5 BEST AVAILABLE TECHNIQUES FOR THE MANAGEMENT OF TAILINGS AND WASTE-ROCK IN MINING ACTIVITIES

5.1 Introduction

In understanding this chapter and its contents, the attention of the reader is drawn back to the preface of this document and in particular the fifth section of the preface: “How to understand and use this document”. The techniques and performance levels presented in this chapter have been assessed through an iterative process involving the following steps:

- identification of the key environmental and risk/safety issues for the sector
- examination of the techniques most relevant to address those key issues
- identification of the best environmental performance, on the basis of the available data in the European Union and worldwide
- examination of the conditions under which these performances were achieved; such as costs, cross-media effects, main driving forces involved in implementation of this techniques
- selection of the best available techniques (BAT) for this sector in a general sense.

Expert judgement by the European IPPC Bureau and the Technical Working Group (TWG) has played a key role in each of these steps and in the way in which the information is presented here.

On the basis of this assessment, techniques are presented in this chapter that are considered to be appropriate to the sector as a whole and in many cases reflect current performance of some sites within the sector. Where performance levels are presented, this is to be understood as meaning that those levels represent the environmental and safety performance that could be anticipated as a result of the application, in this sector, of the techniques described, bearing in mind the balance of costs and advantages inherent within the definition of BAT. In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross-media considerations, they are not considered to be appropriate as BAT for the sector as a whole. However, such levels may be considered to be justified in more specific cases where there are special driving forces.

The emission and consumption levels associated with the use of BAT have to be seen together with any specified reference conditions (e.g. averaging periods).

Where available, data concerning costs have been given together with the description of the techniques presented in the previous chapter. These give a rough indication about the magnitude of costs involved. However, the actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and the technical characteristics of the site concerned. It is not possible to evaluate such site-specific factors fully in this document. In the absence of data concerning costs, conclusions on economic viability of techniques are drawn from observations on existing sites.

It is intended that the general BAT in this chapter are a reference point against which to judge the current performance of an existing installation or to judge a proposal for a new installation. In this way they will assist in the determination of appropriate "BAT-based" conditions for the installation. It is foreseen that new installations can be designed to perform at or even better than the general BAT performances presented here. It is also considered that existing installations could move towards the general BAT levels or do better, subject to the technical and economic applicability of the techniques in each case.

In any case there is a need for site-specific solutions for the design, construction, operational, closure and after-care phases, as well as a permanent control and monitoring of tailings and waste-rock management due to the very different types of mineralisations, mining and mineral processing techniques available, and the different geological, geotechnical, hydrogeological and morphological conditions that occur on a case-by-case and site-by-site basis.

While this document does not set legally binding standards, it is meant to give information for the guidance of industry, Member States and the public on achievable performances, emissions, and consumption levels when using specified techniques.

For tailings and waste-rock management, BAT decisions are based on:

- environmental performance
- risk
- economic viability.

In particular, the consideration of risk is a very site-specific factor.

5.2 Generic

BAT is to:

- apply the general principles set out in Section 4.1
- apply a life cycle management approach as described in Section 4.2.

Life cycle management covers all the phases of a site’s life, including:

- the design phase (Section 4.2.1):
  - environmental baseline (Section 4.2.1.1)
  - characterisation of tailings and waste-rock (Section 4.2.1.2)
  - TMF studies and plans (Section 4.2.1.3), which cover the following aspects:
    - site selection documentation
    - environmental impact assessment
    - risk assessment
    - emergency preparedness plan
    - deposition plan
    - water balance and management plan, and
    - decommissioning and closure plan
  - TMF and associated structures design (Section 4.2.1.4)
  - control and monitoring (Section 4.2.1.5)
- the construction phase (Section 4.2.2)
- the operational phase (Section 4.2.3), with the elements:
  - OSM manuals (Section 4.2.3.1)
  - auditing (Section 4.2.3.2)
- the closure and after-care phase (Section 4.2.4), with the elements:
  - long-term closure objectives (Section 4.2.4.1)
  - specific closure issues (Section 4.2.4.2) for
    - heaps
    - ponds, including:
      - water covered ponds
      - dewatered ponds
      - water management facilities.

Furthermore, BAT is to:

- reduce reagent consumption (Section 4.3.2)
- prevent water erosion (Section 4.3.3)
- prevent dusting (Section 4.3.4)
- carry out a water balance (Section 4.3.7) and to use the results to develop a water management plan (Section 4.2.1.3)
- apply free water management (Section 4.3.9)
- monitor groundwater around all tailings and waste-rock areas (Section 4.3.12).

ARD management

The characterisation of tailings and waste-rock (Section 4.2.1.2 in combination with Annex 4) includes the determination of the acid-forming potential of tailings and/or waste-rock. If an acid-forming potential exists, it is BAT to firstly prevent the generation of ARD (Section 4.3.1.2), and if the generation of ARD cannot be prevented, to control ARD impact (Section 4.3.1.3) or to apply treatment options (Section 4.3.1.4). Often a combination is used (Section 4.3.1.6).

All prevention, control and treatment options can be applied to existing and new installations. However, the best closure results will be obtained when plans are developed for the site closure right at the outset (design stage) of the operation (cradle-to-grave philosophy).

The applicability of the options depends mainly on the conditions present at the site. Factors such as:

- water balance
- availability of possible cover material
- groundwater level

influence the options applicable at a given site. Section 4.3.1.5 provides a tool for deciding on the most suitable closure option.

Seepage management (Section 4.3.10)

Preferably the location of a tailings or waste-rock management facility will be chosen in a way that a liner is not necessary. However, if this is not possible and the seepage quality is detrimental and/or the seepage flowrate is high, then seepage needs to be prevented, reduced (Section 4.3.10.1) or controlled (Section 4.3.10.2) (listed in order of preference). Often a combination of these measures is applied.

Emissions to water

BAT is to:

- re-use process water (see Section 4.3.11.1)
- mix process water with other effluents containing dissolved metals (see Section 4.3.11.3)
- install sedimentation ponds to capture eroded fines (see Section 4.3.11.4.1)
- remove suspended solids and dissolved metals prior to discharge of the effluent to receiving watercourses (Section 4.3.11.4)
- neutralise alkaline effluents with sulphuric acid or carbon dioxide (Section 4.3.11.6)
- remove arsenic from mining effluents by the addition of ferric salts (Section 4.3.11.7).

The respective sections in Chapter 3 on emissions and consumption levels provide examples of the achieved levels. No correlation could be developed between the applied techniques and the available emission data. Therefore, in this document it was not possible to draw BAT conclusions with associated emission levels.

The following techniques are BAT for treating acidic effluents (Section 4.3.11.5):

- active treatments:
  - addition of limestone (calcium carbonate), hydrated lime or quicklime
  - addition of caustic soda for ARD with a high manganese content
- passive treatment:
  - constructed wetlands
  - open limestone channels/anoxic limestone drains
  - diversion wells.

Passive treatment systems are a long-term solution after the decommissioning of a site, but only when used as a polishing step combined with other (preventive) measures.

Noise emissions (Section 4.3.5)
BAT is to:

- use continuous working systems (e.g. conveyor belts, piplelines)
- encapsulate belt drives in areas where noise is a local issue
- first create the outer slope of a heap, and then transfer ramps and working benches into the heap's inner area as far as possible.

Dam design
In addition to the measures described in Section 4.1 and Section 4.2, during the **design** phase (Section 4.2.1) of a **tailings dam**, BAT is to:

- use the once in a 100-year flood as the design flood for the sizing of the emergency discharge capacity of a low hazard dam
- use the once in a 5000 – 10000-year flood as the design flood for the sizing of the emergency discharge capacity of a high hazard dam.

Dam construction
In addition to the measures described in Section 4.1 and Section 4.2, during the **construction** phase (Section 4.2.2) of a **tailings dam**, BAT is to:

- strip the natural ground below the retaining dam of all vegetation and huminous soils (Section 4.4.3)
- choose a dam construction material that is fit for the purpose and which will not weaken under operational or climatic conditions (Section 4.4.4).

Raising dams
In addition to the measures in Section 4.1 and Section 4.2, during the **constructional** and **operational** phases (Sections 4.2.2 and 4.2.3) of a **tailings dam**, BAT is to:

- evaluate the risk of a too high pore pressure and monitor the pore pressure before and during each raise. The evaluation should be done by an independent expert.
- use conventional type dams (Section 4.4.6.1), under the following conditions, when:
  - the tailings are not suitable for dam construction
  - the impoundment is required for the storage of water
  - the tailings management site is in a remote and inaccessible location
  - retention of the tailings water is needed over an extended period for the degradation of a toxic element (e.g. cyanide)
  - the natural inflow into the impoundment is large or subject to high variations and water storage is needed for its control
- use the upstream method of construction (Section 4.4.6.2), under the following conditions, when:
  - there is very low seismic risk

    - tailings are used for the construction of the dam: at least 40 – 60 % material with a particle size between 0.075 and 4 mm in whole tailings (does not apply for thickened tailings)
- use the downstream method of construction (Section 4.4.6.3), under the following conditions, when:
    - sufficient amounts of dam construction material are available (e.g. tailings or waste-rock)
- use the centreline method of construction (Section 4.4.6.4), under the following conditions, when:
    - the seismic risk is low.

Dam operation

In addition to the measures described in Section 4.1 and Section 4.2, during the **operational phase** (Section 4.2.3) of a **tailings pond**, BAT is to:

- monitor stability as further specified below
- provide for diversion of any discharge into the pond away from the pond in the event of difficulties
- provide alternative discharge facilities, possibly into another impoundment
- provide second decant facilities (e.g. emergency overflow, Section 4.4.9) and/or standby pump barges for emergencies, if the level of the free water in the pond reaches the pre-determined minimum freeboard (Section 4.4.8)
- measure ground movements with deep inclometers and have a knowledge of the pore pressure conditions
- provide adequate drainage (Section 4.4.10)
- maintain records of design and construction and any updates/changes in the design/construction
- maintain a dam safety manual as described in Section 4.2.3.1 in combination with independent audits as mentioned in Section 4.2.3.2
- educate and provide adequate training for staff.

Removal of free water from the pond (Section 4.4.7.1)

BAT is to:

- use a spillway in natural ground for valley site and off valley site ponds
- use a decant tower:
    - in cold climates with a positive water balance
    - for paddock-style ponds
- use a decant well:
    - in warm climates with a negative water balance
    - for paddock-style ponds
    - if a high operating freeboard is maintained.

Dewatering of tailings (Section 4.4.16)

The choice of method (slurried, thickened or dry tailings) depends mainly on an evaluation of three factors, namely:

- cost
- environmental performance
- risk of failure.

For tailings management, BAT is to apply:

- dry tailings management (Section 4.4.16.1)
- thickened tailings management (Section 4.4.16.2) or
- slurried tailings management (Section 4.4.16.3).

There are many other factors that influence the choice of the appropriate techniques for a given site. Some of these factors are:

- mineralogy of the ore
- ore value
- particle size distribution
- availability of process water
- climatic conditions
- available space of tailings management.

Tailings and waste-rock management facility operation

In addition to the measures described in Section 4.1 and Section 4.2, during the **operational phase** (Section 4.2.3) of **any tailings and waste-rock management facility**, BAT is to:

- divert natural external run-off (Section 4.4.1)
- manage tailings or waste-rock in pits (Section 4.4.1). In this case heap/dam slope stability is not an issue
- apply a safety factor of at least 1.3 to all heaps and dams during operation (Section 4.4.13.1)
- carry out progressive restoration/revegetation (Section 4.3.6).

Monitoring stability

BAT is to:

- monitor in a tailings pond/dam (Section 4.4.14.2):
  - the water level
  - the quality and quantity of seepage flow through the dam (also Section 4.4.12)
  - the position of the phreatic surface
  - pore pressure
  - movement of dam crest and tailings
  - seismicity, to ensure stability of the dam and the supporting strata (also Section 4.4.14.4)
  - dynamic pore pressure and liquefaction
  - soil mechanics
  - tailings placement procedures
- monitor in a heap (Section 4.4.14.2):
  - bench/slope geometry
  - sub-tip drainage
  - pore pressure
- also carry out:
  - in the case of a tailings pond/dam:
    - visual inspections (Section 4.4.14.3)
    - annual reviews (Section 4.4.14.3)
    - independent audits (Section 4.2.3.2 and Section 4.4.14.3)
    - safety evaluations of existing dams (SEED) (Section 4.4.14.3)
  - in the case of a heap:
    - visual inspections (Section 4.4.14.3)
    - geotechnical reviews (Section 4.4.14.3)
    - independent geotechnical audits (Section 4.4.14.3).

Mitigation of accidents

BAT is to:

- carried out emergency planning (Section 4.6.1)
- evaluate and follow-up incidents (Section 4.6.2)
- monitor the pipelines (Section 4.6.3).

Reduction of footprint

BAT is to:

- if possible, prevent and/or reduce the generation of tailings/waste-rock (Section 4.1)
- backfill tailings (Section 4.5.1), under the following conditions, when:
  - backfill is required as part of the mining method (Section 4.5.1.1)
  - the additional cost for backfilling is at least compensated for by the higher ore recovery
  - in open pit mining, if the tailings easily dewater (i.e. evaporation and drainage, filtration) and thereby a TMF can be avoided or reduced in size (Sections 4.5.1.2, 4.5.1.3, 4.5.1.4, 4.4.1)
  - use nearby mined-out open pits is available for backfilling (Section 4.5.1.5)
  - backfill large stopes in underground mines (Section 4.5.1.6). Stopes backfilled with slurried tailings will require drainage (Section 4.5.1.9). Binders may also need to be added to increase the stability (Section 4.5.1.8)
- backfill tailings in the form of paste fill (Section 4.5.1.10), if the conditions to apply backfill are met and if:
  - there is a need for a competent backfill
  - the tailings are very fine, so that little material would be available for hydraulic backfill. In this case, the large amount of fines sent to the pond would dewater very slowly
  - it is desirable to keep water out of the mine or where it is costly to pump the water draining from the tailings (i.e. over a large distance)
- backfill waste-rock, under the following conditions (Section 4.5.2), when:
  - it can be backfilled within an underground mine
  - one or more mined-out open pits are nearby (this is sometimes referred to as 'transfer mining')
  - the open pit operation is carried out in such a way that it is possible to backfill the waste-rock without inhibiting the mining operation
- investigate possible uses of tailings and waste-rock (Section 4.5.3).

Closure and after-care

In addition to the measures described in Section 4.1 and Section 4.2, during the **closure and after-care phase** (Section 4.2.4) of **any tailings and waste-rock management facility,** BAT is to:

- develop closure and after-care plans during the planning phase of an operation, including cost estimates, and then to update them over time (Section 4.2.4). However, the requirements for rehabilitation develop throughout the lifetime of an operation and can first be considered in precise detail in the closure phase of a TMF
- apply a safety factor of at least 1.3 for dams and heaps after closure (Section 4.2.4 and 4.4.13.1), although a split view concerning water covers exists (see Chapter 7).

For the closure and after-care phase of tailings ponds, BAT is to construct the dams so that they stay stable in the long term if a water cover solution is chosen for the closure (Section 4.2.4.2).

5.3 Gold leaching using cyanide

In addtion to the generic measures in Section 5.2, for all sites applying gold leaching using cyanide, BAT is to do the following:

- reduce the use of CN, by applying:
  - operational strategies to minimise cyanide addition (Section 4.3.2.2)
  - automatic cyanide control (Section 4.3.2.2.1)
  - if applicable, peroxide pretreatment (Section 4.3.2.2.2)
- destroy the remaining free CN prior to discharge in the pond (Section 4.3.11.8). Table 4.13 shows examples of CN levels achieved at some European sites
- apply the following safety measures (Section 4.4.15):
  - size the cyanide destruction circuit with a capacity twice the actual requirement
  - install a backup system for lime addition
  - install backup power generators.

5.4 Aluminium

In addition to the generic measures in Section 5.2 for all alumina refineries, BAT is to do the following:

- during operation:
  - avoid discharging effluents into surface waters. This is achieved by re-using process water in the refinery (Section 4.3.11.1 or, in dry climates, by evaporation
- in the after-care phase (Section 4.3.13.1):
  - treat the surface run-off from TMFs prior to discharge, until the chemical conditions have reached acceptable concentrations for discharge into surface waters
  - maintain access roads, drainage systems and the vegetative cover (including re-vegetation if necessary)
  - continue groundwater quality sampling.

5.5 Potash

In addition to the generic measures in Section 5.2 for all potash sites, BAT is to do the following:

- if the natural soil is not impermeable, make the ground under the TMF impermeable (Section 4.3.10.3)
- reduce dust emissions from conveyor belt transport (Section 4.3.4.3.1)
- seal/line the toe of the heaps outside the impermeable core zone and collect the run-off (Section 4.3.11.4.1)
- backfill large stopes with dry and/or slurried tailings (Section 4.5.1.6).

5.6 Coal

In addition to the generic measures in Section 5.2 for all coal sites, BAT is to do the following:

- prevent seepage (Section 4.3.10.4)
- dewater fine tailings <0.5 mm from flotation (Section 4.4.16.3).

5.7 Environmental management

A number of environmental management techniques are determined as BAT. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

BAT is to implement and adhere to an Environmental Management System (EMS) that incorporates, as appropriate to individual circumstances, the following features: (see Chapter 4)

- definition of an environmental policy for the installation by top management (commitment of the top management is regarded as a precondition for a successful application of other features of the EMS)
- planning and establishing the necessary procedures
- implementation of the procedures, paying particular attention to
  - structure and responsibility
  - training, awareness and competence
  - communication
  - employee involvement
  - documentation
  - efficient process control
  - maintenance programme
  - emergency preparedness and response
  - safeguarding compliance with environmental legislation
- checking performance and taking corrective action, paying particular attention to
  - monitoring and measurement (see also the Reference document on Monitoring of Emissions)
  - corrective and preventive action
  - maintenance of records
  - independent (where practicable) internal auditing in order to determine whether or not the environmental management system conforms to planned arrangements and has been properly implemented and maintained
- review by top management.

Three further features, which can complement the above stepwise, are considered as supporting measures. However, their absence is generally not inconsistent with BAT. These three additional steps are:

- having the management system and audit procedure examined and validated by an accredited certification body or an external EMS verifier
- preparation and publication (and possibly external validation) of a regular environmental statement describing all the significant environmental aspects of the installation, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate
- implementation and adherence to an internationally accepted voluntary system such as EMAS and EN ISO 14001:1996. This voluntary step could give higher credibility to the EMS. In particular EMAS, which embodies all the above-mentioned features, gives higher credibility. However, non-standardised systems can in principle be equally effective provided that they are properly designed and implemented

Specifically for the management of tailings and waste-rock, BAT is to apply an integrated risk/safety and environmental management system. Therefore environmental management has to be developed and carried out jointly with the risk assessment/management described in Section 4.2.1 and the operation, supervision and maintenance management described in Section 4.2.3.1.