-use or other interests.

## 5.4Detailed site investigation and quantification of problems

If, based on the initial site assessment, it is decided that remedial measures are required at a facility, a detailed site investigation is necessary in most cases as a basis for any further decisions on required remedial actions and risk evaluation. The information may need to be complemented and extended in order have sufficient information and data. The objective of the detailed site investigation is to:

- Collect sufficient information to fully understand the reasons and extent of the problem.
- Collect sufficient information to be able to evaluate potential remedial options.

In order to be able to evaluate the situation and the effect of potential remedial options it may be necessary not only to investigate the actual facility but also the surroundings which leads to the development of a conceptual model and understanding of the site. Additional investigations may include, e.g., characterisation of deposited waste and its current condition, effects on the recipient, more detailed geotechnical design, construction and status of structures and underground, hydrological investigations, information required in order to be able to assess various remedial options, etc. It may also be relevant to revisit the initial risk assessment and review it based on the new and more detailed information obtained. The risk

not the ones being addressed, for various reasons. Prioritization is a matter of perception. Sometimes it makes sense to think of "bands" or groups of sites with common characteristics as being essentially equivalent for funding purposes. Additionally, more often than not, other determining factors influence which sites get addressed first, such as: available agency resources, litigation (or lack thereof!), and external pressures.

assessment at this stage should give guidance on which risks the facility is related to, what is the risk associated with the current contaminant load today and the expected future load, how much and what type of risk reduction is required in the short- medium- and long-term, if the remedial actions should be oriented towards the contaminant sources, the transport of contaminants, exposure pathways or the receptor. The strategy is illustrated in figure 2.

It is important to have sufficient information as a basis for any remedial measures in order to avoid spending the resources on the facilities, the wrong measures or on measures that do not obtain the desired results.

The detailed site investigation may change the ranking between sites as more information becomes available.

Within the the UK Prioritising of abandoned non-coal mine impacts on the water environment (NoCAM) Project funded by Defra, Welsh Government and DCLG (managed by Environment Agency) to prioritise rivers most impacted by abandoned metal mines and posing greatest risk of failing aims of Water Framework Directive. The project has produced 13 reports and a non-technical summary (Annex II). The project publications provide a timely European example of dealing with abandoned mines. In particular it is worth mentioning:

- Report 2: The national picture (England & Wales)
- Report 12: Future management of abandoned non-coal mine water discharges. This sets out a framework for how to deal with pollution from mine waters and mine wastes. It also estimates the costs of cleaning up this pollution in England & Wales.
- Report 13: Hazards and risk management at abandoned non-coal mine sites.

The reports are available at http://publications.environment-agency.gov.uk.

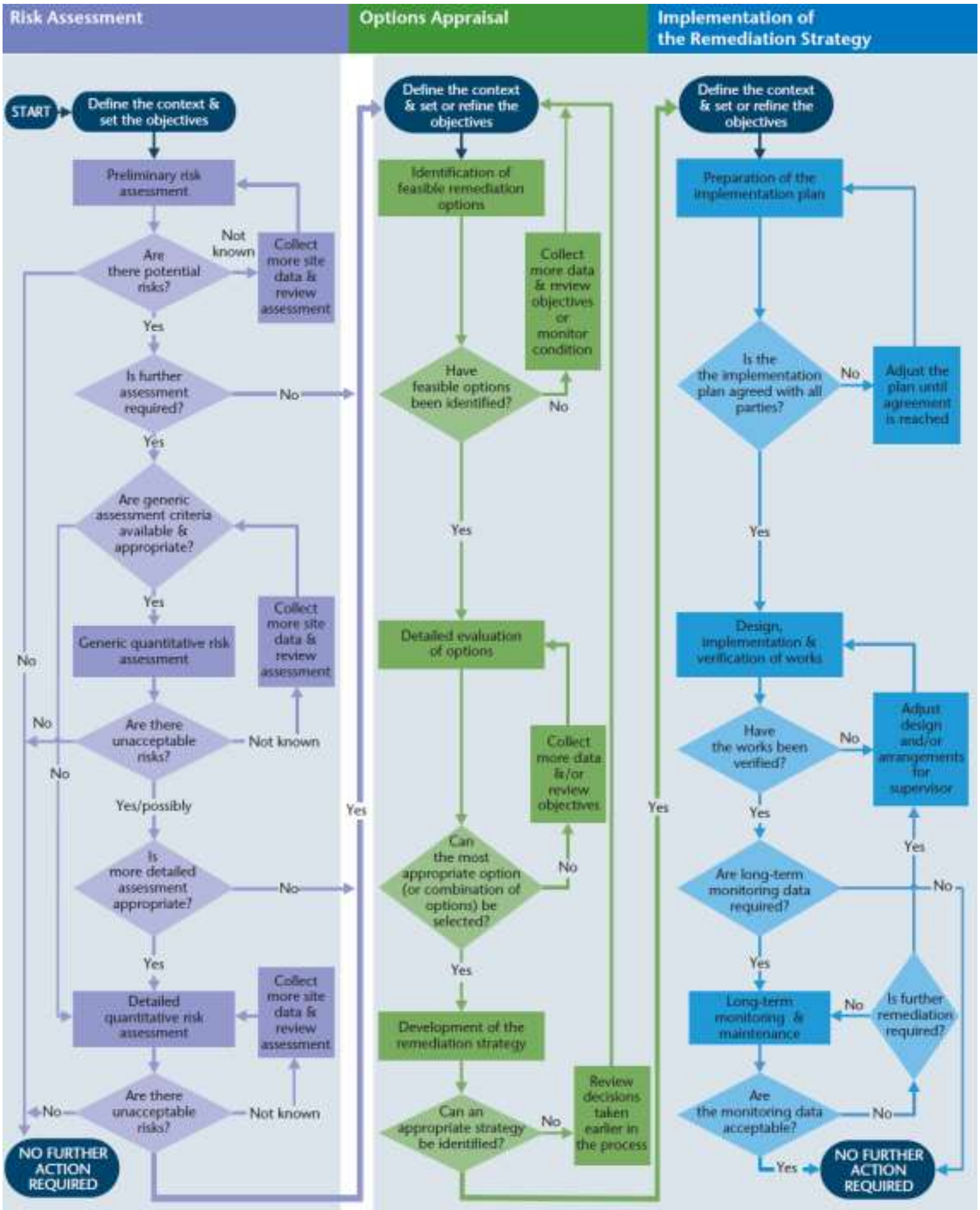


**Figure 2.** Schematic representation of proposed strategy for risk assessment, evaluation of remedial option and implementing and evaluating such remedial options for closed and abandoned extractive waste facilities (from Defra-EA "Model procedures for the management of land contamination").

## 5.5Investigation of remedial options and risk evaluation

During the investigation of potential remedial options it is evaluated which of all potential remedial measure (or combination of measures) is the most appropriate for the specific facility. The investigations will end up in the risk evaluation by which the chosen or recommended remedial option is selected. The potential risk reduction with each remedial alternative is assessed.

The starting point for the investigation of remedial alternatives is the overall remedial objectives set for the programme and the facility (site) and the results of the risk assessment. The potential remedial measures are evaluated against different criteria and the options that do not fulfil the objectives or that are not technically feasible are eliminated. Thereafter the remaining options are assessed with regard to costs, technical possibilities and shortcomings, risk during and after the implementation and their impact on the environment. The following approach is suggested by (Guidelines for preparing a mining site rehabilitation plan and general mining site rehabilitation requirements, Ministry of Natural Resources, Quebec, Canada, 1997):

First select potential methods using the available documentation (bibliography). Using selection and weighting criteria, the proponent must analyse the various rehabilitation scenarios based on information from the relevant documentation. His comments must show:

- that the rehabilitation method is appropriate for the site;
- the main advantages and disadvantages of each method;
- the cost/benefit ratio of the solution selected.

For the options that are assessed as fulfilling the objectives and as technically feasible the risk evaluation will result in a balance of total environmental and safety results (positive and negative) of the options, the technical risks of the options, and the costs related to the different options. In this way the risk evaluation will serve as a basis for the decision of the selected remedial option (combination of options) for the facility. The risk evaluation is preferably performed in close co-operation with all involved parties and sometimes also involving stakeholders.

The result of the risk evaluation will be a proposal of the remedial measure (combination of measures) to implement. The following approach is suggested by (Guidelines for preparing a mining site rehabilitation plan and general mining site rehabilitation requirements, Ministry of Natural Resources, Quebec, Canada, 1997):

The proponent must describe the cost for each proposed rehabilitation scenario, comparing the costs related to the different possibilities studied for each activity. Information sources and bibliographical references must be included for easy data access.

- Provide all working hypotheses used to compare and select mining site rehabilitation methods.
- Present the selection and weighting criteria the evaluation criteria for the proposed rehabilitation methods. The method chosen (checking systems, interrelations grids, etc.) and the elements used to support the proposal must be explained. The following elements should be included:

    1. feasibility (technically and economically proven methods);
    2. efficiency and reliability of the methods used;
    3. durability (mid-term and long-term given environmental restrictions);
    4. inspection and maintenance needs;

5. site safety;
6. cost (short-term and long-term);
7. risks associated with environmental impact.

In evaluating risks associated with environmental impact, the proponent should consider events that might occur after rehabilitation work (short-, medium- and long-term). He must also consider structural reliability (deficiency risks, risks associated with recurrence periods) and proposed methods, the extent of potential impacts and control capacity in the event of reduced performance or breakage. The analysis must take potential impacts on the human and natural environments into account.

At this stage it is possible to formulate detailed measurable objectives for the remedial measures. The detailed measurable objectives are the objectives necessary to reach the overall objectives and they should be formulated in a way that they are possible to measure and control by implementing a control programme (see section 5.8).

The Defra-EA "Model procedures for the management of land contamination" sets out a comprehensive framework that can be applied to mine sites (although it focuses on the UK situation the approach is generic). It can be found on the UK Environment Agency's web-site at http://www.environment-agency.gov.uk/research/planning/33740.aspx. The report gives a schematic representation of the site specific risk assessment, evaluation of remedial options and implementation of remedial strategy which is general enough also to be applicable to closed and abandoned mines.

## 5.6Stakeholder consultation and decision to implement remedial actions

The remediation of abandoned extractive waste facilities normally affects various authorities, land owners, neighbours, and other stakeholders. In order to obtain optimal the support for the measures stakeholder consultations are recommended. For some measures, permitting may be required which also will imply stakeholder consultations.

The importance of stakeholder consultations cannot be sufficiently emphasised, which is shown be the experience from other programmes for the remediation of abandoned mines around the world. Various stakeholders may have their focus on aspects that may not have been fully covered in the planning process. Post-closure land use is often more of an issue for neighbouring houses, whilst recipient water quality may be highlighted by authorities and fishing clubs. Thought should be given on how to manage expectations or managing conflicting views.

Stakeholder engagement is essential, but it is recommended that such liaison is appropriately targeted/phased during investigations. It is recommended that stakeholder engagement occurs at a number of points during the overall timeframe of a remediation project, as appropriate to the task at hand. Various means can be used, including information meetings, web-based information, specific meetings with targeted stakeholders, formation of interest groups, etc.

Based on the evaluation of remedial options, the risk evaluation and the stakeholder consultations, the decision on which option to implement can be taken.

## 5.7Detailed remedial design and implementation

Once the remedial measures to implement have been determines the detailed design and construction requirements can be developed and implemented. Necessary permits (if any) need to be obtained.

## 5.8Follow-up and feedback

It is important to document the entire programme process, the overall objectives, the site specific investigations, the process of choosing remedial option, the measurable objectives, the stake holder consultation process, the design, the construction phase and "as built", results from control programme, etc. The documentation should include technical, scientific, and economical aspects of the programme as well as other aspects. The purpose of the documentation is to improve the process, serve as a basis for further risk communication, for planning processes etc.

The follow-up of the remedial measures should consist of a control programme containing, but not limited to:

- Construction/implementation control
- Performance control
- Reference control

## 5.9Conducting education, research and outreach activities

However necessary remediating abandoned extractive waste facility may be, the public knowledge about mining in general and abandoned site remediation in particular is very limited. In addition, proper closure of mine sites is a relatively new concept, which is still an evolving science. In particular, cost effective remedial measures needs to be further developed and the actual performance of applied methods needs to be further documented and understood.

The costs involved in remediating abandoned mine sites is considerable, and in order to gain support and funding for future remedial programmes and the implementation of on-going programmes, outreach activities are required.

# 6. Guidance on Remedial options

## 6.1Re-opening of mining activity or re-processing of waste

If economically viable, the re-opening of mining activities at the site or the re-processing of old waste may be one of the environmentally attractive and cost effective remedial options for closed and abandoned mines. This may be feasible due to increasing commodity prices making mining of previously unprofitable mineralisation's economically viable, additional exploration efforts, improved mineral processing techniques or a different focus on value minerals mining activities may be re-opened at a closed or abandoned site. This alternative should always be held in mind when exploring rehabilitation options for closed and abandoned mines and prioritising remedial measures between sites. Such a re-opening possesses an opportunity which may be a cost effective way to permanently close waste facilities by re-using the affected foot-print or reprocessing the waste followed by a planned and designed closure. It is recommended to facilitate such reopening of sites where possible and not adding unnecessary administrative burden on projects that can lead to the rehabilitation of closed or abandoned sites.

## 6.2Permanent remedial options

Numerous publications are available on available remedial options for extractive waste facilities as reflected in the list below. In addition, there is comprehensive guidance on specific chemical, technical and geotechnical issues specifically related to extractive waste facilities. The list below only gives examples of the available literature on the subject and it is recommended that specific literature is consulted for each type of extractive industry as the suitable remedial measures vary considerable depending on waste type, the geochemical characteristics of the waste, the climatic and hydrological conditions at the site, available cover materials, etc.

Closure techniques and remedial options are discussed in, e.g.:

Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities, European Commission, JRC, Institute for Prospective Technological Studies, Seville, Spain. Produced in 2004 but formally adopted by the EU Commission as 2009/C81/06 on 7 January 2009.

The Closure Handbook, Environmental Techniques for the Extractive Industries. Heikkinen et al., 2008.

IAEA provides guidance on closure of waste facilities within the uranium mining industry in publications such as:

Guidebook on good practice in the management of uranium mining and mill operations and the preparation for their closure, IAEA, 1998.

Environmental contamination from Uranium Production Facilities and their Remediation Proceedings of an International Workshop Lisbon, 11–13 February 2004. IAEA, 2004.

ICOLD has published guidance on closure of tailings management facilities in in publications like:

Bulletin 106. A guide to Tailings Dams and impoundments - Design, construction, use and rehabilitation. ICOLD, 1996.

A new ICOLD Bulletin on closure aspects of tailings dams is about to be published titled:

Sustainable design and post-closure performance of tailings dams. ICOLD Bulletin XXXX, 2011. This guidance is expected to be published by the end of year 2011 and it will be available at www.icold-cigb.net

Acid Rock Drainage is one of the major issues related to the closure and remediation of extractive waste facilities containing sulphide waste. Guidance on characterisation, prediction, prevention, control, treatment and monitoring of ARD is given in, e.g.:

GARD-Guide (Global Acid Rock Drainage Guide), INAP, continuously up-dated and available at www.gardguide.com

The MEND Manual Volumes 1 to 6 on the sampling and analysis, characterisation, prediction, prevention, control, treatment and monitoring of ARD published by MEND, 2000. Available at http://www.mend-nedem.org/reports/categories-e.aspx.

The PYRAMID Engineering Guidelines for passive remediation of acidic and/or metalliferous mine drainage and similar wastewaters. Available at: www.imwa.info/piramid/files/PIRAMIDGuidelinesv10.pdf

The European Commission is developing guidance on characterisation and sampling of extractive waste and cyanide through CEN TC 292. These guidance documents are expected to be published during year 2011/12.

## 6.3Indicative list on remedial options for common problems

The measures to implement need to be evaluated for each particular facility to close. However, some of the most common risk factors, rehabilitation objectives and potential remediation strategies for tailings and waste-rock facilities are indicated in tables 3 and 4. More examples are given in the references outlined above and in Appendix III “The Legacy of abandoned mines: The context and the action in Portugal”.

**Table 3.** Example of risk factors, rehabilitation objectives and potential remediation strategies for tailings management facilities (modified from Heikkinen et al, 2008).

| Potential risk factors | Rehabilitation objectives | Examples of remediation methods |
|---|---|---|
| **PHYSICAL STABILITY ISSUES** | | |
| Safety of tailings dams | • Factor of safety > 1.5 for static conditions<br>• Sufficient discharge capacity<br>• Resistance to erosion, including extreme events | • Landscaping, particularly of sloping surfaces; discharge and drainage systems; retaining embankments; contoured furrowing to arrest erosion; revegetation; regular inspections and monitoring |
| General safety | • Compliance with safety requirements | • Prevention of public access; fencing off dangerous areas, displaying clear warning signs<br>• Periodic inspections |
| Dust generation, winnowing and accumulation of silt or slime | • Prevention of dust ablation and erosion | • Revegetation programs, settling ponds, contoured erosion furrows |
| Disruption to surface runoff and groundwater recharge | • Management of surface water in and around tailings area | • Landscaping and drainage channels |
| **CHEMICAL STABILITY ISSUES** | | |
| Generation of acid mine drainage and/or leaching of hazardous metals; Leaching of residual processing chemicals and other pollutants, high metal content in tailings | • Compliance with water quality objectives, soil quality objectives | • Containment and active or passive treatment of influenced waters; covering tailings with impermeable compacted layers; monitoring of drainage water quality; raising water table (anoxic conditions), ongoing monitoring<br>• Monitoring and management of water chemistry and hydrology |
| **LAND USE ISSUES** | | |
| Negative aesthetic impact; Limitations on post-closure activities | • Restoration to functional ecosystem, with recreational value | • Landscaping of impoundment surface and embankment slopes; revegetation programs |

**Table 4.** Example of risk factors, rehabilitation objectives and potential remediation strategies for waste-rock management facilities (modified from Heikkinen et al, 2008).

| Potential risk factors | Rehabilitation objectives | Examples of remediation methods |
|---|---|---|
| **PHYSICAL STABILITY ISSUES** | | |
| Subsidence and slope failure, erosion, impact on surface runoff and groundwater infiltration | • Mitigation of slope instability, erosion and siltation | • Landscaping with slope reduction and furrowing, drainage systems, settling ponds, earthen and rock retaining walls, revegetation programs, site monitoring |
| Safety | • Compliance with established safety guidelines | • Prevention of public access; fencing off dangerous areas, displaying clear warning signs |
| Disruption of surface runoff and groundwater infiltration and migration | • Management of surface water drainage and runoff, ensure effective groundwater recharge | • Landscaping and furrowing, containment and drainage channel systems |
| **CHEMICAL STABILITY ISSUES** | | |
| Generation of acid mine drainage and/or leaching of metals or contaminants, high metal content in waste rock | • Compliance with water quality objectives and soil quiality objectives | • Containment and active or passive treatment of mineinfluenced waters; monitoring drainage water quality; using impervious cover on waste rock pile; elevation of water table (anoxic conditions), ongoing site monitoring<br>• Monitoring and management of water chemistry, hydrology and potential pollutant migration |
| **LAND USE ISSUES** | | |
| Negative aesthetic impact; Limitations on post-closure activities | • Restoration to natural state, other forms of land use compatible with sustaining natural ecosystem diversity<br>• Utilization of waste rock | • Landscaping and slope reduction, revegetation programs, use of waste rock as mine backfill and/or in earthworks |

## 6.4 Indication of costs related to remediation of facilities

Closure costs vary significantly between mine sites as stated by the World Bank and the International Finance Corporation 2002[3]. The costs of physical mine closure vary greatly, depending on the age, location, and type of mine and mineral extracted. The variation depends largely on the physical size of the mine and its infrastructure, the history of environmental management (often linked to the age of the mine), the volume of waste, and the geological characteristics (acid rock drainage issues, for instance). Other factors that influence closure costs include the access to suitable cover materials. Here the use of alternative materials, such as residual and recycled materials, may be an option attractive both from an environmental and a cost perspective, e.g. sewage sludge, ashes, slag, fibres and ashes from paper and pulp industries, agricultural waste, etc.

Closure costs (mainly related to the extractive waste) for environmental issues range from less than US$1 million (approximately 0,7 M€) each for small mines to hundreds of millions of dollars for large open pit mines. More typically, closure costs will range in the tens of millions of dollars. Preliminary research indicates that medium-size open pit and underground mines operating in the past 10 to 15 years cost US$ 5-15 million (approximately 3-12 M€) to close, while closure of open pit mines operating for over 35 years, with large waste and tailings facilities, can cost upwards of $50 million (approximately 35 M€). The occurrence of acid rock drainage adds significant costs in terms of dam and dump rehabilitation and water treatment. Costs need to be estimated on a case by case basis.

An indication of the closure costs related to potentially acid generating extractive waste can be obtained by estimates performed within the Canadian MEND programme[4]. Based on nationwide estimates of the total amount of extractive waste in Canada and assessing how much of that waste is potentially acid generating they estimated the total closure cost for the potentially acid generating waste under different assumptions regarding remedial method, table 5.

As can be concluded from table 5, the MEND programme estimated a total closure cost of approximately 1-2 $/ton tailings and 0,6-3 $/ton waste-rock. This can e.g., be compared to the closure costs for the failed tailings pond in Aznalcóllar which contained approximately 13 Mton of tailings and cost approximately 37 M$, resulting in a cost of approximately 2,8 $/ton. The cost for treatment of the collected drainage from the closed pond for at least 10 years will have to be added to obtain the total cost for the closure of the Aznalcóllar TMF.

[3] World Bank and IFC, 2002. It's Not Over When It's Over: Mine closure around the world.

[4] MEND, 2000. MEND Manual Volume 4. Prevention and control. Available at http://www.mend-nedem.org/reports/categories-e.aspx.

**Table 5.** Indicative costs for remediation potentially acid generating extractive waste based on nation wide estimates of the total amount of extractive waste in Canada and assessing how much of that waste is potentially acid generating they estimated the total closure cost for the potentially acid generating waste under different assumptions regarding remedial method (modified from MEND, 2000).

| Parameter | Tailings | Waste rock |
|---|---|---|
| Total amount in Canada (Mton) | 6800 | 6290 |
| Total amount of potentially acid generating waste in Canada (Mton) | 1900 | 750 |
| **Closure option** | | |
| Collect and treat ($billions) | 1,5 | 0,4 |
| Water cover ($billions) | 1,5 | N.A. |
| Dry cover ($billions) | 3,2 | 0,7 |
| Relocate to pit ($billions) | N.A. | 2,1 |
| **Unit costs** | | |
| Collect and treat ($billions) | 0,8 | 0,6 |
| Water cover ($billions) | 0,8 | N.A. |
| Dry cover ($billions) | 1,7 | 0,9 |
| Relocate to pit ($billions) | N.A. | 2,8 |
| Cost range per ton ($/ton) | 0,8-1,7 | 0,6-2,8 |

Further guidance regarding unit costs for remedial measures is given in the Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities (BREF, 2008).

# 7. References


BAT/Best available technology/BREF (2009): The Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities, European Commission, JRC, Institute for Prospective Technological Studies, Seville, Spain. Produced in 2004 but formally adopted by the EU Commission as 2009/C81/06 on 7 January 2009.

Da Silva Daniel F (2003). Abandoned mines in Portugal – A programme of rehabilitation. In: Puura, E. et al (editors). Proceedings of the Workshop 'Mine and Quarry Waste – The Burden from the Past', Orta, May 27-28, 2002. European Commission Joint Research Centre, pp 69-72.

Johnsson, 1998. Issues in the decommissioning of abandoned mines – A New South Wales Perspective. In proceedings to Workshop on Environmental Issues in Decommissioning of Mine Sites (Eds. C.J. Asher and L.C. Bell), pp 89-93.

Potter H, 2011. Comments on first draft of Closure guidance for closed and abandoned mine sites.

Puura and D'Alessandro, 2005. A classification system for pressures related to hazardous water emissions from mine sites - comparison of pressures in ten EU Accession Countries. Available at: http://viso.jrc.ec.europa.eu/pecomines_ext/results/index.html

**Appendices:**

| | |
|---|---|
| ***AI*** | **Questionnaire questions on abandoned facilities** |
| ***AII*** | **Project Summary: Prioritisation of abandoned non-coal mine impacts on the environment (separate document)** |
| **AIII** | **The Legacy of abandoned mines: The context and the action in Portugal (separate document)** |

## Appendix 1

## Questionnaire questions on abandoned facilities

# Appendix 1

## Questionnaire questions on abandoned facilities

| Commodities | | Type of extraction activity | | | | | Type of waste facilities | | | | | | Classification of facilities | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Open pit/quarry | Underground | In-situ leaching | Sub-aqueous | Other | Tailings pond | Tailings heap | Waste rock dumps | In pit disposal | Underground disposal | Other | Number of Class A facilities | Seveso facilities |
| General Information | | | | | | | | | | | | | | |
| Legal situation | | | | | | | | | | | | | | |
| METALS | | | | | | | | | | | | | | |
| INDUSTRIAL MINERALS | | | | | | | | | | | | | | |
| Stone: | | | | | | | | | | | | | | |
| MINERAL FUELS AND RELATED MATERIALS | | | | | | | | | | | | | | |

| Commodities | | Main environmental issues | | | | | | Risk of transboundary effects | Main Closure options for waste facilities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Physical dammage | Contaminant leching | ARD | Dust | Land use | Other | Please specify site/mining area and type of potential effect | Tailings pond | Tailings heap | Waste rock dumps | In pit disposal | Under ground disposal | Other |
| General Information | | | | | | | | | | | | | | |
| Legal situation | | | | | | | | | | | | | | |
| METALS | | | | | | | | | | | | | | |
| INDUSTRIAL MINERALS | | | | | | | | | | | | | | |
| Stone: | | | | | | | | | | | | | | |
| MINERAL FUELS AND RELATED MATERIALS | | | | | | | | | | | | | | |